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24 October–7 November 1970, Tehran, Iran

Vol. II. Technical papers

UNITED NATIONS

Department of Economic and Social Affairs

SIXTH UNITED NATIONS REGIONAL CARTOGRAPHIC CONFERENCE FOR ASIA AND THE FAR EAST

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NOTE

This volume of the Sixth United Nations Regional Cartographic Conference for Asia and the Far East, held in Tehran, Iran, from 24 October to 7 November 1970, contains the technical papers submitted to the Conference by the participating Governments. The report of the conference is contained in volume I.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Secretariat concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers.

In the present publication, references to "China" and to the "representative(s) of China" are to be understood in the light of General Assembly resolution 2758 (XXVI) of 25 October 1971. By that resolution, the General Assembly *inter alia* decided:

> "to restore all its rights to the People's Republic of China and to recognize the representatives of its Government as the only legitimate representatives of China to the United Nations, and to expel forthwith the representatives of Chiang Kai-shek from the place which they unlawfully occupy at the United Nations and in all the organizations related to it."

Symbols of United Nations documents are composed of capital letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

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PRESENTED TO THE CONFERENCE

AGENDA ITEM 6

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CARTOGRAPHIC ACTIVITIES IN THE UNITED STATES OF AMERICA, 1967–1970

Paper presented by the United States of America[1]

GEODESY

The basic horizontal control in the United States of America has been extended mainly as area networks between existing arcs of triangulation. This has been done for general use in mapping and various types of engineering programmes, such as highway construction, water diversion and reclamation projects and the development of urban and suburban areas. Continued use has been made of electronic measuring equipment particularly in connexion with the extension of the high accuracy transcontinental traverse surveys used to strengthen the basic horizontal control network in the country and to provide scale for the geodetic satellite triangulation network. By the end of 1969 11,330 km of these traverse surveys had been completed.

Surveys for the measurement of earth movement have continued. During the period of this report these surveys were in areas of Alaska, California, Colorado, Nevada, Texas and Utah where detected movements had caused concern. Reports on geodetic surveys in the Anchorage and Prince William's Sound areas of Alaska have been made available in publications of the Environmental Science Services Administration (ESSA).

Relevelling has continued in the United States over the basic network to up-date elevations which have changed for various reasons. Astronomical observations for latitude, longitude and azimuth are being continued in connexion with orientation control of the horizontal network with particular emphasis on the transcontinental traverse surveys where astronomic observations are made at intervals of 20 to 30 km.

In the years 1967 to 1969 the National Geodetic Satellite Program continued with fourteen BC-4 camera crews participating. These teams observed the PAGEOS and ECHO satellites from forty-four stations in twenty-three countries around the world. The project had active participation from the Coast and Geodetic Survey, United States Army Topographic Command (TOPOCOM) and the United States Air Force, as well as British, German, Australian, South African and Mexican personnel. Upon completion, the basic network will provide interconnecting ties to all the major data in the world and provide the foundation for a common world reference frame. In addition, the project will furnish the most accurate value of the size and shape of the earth that has ever been determined.

In March 1969, as a part of its field surveys programme, the Army Topographic Command established a number of modified first order astronomic positions in the Kwajalein Atoll. The purpose of the project was two-fold; the determination of the deflections of the vertical at selected sites and an adequate distribution of astronomic stations which would meet future requirements for deflections of the vertical. During May and June 1969, eighteen astros were established and two additional astros were established early in 1970 bringing the total to twenty.

The following stations were occupied by SECOR or BC-4 in the area bounded by 50° E–150° E and 40° N–40° S sometime during the reporting period (January 1968 to October 1970):

SECOR: Meshed, Iran; Chagos; Chiang Mai, Thailand; Singapore; Hong Kong; Zamboanga, Philippines; Darwin, Australia; Palau Islands; Manus, Territory of New Guinea; and Guam.

BC-4: Meshed, Iran; Mahe, Seychelles; Chagos; Mauritius; Cocos Island; Chiang Mai, Thailand; Zamboanga, Philippines; Perth, Australia; Culgoora, Australia; Thursday Island, Australia; and Kanoya, Japan.

The field survey effort in Iran during the report period was accomplished by military personnel of the Topographic Training Team (TTT), military and civilian personnel of the National Geographic Organization (NGO) of the Imperial Iranian Army and civilian advisers and technical representatives of TOPOCOM.

Since January 1968 the astronomic observation programme has been completed by members of TTT. A total of five first order positions were established at various points throughout the country. Geodetic levels, precise electronic traverse, control of horizontal and vertical picture points and panelling of control points for aerial photograph missions have been accomplished by a combined effort of TTT, NGO and TOPOCOM advisory personnel. The project was initiated in early 1968 and by October 1970 approximately 23,500 square miles will have been completed of the required 24,475 square miles. By 30 June 1970 the reflight of the north-east border area at a much smaller scale will be completed. Panelling of 152 control points and aerial photography missions covering

[1] The original text of this paper appeared as document E/CONF.57/L.11.

17,145 square miles in the north-west border area will be accomplished prior to October 1970.

Astronomical observations by the Naval Oceanographic Office (NAVOCEANO) were accomplished at fourteen sites in order to provide data on local deflections of the vertical. These data will be used to calibrate inertial navigation systems. Continuation of the LORAN transmitter calibration programme by the Coast Guard required that calibration points be surveyed by classical geodetic methods. Sites were surveyed in the operational area of the Mediterranean nets and those of the eastern United States. In support of the mobile doppler network of the Satellite Geophysics Program, NAVOCEANO made geodetic surveys to tie van sites into the local control in twenty-one areas.

Gravimetry

Present-day science and technology requires accurate knowledge of the earth's gravity field. Fuel and mineral deposits are located by intensive field surveys. Regional surveys on land and sea bring out broad patterns of crustal structure and are used in calculating improved absolute datum values for triangulation networks. Space vehicles and inertial navigation systems require precise calibration values and knowledge of the external gravity environment.

A gravity survey was completed in 1968 in the south-western portion of Texas, an area previously devoid of gravity coverage. This survey, accomplished under very difficult conditions due to remote station locations and poor roads, involved traverses along 1,000 miles of spirit level lines, and approximately fifty stations within the various levelling loops to provide the additional coverage necessary to control gravity contours. Another area gravity survey was conducted in central Oklahoma in 1968 and 1969, comprising 1,000 new stations throughout an area of 15,000 square miles.

A special gravity survey was conducted in the vicinity of Washington, D.C., to determine relative deflections of the vertical at the United States Naval Observatory and two astronomical observatories operated by the Coast and Geodetic Survey. This survey provided a basis for precise intercomparison of astronomic positions observed at the three sites.

In 1962, special gravity observations were accomplished in the San Joaquin Valley in connexion with the study of earthquake mechanisms in that region. The observations were made on an extensive network of level lines to establish a basis for future repeat surveys of gravity and elevation at these points. The first of the repeat gravity surveys was completed in early 1970 in conjunction with a complete re-running of the spirit level observations. It is hoped that this programme of repeat operations will serve to clarify the nature of vertical ground movements and disclose any changes in gravity anomaly which may occur in this disturbed region.

In Iran the co-operative field survey effort virtually completed gravity requirements. Only the north-east and north-west border areas were not completed by January 1970. Approximately 200 additional secondary observations were completed between January 1968 and June 1968. Operations were shifted to the north-east border area where fifteen National Gravity Base Reference Stations and 275 secondary stations have been observed to date. Approximately 1,000 additional secondary stations will be observed by the end of the field season in November 1970.

Employing La Coste & Rhomberg and Graf-Askania underway gravity meters aboard the USC&GS ships *Surveyor*, *Oceanographer* and *Discoverer*, marine gravity observations were taken in Pacific and Alaskan waters, on the scientific expedition around the world by the *Oceanographer* in 1967 and on the East Coast Upper Mantle Project survey over east-west track lines at ten-mile spacing and off shore to 500 miles. Measurements were also taken on oceanographic expeditions to the south Atlantic and the west coast of Africa. During the 1968 and 1969 seasons the *Surveyor* and *Oceanographer* participated in an extensive gravity survey of Norton Sound off the western coast of Alaska.

Bottom gravity meter surveys were conducted off the south-east coast of the United States in continuation of the continental shelf gravity development programme. A new gravity test range was established in the area immediately west of Cape Flattery, Washington, for convenient evaluation of gravity meters operating out of the Pacific Marine Center located at Seattle, Washington.

Geomagnetism

The United States Coast and Geodetic Survey has compiled and published the 1970 magnetic declination chart of the United States. In collaboration with TOPOCOM and as a part of the Inter-American Geodetic Survey programme, the Coast and Geodetic Survey has compiled the magnetic declination chart for Central and South America. The magnetic declination chart of the world for 1970 was compiled by the Coast and Geodetic Survey in collaboration with the Naval Oceanographic Office and then published by the Navy.

As reported in the Fifth United Nations Regional Cartographic Conference, the Coast and Geodetic Survey has continued its policy of developing and refining the procedures for analysing survey data with the objective of compiling more useful and accurate regional and world magnetic charts. The analytical methods used are briefly described below.

The procedure for the world chart included the initial derivation of a mathematical model of the secular change of declination derived from world-wide magnetic observatory values (annual means recorded since 1937). This model was used to reduce to epoch 1970 the half-million available magnetic vector measurements derived from land, sea and airborne surveys, including some 35,000 new values from Project Magnet that were not available for the 1965 chart. The reduced values were sorted into 648 areas, each measuring 10° by 10° in latitude and longitude. Where feasible, a representative value at the mean position was computed from a local model for each area, the local model consisting of eight harmonic coefficients. For those areas where this type of smoothing was not feasible, the original values were retained. The compressed file consisted of unequally spaced values at approximately 6,000 geographical positions.

A model using 168 spherical harmonic coefficients (degree and order 12) was fitted to this compressed file. This model of the main geomagnetic field along with the secular-change model was then used to generate digital data, defining the positions of closely-spaced points along lines of equal declination and equal annual change. These results were used by the Naval Oceanographic Office to scribe on a plastic base the isogonic and isoporic lines

automatically in a form suitable for direct reproduction and printing.

The entire series of world magnetic declination charts for 1970 includes the following:

(*a*) A Mercator projection extending from 84° North to 70° South at a scale of 1:39,000,000 at the equator;

(*b*) North and south polar stereographic projections extending from latitude 55° to the poles at a scale of 1:12,500,000 at latitude 71°;

(*c*) North and south polar stereographic projections extending from latitude 55° to the poles at a scale of 1:10,000,000 showing lines of equal grid variation. These charts are used as navigation aids. Grid variation is the angle between the grid meridian and the magnetic meridian.

The magnetic chart of the United States was also compiled using analytic methods. The raw data consisting of 50,000 magnetic measurements of declination were reduced to epoch 1970. Wild and anomalous values were then deleted from the data set. For each half-degree grid of latitude and longitude, mean values of declination were computed. In order to obtain values of declination for those half-degree areas for which no results were available, a preliminary mathematical model was used. This model was a seventh-degree polynomial derived from the one-degree quad means. The complete data set, now consisting of a mean value for every half-degree quad in the region of conterminous United States, was then subjected to a least-squares analysis. The region was divided into overlapping $12° \times 12°$ quads and polynomials were derived applicable to each inner $8° \times 8°$ quad. Thirty-six coefficients were determined for each area. These sets of coefficients were then used directly to contour automatically the mainfield isogonic lines.

For the lines of annual change, the results from approximately 100 United States repeat stations were analysed to produce one 15-coefficient model suitable to plot automatically the isoporic lines. Near the borders of the chart the isopores were reconciled with those on the world chart. Additional magnetic information from nearby regions, such as Canada and Mexico, were used to control the model.

Somewhat similar procedures were used in the compilation of the chart for the Alaska region as well as for the Inter-American series of magnetic declination charts.

In October 1968, the World Magnetic Survey Board endorsed the International Geomagnetic Reference Field (IGRF). The IGRF, a mathematical model of the Earth's magnetic field, is being more widely accepted as a useful tool in removing regional magnetic gradients from magnetic measurements made in geophysical (including oceanographic) surveys. In 1969, the Coast and Geodetic Survey published tables and small-scale magnetic charts of total magnetic intensity and annual change. The tables consist of grid values at every 2° intersection of latitude and longitude for the entire Earth. The publication, *ESSA Technical Report, C&GS 38*, also includes a print-out of a computer programme which can be used to derive, using the eighty spherical harmonic coefficients of the IGRF, all of the magnetic vectors and corresponding rates of annual change.

An extensive shipboard geophysical survey of the northern Bering Sea was begun by the Coast and Geodetic Survey in 1968 and will continue through 1970. A portion of the geomagnetic data (derived from a towed proton magnetometer) has been presented as a residual anomaly map at a scale of 1:250,000, the residuals being obtained by subtracting the model given by the International Geomagnetic Reference Field—1965.9. Similar work was done on the continental shelf adjacent to North Carolina (United States Atlantic coast). Residual anomaly maps are now in press for this area.

Since 1967, the Naval Oceanographic Office shipboard geophyical surveys in the Pacific Ocean were limited to the general area east of the 140° meridian between the latitudes 25° North and 50° North. Approximately 47,000 track miles of gravity, magnetic and bathymetric data were obtained during this period. No major surveys in the Pacific area were undertaken by other Navy activities, although several projects sponsored by the Office of Naval Research are planned for this year. These include a survey by the University of Hawaii in the Solomon Islands area.

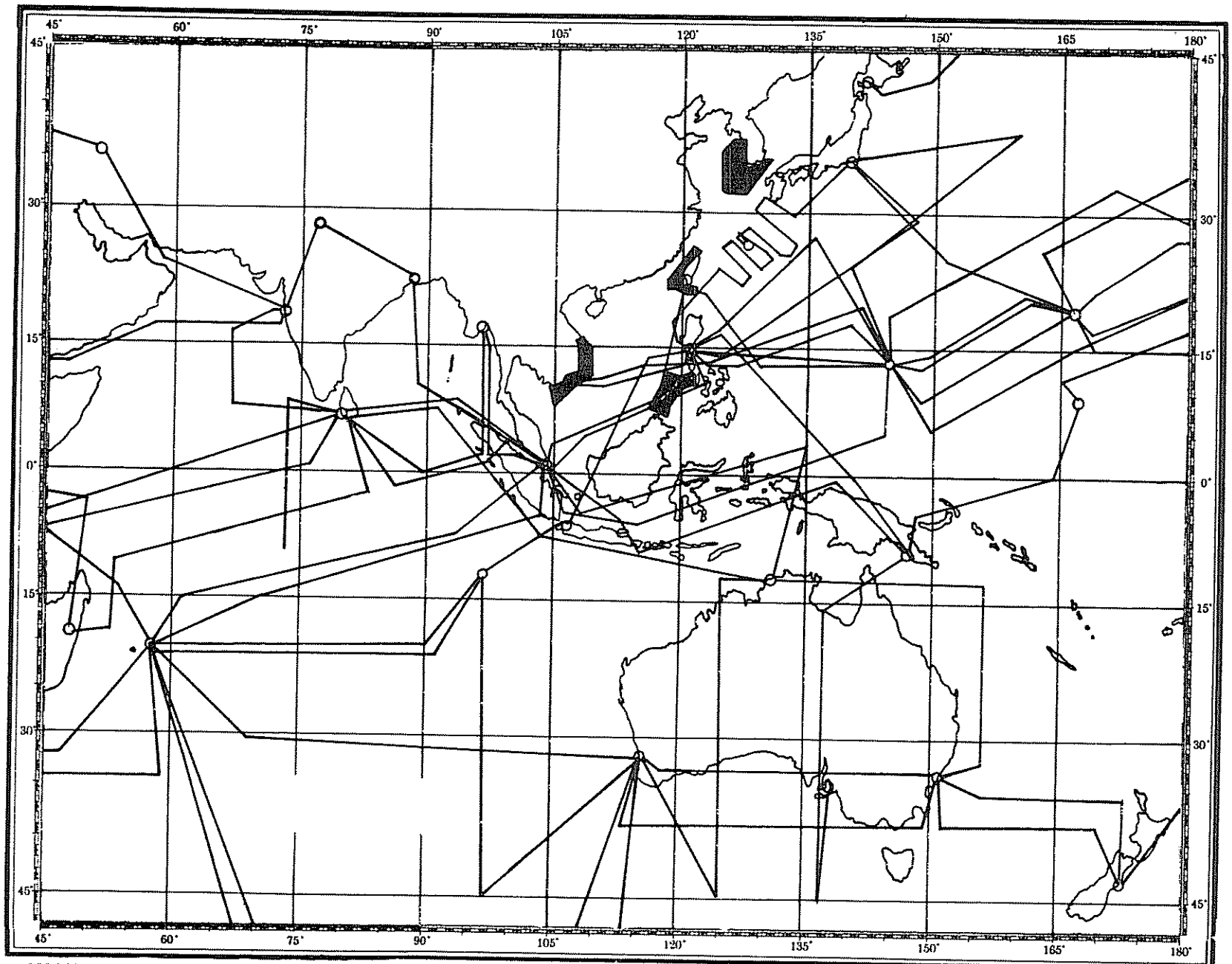
The Naval Oceanographic Office's Project Magnet, a continuing world-wide airborne magnetic survey, gathered approximately 249,000 nautical miles of magnetic data in the area, including 100,000 nautical miles on special fine grain surveys in the Republic of Viet-Nam, the Formosa Strait, the Yellow Sea and the Philippines. The figure shows the tracks and the special survey areas flown during the period from January 1967 to May 1970. Land gravity measurements were made in several of the countries visited and it is standard procedure to forward these as well as the magnetic data to those countries granting permission to overfly or land. All airborne magnetic data are available in the Naval Oceanographic Office Special Publication No. 66 and its supplements, and microfilm copies of the original total magnetic intensity recordings are available at a nominal cost.

Seismology

The United States Coast and Geodetic Survey's world-wide earthquake location programme has continued, issuing approximately 5,500 epicentres annually during the past two years. The volume has remained high due essentially to improved electronic computer facilities.

Prompt information on over 100 large (magnitude $6\frac{1}{2}$ or greater) earthquakes was provided during the past two years by the C&GS National Earthquake Information Center. Data on the location, magnitude and felt or damage effects are determined within two to three hours and then released to the principal press services and a number of scientific groups. Seismic readings for the earthquake location programme are received at the National Earthquake Information Center in Rockville, Maryland, from C&GS/ESSA observatories at Guam, Honolulu, Newport, Palmer and Tucson. Additional readings from the Pacific Tsunami Warning System are frequently utilized.

The association of earthquakes with underground nuclear explosions has been studied in some detail during the past few years. Examination of records from underground nuclear explosions at the United States Atomic Energy Commission's (AEC) Nevada Test Site (NTS) has shown an increase in earthquake activity in nearby regions to a degree dependent on the size of the explosion. The earthquakes are usually one or two orders of magnitude lower than the initial explosion, somewhat analogous to the major earthquake versus after-shock relation. After the "Boxcar" underground nuclear test in April 1968,



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Project magnet surveys, January 1967–May 1970

thousands of after-shocks occurred in the following six-week period. Most were found to be shallower than the hypocentres of natural earthquakes in the Nevada area. After "Benham", a 1.1-megaton shot at NTS in December 1968, some 10,000 after-shocks were recorded during the following four-week period. According to the AEC, each shot caused linear fracturing and faulting for a distance of nearly five miles on Pahute Mesa, where the tests occurred, producing similar displacements to those caused by some earthquakes.

The AEC conducted another calibration shot, this time in Amchitka Island in the Aleutian chain, to perfect a thermo-nuclear device. As the shot was announced many weeks in advance of detonation on 2 October 1969, considerable political interest was evidenced by groups in the United States, Canada and Japan. The concern of the foreign countries was caused by the speculation that a tsunami might be generated and propagated across the Pacific Ocean with great damaging effects. The explosion, a 1.2-megaton yield at 4,200 ft below sea level, was successfully detonated at 12:06 p.m. Bering Daylight Time on 2 October, with a computed magnitude of 6.5. As predicted by the AEC, neither venting of radioactive debris nor tsunami generation occurred.

Seismicity and after-shock studies offer the most obvious direct approach to the earthquake prediction problem. Several studies have been conducted to investigate the space and temporal aspects of seismic occurrence and energy release. During this report period, special equipment and/or personnel were sent to investigate earthquakes in Fairbanks, Alaska, June 1967; Borrego Mountains, California, April 1968; Caracas, Venezuela, July 1968; Iran, August 1968 and Santa Rosa, California, October 1969.

A significant development of the Tsunami Warning System (TWS) was achieved in September 1967 with the dedication of the Alaska Regional Warning System. In addition to the tripartite network at the nerve centre of the System—Palmer Observatory—seismic data are telemetered from Adak, Gilmore Creek and Kodiak. Tide stations at Shemya, Adak, Unalaska, Cold Bay, Kodiak and Seward continuously telemeter sea-level data to Palmer, while Sitka transmits both seismic and tidal information to Palmer via a teletype circuit. Tsunami warnings are disseminated throughout Alaskan coastal areas by Palmer through the Alaska Disaster Office and Alaska Command. All data from Palmer are transmitted to Honolulu Observatory for use in the Pacific Tsunami Warning System.

The Pacific Tsunami Warning System was continued with expansion in seismic and tidal detection network and improvements to communications. Up-grading of equipment at participating seismic and tide stations has begun and will continue over the next several years. The initial installations are remote recording systems for tide stations located in exposed locations or at great distances from communications facilities and new visible recording seismographs for certain stations. The following tide stations are scheduled to receive new instrumentation during 1970: Apia, Western Samoa; Suva, Fiji; Marsden Point, New Zealand; Rikitea, French Polynesia; Valparaiso, Chile; La Punta, Peru; Crescent City, California; Tonga Islands; Okinawa; Amchitka Island, Alaska; Johnston Atoll and Salina Cruz, Mexico. Plans call for eventually telemetering all TWS data via satellite relay to the operations centre at Honolulu Observatory. The visible recording seismographs are to be installed at Apia, Western Samoa; Suva, Fiji; Port Moresby, Papua; Manila, Philippines; Hong Kong; Guam, Mariana Islands; Wellington, New Zealand; Huancayo, Peru; Antofagasta, Chile; Tucson, Arizona and La Plata, Argentina.

The International Co-ordinating Group for the TWS held its first meeting in Honolulu in March 1968. Their second meeting was held at Vancouver, B.C., in May 1970. This group was formed by the Inter-governmental Oceanographic Commission to provide guidance for the International Tsunami Information Center at Honolulu. Scientists from several countries presented their latest research findings at the IUGG Tsunami Symposium held at Honolulu in October 1969.

A regional tsunami warning system for Hawaii will begin operation in July 1970. Signals from eight seismograph stations and two tide stations will be telemetered to Honolulu. In addition to providing early warning to Hawaii during locally generated tsunamis, the data from this network will provide a basis for the preliminary location of potentially tsunamigenic earthquakes around the Pacific.

Efforts to prepare educational material on earthquakes and related phenomena continued. A fifteen-page pamphlet entitled *Earthquakes* was prepared and distributed and a 9×12 inches colour poster with earthquake and tsunami safety rules was issued. In addition, a small pamphlet, *Regional Tsunami Warning System in Alaska*, was distributed in Alaska's coastal communities. The NEIC also began a bimonthly magazine, entitled *Earthquake Information Bulletin*, to provide current information on earthquakes and seismological activities of interest to both general and specialized readers.

ESSA's Coast and Geodetic Survey continued to expand its network of strong-motion accelerographs in the United States. The present total is 363 accelerographs and 372 seismoscopes. During 1969, strong-motion instruments were expanded to Haddam, Connecticut; Cape Girardeau, Missouri and Savannah River, South Carolina.

A seismic risk map of the United States was issued in January 1969. The map, a revision of that originally prepared by the Coast and Geodetic Survey in 1948, was presented by Dr. S. T. Algermissen at the Fourth World Conference on Earthquake Engineering in Santiago, Chile.

Seismic reflection data were taken by the Coast and Geodetic Survey during the 1969 North Bering Sea survey and were published in a 1970 Coast and Geodetic Survey Data Report.

Automated plotting of seismological data has become an integral part of seismological research at the C&GS. Cumulative seismicity maps and comprehensive seismicity studies now in progress rely upon this technique to reduce the time necessary to draft figures, graphs and maps. In addition, the combination of high-speed computer processing of large amounts of data and automated plotting techniques makes possible seismological studies which were heretofore impossible.

Hydrography and Oceanography

The Environmental Science Services Administration (ESSA) has continued support of programmes in nautical charting, continental shelf mapping, SEAMAP (deep ocean mapping), estuarine flushing prediction as well as tide and tidal current predictions as described below.

In addition to the routine hydrographic surveys conducted by ESSA's fleet of fifteen survey vessels in the coastal waters of the United States and its possessions, mobile field parties, which operate from shore bases, carried out in-shore hydrographic surveys in certain Atlantic and Gulf of Mexico coastal areas where the demand for small-craft charts is particularly intense. The *Ride* and *Heck* performed wire-drag surveys of the approaches to a number of harbours and the *Ferrel* executed the first circulatory survey for the specific purpose of making estuarine flushing predictions.

Seventy small-craft charts have been published to date providing charted information to recreational and small boat operators in United States waters. A total of 822 conventional charts are currently on issue and, during the three years covered by this report, eight new charts were published. Thirty bathymetric maps have been issued for public use. Important areas covered now include parts of the Bering Sea, California and Oregon coasts and areas of the Middle Atlantic continental shelf.

Through close affiliation with the Weather Bureau and various earth sciences, atmospheric and oceanographic laboratories forming a part of ESSA, progress has been made in solving problems involving the land, sea and air inter-relationships. Four major C&GS ships were participants in the most intensive scientific investigation ever conducted over a large area of the ocean. The major purpose of the Barbados Oceanographic and Meteorological Experiment (BOMEX) was to increase an understanding of the mechanism of ocean–atmosphere interaction the primary process that drives the atmosphere's circulation and weather systems.

The *Oceanographer*'s "Global Expedition" circumnavigational voyage in 1968 demonstrated interagency and international co-operation of a high order and contributed much to international oceanography. During the trip, the C&GS made shipboard time and space available for agencies and institutions of other countries in an effort to advance the state-of-the-art. In 1969 the ship *Discoverer* also participated in an international co-operative project across the equatorial region of the Atlantic Ocean to carry out, in detail, sea–air interaction studies in a region where the trade winds generate much of the weather for North America.

Some of the special projects completed by ESSA since 1967 were a special transatlantic cable-laying survey between Rhode Island and Spain, polar front physical oceanographic investigations in the North Pacific Ocean and similar oceanographic investigations of the Gulf Stream.

Significant progress has been made on project SEAMAP (Scientific Exploration and Mapping Program) covering the North Pacific between the Aleutians and Hawaii and eastward to the west coast of the United States. A contract was awarded to process and plot archival data obtained in the area. When completed, the unclassified version of the data will furnish scientists, geologists and others with a unique opportunity to study the characteristics of the deep ocean.

Improvements in navigational procedures were reflected in nautical charts this past year when the C&GS began indicating "traffic-lanes" on charts for New York and San Francisco harbours and Delaware Bay. "Fairways" are now depicted on Gulf of Mexico charts to indicate channels kept clear of oil-drilling operations.

The C&GS annually contributes over 1,000 articles (including submission of corrected chartlets) for the weekly publication, "Notice to Mariners", which alerts chart users to recent changes affecting chart information. This timely service is extremely beneficial to the mariner and tends both to maintain the integrity and to improve the quality of the nautical charting service.

Considerable progress has been made by the C&GS since 1967 in acquiring and putting to use up-to-date data acquisition equipment and in converting to automated cartographic uses of that data.

In accordance with an agreement made at the Eighth International Hydrographic Conference, Monaco, May 1962, most maritime nations are participating to produce bathymetric plotting sheets of the world's oceans. These plotting sheets are forwarded to International Hydrographic Bureau headquarters in Monaco for compilation of the General Bathymetric Charts of the Oceans (GEBCO). The United States commitment, being fulfilled by the United States Coast and Geodetic Survey and Naval Oceanographic Office includes the North Pacific, Arctic and west half of the Atlantic Oceans. Thirty-six plotting sheets for GEBCO Area AI are complete and available to the public as indicated in NAVOCEANO'S Catalog of Nautical Charts and Publications.

In the United States basic Navy hydrographic surveys were accomplished along the coast of San Francisco and San Diego, California, Cape Cod, Massachusetts and in the vicinity of Oahu, Hawaii.

Since the last United Nations Regional Cartographic Conference in Canberra, the United States Navy has retired five Navy-manned coastal survey ships and commissioned two new civilian-manned ships. The last Navy-manned survey was in 1969. During this period the Navy has continued collecting data in South-east Asia and has now shifted emphasis to the Korean Peninsula and the Pacific islands. The Navy-manned survey ships collected a total of 92,000 miles of soundings in South-east Asia, 17,000 miles in Guam and Trust Territories of Pacific Islands, 1,900 miles in Hawaii and 10,000 miles off the coast of Korea. The civilian-manned ships surveyed a total of 5,700 miles off the California and Massachusetts coasts.

In regard to hydrographic surveying in general, the United States Navy's Harbor Survey Assistance Program should also be mentioned. This is a programme started in late 1964 designed to develop a hydrographic surveying and mapping capability in developing countries. By sending American hydrographic engineers into the field to assist and train host country personnel in carrying out hydrographic surveys of their ports and harbours, these countries can then maintain accurate charts and thus stimulate foreign trade and hopefully raise their general economic conditions. Equipment and technical assistance have been provided to Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Honduras, Guatemala, Jamaica and Nicaragua. Efforts to date have been quite successful and it is believed that several of these countries now have an adequate capability. Although this programme has been limited to Latin America and the Caribbean, a similar programme for Asia and the Far East supported by the United Nations or one of the leading maritime nations is worthy of consideration by this group.

Since July 1967, the Naval Oceanographic Office has published 172 new nautical charts or new editions of

nautical charts in the Indian Ocean and the Pacific Ocean (excluding North and South America, Hawaii and the coast of Africa). For this report, new chart coverage is described using the following three categories: small-scale general ocean and sailing charts—smaller than 1:600,000; medium-scale coastal charts—1:75,000 to 1:600,000; and large-scale harbour approach and port coverage—larger than 1:75,000.

Among these 172 new nautical charts or new editions of nautical charts produced for the Pacific and Indian Oceans were: 21 small-scale charts for the Japanese Islands, the Philippine Sea, the South China Sea and the Bay of Bengal; 43 medium-scale charts in the Persian Gulf, the Arabian Sea, the Bay of Bengal, the South China Sea and the Philippine Sea and 108 large scale charts for numerous ports and harbours including Hong Kong, Singapore, Hannan Ko, Akasi Seto, Hiroshima Wan, Inch 'on Hang, Suruga Wan, Hai Phong and the Rangoon River.

In addition to this nautical chart coverage NAVOCEANO produces and maintains many special-purpose charts, weekly Notices to Mariners, Sailing Directions, Pilot Charts, Light Lists and Radio Aids. New products in these categories are the January 1967 to May 1970 Sailing Directions for Nova Scotia, west coast of Greenland, South America, Baltic (vol. II), south-west coast of Africa, Mediterranean (vol. III), south-east coast of Africa, west coast of India, western shores of the South China Sea, and Japan (vols. I and II) (Nos. 12, 16, 23, 43, 50, 54, 60, 63, 93, 95A and 96).

To facilitate the provision of global chart coverage to its mariners, the United States has entered into bilateral agreements with other countries whereby each may issue for sale to the general public modified facsimile reproductions of the other's nautical charts. As of May 1970, agreements had been made with the Republic of the Philippines, the Republic of Korea, the Republic of China, Indonesia and Japan in the Far East, as well as with Brazil, Canada, the Federal Republic of Germany, Italy, Mexico, Argentina, Belgium, Chile, France, Greece, Guatamala, the Netherlands, Spain and the United Kingdom in the western hemisphere. These agreements are in accordance with resolutions of the International Hydrographic Bureau.

Topographic maps and aerophotogrammetry

During the report period, the United States continued its co-operative programmes with several Asian and Far Eastern countries. Progress in specific areas will be reported separately by the nations concerned. Other items of general interest by various United States mapping agencies are noted below.

The United States mapping programme for Asia and the Far East during the 1968–1970 period was primarily directed towards 1:250,000 scale mapping of those areas where mapping sources are available. The over-all production area of interest stretches from Iran in the Middle East to Japan in the Far East. The United States also has co-operative mapping agreements with many countries in Asia and the Far East and large scale mapping has also been accomplished in some of the countries under the provisions of these agreements. These large scale maps are important to the countries concerned because of their potential use in national and regional development. In one unique instance of mapping accomplished purely for regional development, the United States monitored the commercial production of a series of about five hundred 1:10,000 scale maps in a portion of the Mekong River Basin in support of the Mekong developmental projects sponsored by the United Nations Economic Commission for Asia and the Far East.

In Iran, the United States assisted with field classification. This project was accomplished primarily by personnel of the National Geographic Organization, Imperial Iranian Army (NGO) with assistance from the TOPOCOM technical representatives. Classification was completed primarily in the north-east, east central and south-west central sections of the country. Approximately 30,000 square miles were classified during this period.

The United States Antarctic Research Program (USARP) administered and funded by the National Science Foundation (NSF) is the mechanism by which the United States participates with eleven other signatory nations of the Antarctic Treaty in a co-operative scientific research effort to learn more about this little known continent. The Geological Survey of the United States Department of the Interior receives its funds from NSF for cartographic and physical science investigations in support of these USARP activities. Topographic mapping by the Survey in Antarctica, which began in 1957 on a small scale, requires the services of between five and nine men annually from the Topographic Division and they spend approximately five months of the year in the Antarctic establishing geodetic control and inspecting aerial photography for mapping and scientific investigations. Seven men were deployed to the continent for the 1969–1970 austral summer season, and based on current plans, five men will probably be deployed next season. To date, seventy-two reconnaissance topographic maps at 1:250,000 scale of western Antarctica have been published and an additional twenty-nine are in the compilation stage. Seven shaded relief sketch-maps at the scale of 1:500,000 have also been published covering northern Victoria Land and the coastal areas of Marie Byrd and Ellsworth Lands between Cape Colbeck (159° W) and the Lassiter Coast (60° W). In addition to the continuing mapping programme, scientists of the Department of Interior are frequently involved in geologic, glaciologic, gravimetric, seismic and aeromagnetic investigations in Antarctica. Last season four geologists went to Antarctica for approximately four months to initiate a three-year geologic mapping programme in eastern Ellsworth Land.

Development of a computational analytical system of aerotriangulation was completed and is in operation at the United States Coast and Geodetic Survey. The system includes the use of both monocular and stereocomparators for the measurement of aerial photographs, the metric calibration of wide-angle aerial photogrammetric cameras through stellar exposures and the compensation of aerial film distortion through the use of eight camera fiducial marks. The entire data reduction is accomplished through the use of electronic computers and all programming has been done in Fortran language and is adequately documented for dissemination.

The computer programmes allow for the compensation of lens distortion, film deformation, atmospheric refraction and camera calibration. They accomplish strip aerotriangulation using either the two-photograph or the three-photograph method of relative orientation and linear or non-linear strip adjustment to accomplish a least-squares fit to any number of horizontal and vertical ground control points. They also accomplish the adjustment of blocks of

overlapping strips containing up to 200 aerial photographs by the simultaneous orientation of all photographs to fit a small or large number of ground control points through the minimization of plate image residual errors in accordance with the method of least-squares.

Provision was also made for varying the relative weight of photograph images as a function of radius, the relative weight of the photograph images of photogrammetric pass points and ground-control points and the relative weight of the photogrammetrically and geodetically determined ground positions.

Photogrammetric measurement of floating targets has been successfully used to determine current velocities in harbour areas. This technique has been applied to the study of the movement of ocean currents. Floating targets placed by ship determined the velocity of the western edge of the Gulf Stream to an accuracy within 0.5 knot.

The United States Geological Survey is developing automatic techniques for use in the cartographic phases of mapping. The objective at the present stage of development is to convert an existing map to digital form, add data to the digitized record for up-dating the map and produce drawings of the up-dated map with a precise automatic plotter. Specifications for an optical scanner have been written and techniques for symbol discrimination along with software for processing the data are being developed.

In the interest of advancing the development of automatic cartography, the United States Geological Survey and the Experimental Cartography Unit, Royal College of Art, Oxford, England, co-sponsored a symposium on Map and Chart Digitizing in Washington, D.C., 7 and 8 October 1969. The main participants were cartographers, engineers and technicians from United States federal agencies and from organizations in Canada and England. On a technical level, the participants discussed methods and equipment for converting linear and point data from graphic to digital form. The proceedings are available from the Clearinghouse for Federal Scientific and Technical Information, 5285 Port Royal Road, Springfield, Virginia 22151.

A second-generation version of a precise image correlator and measuring system has been built and is now being evaluated for applications in geological survey mapping. The system has the unique capability of recording and storing an unlimited number of signatures and positions that define image points and correlating signatures of corresponding points appearing on overlapping or time-variant photographs or on imagery from other bands of the electromagnetic spectrum. The main components of the system are the RAI image correlator, with punched-card memory, and a comparator with associated read-out-and-recording equipment. The system effectively eliminates manual pointing and marking of photogrammetric pass points, a major source of error in aerotriangulation. It also has potential for a variety of other photogrammetric applications, such as combining information derived from metric photographs and from non-metric remote-sensor imagery.

A new system to automate the production of orthophotographs is under development in the United States Geological Survey. The system includes three distinct steps: deriving profiles in a stereoscopic model by either manual or automatic means, automatic following of the profiles and coupled automatic operation of the orthophoto instrument.

An analogue profiler has been designed and is being built for manual scanning and recording of terrain profiles in a stereoscopic model formed by a direct projection stereoplotter. A photographic technique for automatically recording profiles from a stereoscopic model is also being developed. In this technique, edge-enhanced photographs, one positive and one negative, are used in a double-projection stereoplotter to form the model. The intersections of corresponding rays from the positive and negative images form a continuous grey line in the model, which can be recorded photographically.

An automatic line follower has been designed and is being built which will automatically follow analogue profiles by means of a photocell sensor.

The final element of the system, now being built, is a single-projector instrument for off-line automatic production of orthophotographs. It will use synchronized and co-ordinate signals from the automatic line follower to control its Y and Z scanning motions.

Geology and geological mapping

United States international technical co-operation in geology and geologic mapping is supported, through the United States Department of State, by the Agency for International Development, the United Nations and other agencies. Over the past decade, the central theme of United States Geological Survey assistance to developing nations has been the strengthening of counterpart central government geologic, hydrologic and topographic institutions to better enable them to evaluate indigenous natural resources and thereby effect orderly development of the resources in advancing their own national economies. Methods utilized include: training Earth-science specialists from the host country, accomplished by assigning students to field parties and laboratories in the United States or by extending in-service training to them in their home countries, providing advisory service in establishing or improving designated local Earth-science institutions, engaging in broad co-operative programmes designed to explore, investigate, assess and appraise indigenous mineral and water resources, lending advice, support and encouragement to local educational institutions and professional societies, with the objective of developing a broader Earth-science community and encouraging a free exchange of scientific information between American institutions and specialists and their counterparts in the developing nations.

As of January 1970, seventy United States Geological Survey specialists were at work in thirteen countries at the request of the host Governments. Academic and/or in-service training in the United States was being extended to thirty-five scientists and technicians from abroad. In Asia and the Far East, co-operative programmes are under way in Indonesia, Korea, Nepal and Pakistan.

National resources inventory

Since the Fifth Cartographic Conference the United States Engineer Agency for Resources Inventory (EARI) has continued its programme of providing feasibility studies, resources inventories, data management services, planning assistance and geographic and engineering support to developing regions of the world. Representative of the

EARI publications produced and distributed during the past three years are the following:

(*a*) National Resources Inventory, Venezuela—July 1968;

(*b*) Accelerated Development, Plain of Reeds (Feasibility Study)—July 1968;

(*c*) Pilot Drainage and Irrigation Project, Than Quoi, An Giang Province, Viet-Nam (Feasibility Study)—July 1968;

(*d*) Atlas of Physical, Economic and Social Resources of the Lower Mekong Basin—September 1968;

(*e*) Support to Land Reform, Viet-Nam:

(i) An Giang Province, Viet-Nam Resources Inventory —December 1968;

(ii) A Program to Speed Land Distribution (Province-wide Cadaster)—March 1969;

(iii) Soils of An Giang Province, Viet-Nam—March 1969;

(iv) A Program to Obtain Maximum Agricultural Production in An Giang Province, Viet-Nam—March 1969;

(*f*) Resources Atlas Project, Thailand, Atlas No. 1, Changwat, Nakhon Phnom—March 1969;

(*g*) Selected Bibiliography Lower Mekong Basin, two volumes (adjunct to Mekong Atlas)—1969.

Aeronautical charts

The continuing increase in international air operations, with the resulting congestion and limitation of controlled airspace, has continued to cause major problems in the control of today's air traffic. Changes in air traffic control procedures, the introduction of new air navigation systems and increased emphasis on air safety have brought about extensive and continuing reviews and redevelopment of aeronautical charts and flight information publications. The Air Force Aeronautical Chart and Information Center (ACIC) produces world-wide aeronautical charts and flight information publications. These products are made available to commercial and governmental organizations as well as to private individuals who may purchase them from the United States Coast and Geodetic Survey. The Coast and Geodetic Survey produces and distributes aeronautical charts and flight information publications covering the conterminous United States, Alaska and Hawaii, as well as charts for long range flight over the Pacific and Atlantic Oceans. United States aeronautical charts and flight information publications are also made available to many countries and organizations through mutual exchange agreements.

At the present time, flight information for the Asian and Far East areas is provided jointly by the Pacific-South-East Asia series of Flight Information Publications (FLIPs) and the Australia, New Zealand, Antarctica FLIPS. These FLIPs consist of Planning Documents and Enroute Charts (with Supplements) designed to provide the aircrew with all aeronautical information necessary to flight operations. It is anticipated that these products will be issued at 56-, 84- and 112-day intervals respectively commencing in 1971 for compatibility with the ICAO 28-day AIRAC System. A continuing programme is conducted to improve, expand or modify the content of these publications to satisfy changes in air traffic control procedures and navigation systems.

Large size Operational Navigation Charts (ONC) at 1:1,000,000 scale coverage of all major land masses have now been completed. Maintenance will be continued to assure currency of these charts.

Two hundred and fifty sheets of the Tactical Pilotage Chart (TPC) series, 1:500,000 scale, are now available. This TPC series is designed primarily for low altitude high speed navigation. Sheet lines are based on a quadrant division of the ONC series. Coverage of South-East Asia, Japan, Philippines and most of the Indonesia area is available.

In the northern hemisphere, the Jet Navigation Chart, 1:2,000,000 scale, is being converted to a new set of specifications. The new chart will have the appearance of the ONC with the addition of blue water tints and depth curves. In the southern hemisphere the United States, in conjunction with Australia, is producing the new Jet Navigation Chart Series. The planned completion dates are 1973 for the entire southern hemisphere and 1976 for the northern hemisphere.

For general navigation and planning purposes, the Aeronautical Chart and Information Center has produced the 1:5,000,000 scale USAF Global Navigation and Planning Chart (GNC) series. This series of charts is designed to satisfy long range air navigation requirements as well as provide for preflight planning. Complete coverage of the world is now available.

The Aircraft Position Chart series, produced by the United States Coast and Geodetic Survey, provides coverage for long range flight from California, Hawaii and Alaska to Japan, the Philippines, Viet-Nam, Tahiti, Fiji, Samoa, New Zealand and Australia. All charts in the series have been revised since the last conference. These charts are on the Lambert conformal conic projection at a scale of 1:6,250,000 and the Mercator conformal projection at 1:5,000,000. Full aeronautical data for long range navigation are furnished, including LORAN and navigation grid.

The Controller Charts are specialized aeronautical charts developed by the Federal Aviation Administration for use with display consoles in the Air Route Traffic Control Centers. Coverage of the conterminous United States now consists of thirty-two sheets at scale 1:500,000, fifteen at 1:250,000 and four at 1:1,000,000. One additional chart of the Hawaiian Islands at scale 1:500,000 has been produced since the last conference. This series of charts is designed to fit the unique environment of the air traffic controller and ensures that the information used by the controller agrees with the information available to the pilot.

At the time of the last conference Low Altitude Enroute (Radio Navigation) Charts of the conterminous United States had been revised to meet requirements of both civil and military aviation, replacing two separate series previously produced for civil and military use respectively. High Altitude Enroute Charts of the conterminous United States, Low and High Altitude Enroute Charts of Alaska, Standard Instrument Departure (SID) Charts and approximately 80 per cent of the Instrument Approach Procedure Charts for United States civil aerodromes have since been similarly revised for joint use and published by the Coast and Geodetic Survey, replacing separately-produced civil and military chart series.

Approved joint specifications provide also for the preparation of compilation bases at scale 1:500,000 and 1:1,000,000 of the conterminous United States and Alaska from which both civil and military editions of

visual flight charts are produced. The compilation bases as well as the complete civil editions are produced by the Coast and Geodetic Survey. Both editions feature relief shadings. Coverage of Alaska in sixteen sheets at the 1:500,000 scale has been completed, and thirty of thirty-seven charts which will cover the conterminous United States have been published. One of six charts which will cover Alaska at scale 1:1,000,000 has been published. The conterminous United States will be covered in eleven sheets at 1:1,000,000. The civil editions of each chart, titled Sectional Aeronautical Charts at 1:500,000 and World Aeronautical Charts at 1:1,000,000, are printed in two halves (back-to-back) and include a full aeronautical information overprint. The military editions are printed in the Tactical Pilotage Chart (TPC) and Operational Navigation Chart (ONC) formats (full sheet, printed on one side) and include a stable limited aeronautical overprint.

An Instrument Flight Rule (IFR) Planning Chart has also been produced by the Coast and Geodetic Survey under joint specifications for use by both civil and military aviation. A Visual Flight Rule (VFR) Planning Chart backs up the IFR Planning Chart for the civil edition. These charts cover the conterminous United States on two sheets at a scale of thirty-two nautical miles to one inch. Both charts are used for flight planning.

The Federal Aviation Administration, in support of United States commitments to the International Civil Aviation Organization (ICAO), has continued its aerodrome obstruction surveying programme in accordance with the obligatory requirements set forth in annex 4 of the ICAO convention. Obstruction charts are available on all aerodromes regularly used by international commercial air transport. Obstruction surveys have also been accomplished on over 600 aerodromes used by domestic commercial air transport.

National atlas

In accordance with a recommendation of the National Academy of Sciences, the United States Geological Survey undertook in 1962 the preparation of the National Atlas of the United States. Work on it was suspended in fiscal year 1964 because of lack of funds, but completion of the bound volume was scheduled for late in 1970. Meanwhile, twenty-three selected maps have been published for separate sales. Approximately 150 pages have been published for the Atlas edition.

The National Atlas is intended to serve primarily as a reference and research tool for government agencies, executives in business and industry, and large research libraries. It will be 19 × 14 inches with many maps on double-page spreads that open to 19 × 28 inches. Some 340 pages of special subject maps will deal with such characteristics of the United States as its physical features, history, economy, social conditions, boundaries and administrative units, indexes of coverage by the principal sets and series of maps and charts and the position of the United States in world affairs. In addition, in the back of the atlas will be an extensive index of features that appear in the National Atlas. Over 100 pages will be devoted to this index. It is anticipated that the bound volumes will sell for approximately $100 and individual pages have been priced at $0.75, $1.00 and $1.50 depending upon their complexity.

Geographical names

The United States has continued its programme of maintenance and up-dating of files of standard geographical names for each country or area of the world, and the use of these names on maps and charts as well as in other materials.

The names are made available in BGN gazetteers issued by the Board on Geographic Names and distributed through the facilities of the United States Army Topographic Command. Gazetteers of countries or areas in Asia and the Far East published since the Sixth Regional Cartographic Conference are Indonesia (2nd edition), 60,000 entries; Mainland China (2nd edition), 108,000 entries; Syria, 28,900 entries; and Undersea Features (world coverage), 1,775 entries.

Additional new editions of gazetteers in Asia and the Far East now in press or in preparation cover, with estimated number of entries: Afghanistan—10,000; China (Taiwan)—20,000; Israel—10,000; Malaysia—60,000; Mongolia—15,000; Republic of Viet-Nam—25,000; USSR—7 volumes 350,000–400,000. Names published in the Malaysia gazetteer will have been checked by the Directorate of National Mapping of Malaysia.

The United States has also continued its participation in co-operative international name standardization activities, including the first United Nations Conference and the first and second sessions of the Group of Experts on Geographical Names, regional conferences in the Americas and bilaterally with the British Permanent Committee on Geographic Names and other bodies or groups interested in the subject.

International Map of the World

The worldwide million-scale series to topographic quadrangle maps (IWM) is sponsored by the United Nations. The coverage required for the United States is fifty-three maps for the conterminous forty-eight states, seventeen for Alaska, and one for Hawaii. Except for six maps along the United States–Canada boundary, which are being prepared by Canada in accordance with understandings reached between the two countries, five maps of the conterminous states remain to be published. Operations are proceeding on these five maps, with the NL-19 Quebec and NI-16 Lookout Mountain maps scheduled for publication within the next few months. In Alaska, thirteen maps are published. The remaining four and the map covering Hawaii are expected to be scheduled in the next two or three years. All maps are being prepared in accordance with the recommendation of the United Nations Technical Conferences in Bonn, 1962, and Edinburgh, 1964.

CARTOGRAPHIC WORK IN JAPAN, 1967–1969

Paper presented by Japan[1]

NATIONAL FUNDAMENTAL SURVEY

Geodetic work

The fundamental geodetic work by the Geographical Survey Institute (GSI) consists of the revision survey of existing control points and the establishment of new minor control points for plains areas where large-scale manning or cadastral surveys are planned.

Triangulation and base-line measurement

The revision survey of 330 principal first-order triangulation stations, which form the framework of the Japanese triangulation net, was started in 1947 and was completed in 1967 for most of the country. The second revision survey was started in 1968 from the Kyushu District, the south-western part of Japan, and is now in progress. The survey will probably take 10 to 15 years to cover the entire country.

Levelling

All tracks of the first-order levelling net in Japan have been revised since 1947. By 1968 the surface of Japan except the Hokkaido District was covered by the fourth revision survey, which was started in 1962.

Astronomical observation

Astronomical latitude and longitude are observed at approximately two-thirds of the principal first-order triangulation stations for the purpose of establishing Laplace stations. The observations are made with astrolabes equipped with the electronic transit detector developed by the Geographical Survey Institute. The astrolabe is calibrated at the Tokyo Astronomical Observatory before and after field observations.

Gravity survey

In order to complete the Western Pacific Calibration Line, two series of pendulum connexions, Japan–Australia including Sydney and Canberra and Japan–Hong Kong, were completed in 1967 and 1969 respectively.

The Geographical Survey Institute pendulum apparatus is used, for the domestic survey, to make observations at six fundamental gravity stations, which are the local reference stations. LaCoste and Rhomberg gravity meters are used for first- and second-order stations.

Magnetic survey

Various kinds of magnetic surveys have been undertaken regularly by the Geographical Survey Institute.

There are ninety-seven first-order magnetic stations in Japan. Five were established in the Kanto District in order to provide more detailed knowledge on secular variations of the Earth's magnetic field in relation to the dynamic processes in the crust.

The first-order magnetic survey has been co-ordinated alternately in the northern and western half of the territory. Twenty of the first-order stations were selected as the standard and are reoccupied every other year; the others are reoccupied every fifth year on the average. All results of the first-order survey have recently been compiled from the beginning with the unified standard of intensity and the method of epoch reduction.

Geodesy in hydrographic work

As the basis for establishing the framework for world-wide geodetic nets, geodetic observations using artificial satellites were carried out at Amam-O Sima and Titi Sima in 1969 so as to determine the geodetic positions of these off-lying islands which play the role of triangulation points in the ocean.

Photoelectric and visual observations of occultations of stars by the moon were made continuously at the hydrographic observatories at Sirahama, Simosato and Kurasiki. Results of reduction of the observed data have been used in the compilation of nautical almanacs.

As part of the Earthquake Prediction Programme, gravity measurements were carried out on the sea in Sagami Wan, approaches to Izu Syoto and the east offing of Honsyu during the period 1966 to 1969. Since 1967, observations of plumb-line deflection have been carried out at eight different off-lying islands.

The occultation of Mars by the moon was observed at Sirahama and Kurasiki hydrographic observatories on 3 January 1967. The total solar eclipse was observed by the Hydrographic Department team in Mexico on 7 March 1970.

Geomagnetism in hydrographic work

In order to compile magnetic charts for the period beginning in 1970, magnetic surveys were carried out during 1969 and 1970 at forty-five land stations throughout Japan and along thirty maritime tracks by aircraft within 800 nautical miles of the coast.

Three basic geomagnetic observations as well as absolute and variation observations of total magnetic force are being carried out at Simosato and Hatizyo Sima hydrographic observatories. These are part of the WMO observation system.

National base maps

The 10-year project to produce new base maps at 1:25,000, reported at the Manila Conference, has been in progress for six years and is proceeding almost as scheduled. More than 85 per cent of the new base maps which were compiled during the last three years were produced by private companies. However, revision surveys of the new base maps are being undertaken by GSI. Regular revision surveys are well under way.

The new Japanese-manufactured topographic plotter which was reported at the Canberra Conference, "Nikon plotter", is being used for plotting the base maps and good results are being obtained.

National large-scale maps

The programme to produce national large-scale maps began in 1960. Some of these maps are already outdated, and revision surveys began in 1967. Maps of this new edition, at 1:2,500 and 1:5,000, cover 16,299 km^2; revision surveys, 3,171 km^2; photo contour maps, 2,802 km^2; and photomaps, 5,898 km^2.

[1] The original text of this paper appeared as document E/CONF.57/L.34.

Compilation of maps

1:50,000 topographic maps

Since 1965, new revised editions of the 1:50,000 series have been prepared from sheets of the 1:25,000 series. A total of 491 sheets were produced by the end of fiscal year 1969 covering 30 per cent of the project.

1:200,000 regional maps

A revision survey of the recompiled sheets of the 1:200,000 series was started in 1965. Some 66 sheets covering Honshu were revised by the end of 1969.

1:500,000 district maps

Recompilation work on the 1:500,000 series was begun in 1965 and completed in 1969. The series consists of seven sheets for the main part of the territory and an additional sheet to cover the other small islands.

1:1,000,000 map "Japan"

The 1:1,000,000 map, "Japan", was issued in 1968. It was annotated with Japanese characters for domestic use, using the IMW base. The revised edition of the IMW was issued in 1969.

CADASTRAL SURVEYS

The cadastral survey in Japan during the period from 1967 to 1969 is as follows:

	1967	*1968*	*1969*	*Total since 1951*
Control-point surveys (pts.)	1,089	1,097	1,010	26,475
Cadastral surveys (km^2)	2,955	3,199	3,260	26,208

PUBLIC SURVEYS

In Japan, public surveys include considerable cartographic work and large numbers of maps have been made for public use at scales of 1:500 to 1:10,000. These surveys have usually been carried out by private firms under directions from various public organizations.

The Forestry Agency, in co-operation with the Geographical Survey Institute, has taken aero-photographs of the mountainous areas in Japan that correspond to the principal forest areas. The Forestry Agency has a project to take photographs of about 190,000 km^2 of Japan. The scale of the photographs is mainly 1:20,000.

Recently, a variety of scales for photography has been used for the purpose of flood forecasting, traffic control, basic investigation for water resources, quantitative analyses of landslides and evaluation of numerical data on the results of construction. There are also construction projects. Investigations, such as for submarine tunnels, building bridges across channels and the course of land subsidence in many cities, are carried out with precise surveys. These form a large part of the official surveys.

THEMATIC MAPS

Land classification map series

The Economic Planning Agency has co-ordinated the preparation of the land classification map series in various scales. Among them are twelve sets of the 1:50,000 series, which consist of three thematic maps, landform classification, surface geology and soil maps. These have been prepared during this period through the co-operation of governmental agencies and universities. This series has totalled forty-one sets since 1954.

In 1969, the Agency completed the 1:500,000 series covering the main part of the country in six sheets and also the relative relief map of Japan at 1:1,160,000.

The Agency is now starting to co-ordinate the compilation of the 1:200,000 series for each local governmental area. The work is being carried out by each local government with the co-operation of experts in the region. The series consists of four thematic maps: land-form classification, surface geology, soil and land-use map, which is subdivided into the present situation map of land use and the classification map of land utilities. This series will be successively completed between 1970 and 1974.

Land-use maps

One sheet of the 1:20,000, two sheets of the 1:25,000 and 17 sheets of the 1:50,000 land-use map have been prepared by GSI and local governments during the period 1967–1969.

Land condition maps

The 1:25,000 land condition maps for Nagoya City and its environs (fifteen sheets) and Hiroshima (one sheet) have been issued during this period. In 1968, GSI also started to prepare the 1:10,000 land condition maps for Kitakyushu City (three sheets), and to revise the 1:25,000 series for the Tokyo and Yokohama area.

Lake charts

Twelve charts of the 1:10,000 series for six lakes were compiled in this period by GSI, and twenty-one lakes (1,620.3 km^2 have been surveyed since 1955. GSI has also revised sheets covering parts of Lake Biwa (52 km^2).

Water-use maps

The 1:50,000 water-use maps have been prepared since 1965 by the Economic Planning Agency in co-operation with GSI. Some twenty-nine sheets were completed by 1969 for several important river systems in Japan, including the Kiso, Yoshino and Yodo.

Snow depth and avalanche maps

Since 1967 the Road Bureau of the Ministry of Construction, in co-operation with GSI, has prepared the snow depth and avalanche maps pertaining to the heavy snowfall regions along the master planning routes for several national expressways.

Geological maps

In regard to the basic geological maps, twenty-four sheets of the 1:50,000 series and their explanatory texts have been prepared by the Geological Survey of Japan (GSJ), the Geological Survey of Hokkaido and the Hokkaido Development Agency during this period. Also six sheets of the 1:200,000 series and one sheet of the 1:500,000 series were prepared by GSJ. In addition to the above-mentioned basic geological maps, many other types of geological maps have been prepared by GSJ.

Soil maps

The 1:50,000 series of soil types and their products for cultivated lands has been prepared by the Agricultural Administration Bureau since 1959. About 70 per cent of the sheets were completed by the end of 1969. About 80 per cent of the entire cultivated land in the country,

totalling 6 million ha, will be covered by this series in the 15-year project which was begun in 1959.

The 1:20,000 series of soil types for national forests has been prepared by the Forestry Agency since 1947. About 60 per cent of the national forests, 7,500,000 ha, had been covered by this series by the end of 1969.

Population maps

The Statistics Bureau of the Prime Minister's Office has prepared several population maps based on the statistical data of the national census in 1965.

These are the atlas maps of population distribution, population change, percentages of workers employed in industries and others at 1:500,000, 1:1,000,000 and 1:1,500,000.

Traffic volume maps

To be used as fundamental materials for road administration, the traffic volume map of Japan at 1:1,200,000 and similar type maps for Tokyo, Nagoya and Osaka regions at 1:200,000 were prepared by the Road Bureau of the Ministry of Construction with the co-operation of GSI in 1968. These maps have been prepared every three years since 1962.

Hydrographic work

Hydrographic survey

The number of hydrographic survey operations carried out since 1967 are as follows:

Type of survey	*1967*	*1968*	*1969*	*1970 (projected)*
Harbour survey	13	17	19	10
Partial survey	180	176	170	173
Passage survey	3	3	3	2
Coastal survey	2	4	3	3
Oceanic survey	1	1	1	1
Bottom sediment survey[a]	1	0	1	0
Survey for the basic map of the sea[b]	1	1	1	1

[a] Investigations of the surface character of the bottom and the sub-bottom geology were conducted to obtain information on anchor-hold of large-sized vessels in shelters during typhoons.

[b] The survey for the basic map of the sea programme started in 1967 is a 10-year programme to investigate the continental shelves around Japan. For this programme, submarine structural, geomagnetic and gravimetric surveys are simultaneously carried out with the bathymetric survey.

Oceanography

For the purpose of revealing the nature of currents in the seas adjacent to Japan, oceanographic observations were carried out quarterly in co-operation with the Japan Meteorological Agency, Fisheries Agency and other organizations. In addition, observations of the Kuroshio variations were carried out twice monthly over the Kuroshio region using aircraft and seagoing vessels. Results of these observations are published as "Charts Showing the Status of the Sea around Japan". The Kuroshio observations are disseminated through radio and photographic reproduction and by "Notices to Mariners".

Observations of sea ice were carried out every winter along the coasts of Hokkaido.

In 1967 and 1968, oceanographic observations as part of the CSK (Co-operative Study on the Kuroshio) programme were carried out over the course of the Kuroshio between Japan and Hawaii.

Tests on the floating-type wave recorder and automatic analyser developed for wave observation in the ocean are under way.

Continuous tidal observations are carried out at some 100 tidal stations all round the country. Data observed are being utilized in tidal predictions. In particular, those data obtained from the stations located on the islands in southern Honsyu are also used for the study of the Kuroshio variations.

Chart reproduction

The following table shows the status of chart reproduction from 1967.

	1967	*1968*	*1969*	*1970 (projected)*
New charts				
Nautical chart	17	10	20	18
Miscellaneous chart	3	9	7	14
Aeronautical chart	0	0	1	1
New editions				
Nautical chart	20	31	32	20
Miscellaneous chart	3	0	5	14
Aeronautical chart	2	0	2	1
Reprint	15	22	3	8
Total	60	72	70	76

The new miscellaneous charts to be issued in 1970 include "The Basic Map of the Sea" series, which will eventually cover the continental shelf area around Japan, each set being composed of the bathymetric chart, submarine structural chart, total magnetic intensity chart and gravity anomaly chart, of 46 × 63 cm, at 1:200,000. The new editions of miscellaneous charts in 1970 are mostly "Charts Showing the Posititions of Set Net Fisheries".

Correction chartlets for keeping charts up to date are issued in an amount of 300 to 360 sheets every year.

The number of charts on issue are: nautical charts—1,167; miscellaneous charts—209; aeronautical charts—15; total—1,391.

Japanese Oceanographic Data Centre

The Japanese Oceanographic Data Centre, established in April 1965 in accordance with an International Oceanographic Commission resolution, is now receiving more than 2,000 CSK data annually from several participating countries. Oceanographic data and documents received from agencies and institutions both at home and abroad are increasing yearly. The data received have been processed and compiled into such publications as *Data Report of CSK*, *CSK Newsletters* and *CSK Atlases*.

Recent cartographic activities

Establishment of standard mesh system for Japan

A mesh system was established for the whole area of Japan and this serves as a basis for analysing special data on the country. Its purpose was to standardize the method of analysing any area or local region in the country and then to gather and synthesize the data referred to any local mesh system. The mesh system has already been used for analysis of the population of the national census and the relative relief analysis of terrain for the whole country.

Preparation for a national atlas of Japan

GSI started the work of examining the contents for a national atlas of Japan and for compiling its base maps in 1969.

Geographical names on maps and charts

GSI and the Hydrographic Office (HO) have been co-operating to standardize geographical names on their topographic maps and nautical and aeronautical charts.

During this period standard geographical names for recompilation of the 1:500,000 district map were decided. Discussions are now being conducted to determine the standard geographic names for the 1:200,000 coastal chart.

SUMMARY OF CARTOGRAPHIC ACTIVITIES IN CHINA,* 1967–1969

Paper presented by China[1]

GEODESY

Compilation and reproduction of geographic co-ordinates of triangulation stations in China

Geographic co-ordinates of all the triangulation stations in China were readjusted and recomputed to a single geodetic datum. During the past three years, the geographic co-ordinates of 125,549 geodetic points and 43,600 triangulation stations were prepared in a separate card system and recomputed, respectively. The project of readjustment and recomputation of the triangulation stations in China was successfuly completed at the end of 1969.

Re-covery and re-establishment of triangulation marks

Since 1966, 170 triangulation stations were re-covered and the points for thirty-seven of these stations were re-established.

Precise levelling

The entire project of levelling 1,600 km of traverse between bench-marks was finished in 1969. From 1967 to 1969, 820 km of levelling were completed. The levelling project was carried out with Wild N-3 precision theodolites and Invar metal bars. The mean-square error does not exceed 4 mm $\sqrt{k}$ (k in km).

PHOTOGRAMMETRY

Air photos ranging from scales 1:4,000 to 1:120,000 are used for photo-interpretation, agriculture, forest inventory and topographic map revision and production.

The different instruments used in photogrammetry are as follows:

RC8 air camera
K17 air camera
Automatic photo-developing machine
A7 autograph
C8 stereoplanigraph
Kelsh plotter
Multiplex
Zeiss SEG-V rectifier
Wild rectifier
Sketchmaster
Wild infra-red Distomat
Tellurometer

The last two instruments are used for ground-control surveys.

Most map sheets are produced with multiplex. The precision of this instrument's products always meets the requirement of second-order photogrammetric instruments. Another instrument used for large-scale city-map plotting is the Kelsh plotter. The following list will give the total number of map sheets produced with the above-mentioned instruments from 1967 to 1969:

137 sheets of topographic maps of China at 1:50,000 (sheet size 15′ × 15′)
22 sheets of topographic maps of China at 1:25,000 (sheet size 5′ × 7.5′)
29 sheets of topographic maps at 1:50,000

MAP COMPILATION AND REPRODUCTION

To meet various requirements, the China Topographic Service has compiled and reproduced the following map sheets:

326 sheets of topographic maps of China at 1:500,000 (sheet size 15′ × 15′)
286 sheets of topographic maps of China at 1:100,000 (sheet size 30′ × 30′)
40 sheets of topographic maps of China at 1:250,000 (sheet size 1° × 1.5°)
99 sheets of terrain studies of China at 1:250,000 (sheet size (1° × 1.5°)
9 sheets of general maps at 1:500,000 (sheet size 2° × 3°)
9 sheets of general maps of China at 1:1,000,000 (sheet size 4° × 6°)
2 sheets of general maps of China at 1:4,000,000
20 sheets of aeronautical charts at 1:1,000,000 (printed on Mead paper)

PLASTIC RELIEF MAPS

In order to obtain an easy and practical interpretation of the terrain features, the Topographic Service has produced plastic maps at various scales, as follows:

Plastic relief maps at 1:250,000
Plastic relief maps at 1:500,000
Plastic relief maps of China at 1:8,000,000
A plastic relief terrestrial globe

PHOTOMAPS

Since 1967, the Topographic service has devoted its efforts to the production of colour photomaps, which are a

* See introductory note at beginning of volume.
[1] The original text of this paper appeared as document E/CONF.57/L.35.

combination of aerial photographs and topographic maps. This kind of map is easy to read and interpret, as well as fairly precise and good-looking.

TOPICAL MAPS

Urban-planning survey

Kaohsiung city

For the urban planning of Kaohsiung city, map sheets at 1:1,200 are to be made for the entire area of Kaohsiung and its suburbs, covering 26,700 ha. The aerial photographs, control points survey and 1:6,000 scale mosaics have been completed.

Twenty-six counties

In order to extend an urban-planning survey, a new organization was established. In the first year of the project, a total of about 18,000 ha comprising twenty-six counties will be surveyed, with map sheets at 1:3,000.

General-purpose survey

Wu-chi harbour topographic maps

Map sheets at 1:3,000 covering 15,000 ha were prepared through the photogrammetric method at a new international harbour. This project was completed at the end of September of this year.

Forest-inventory topographic maps

Topographic maps were prepared at 1:10,000 for a total of about 25,000 ha of the Ta-hsueh mountain forest by using the photogrammetric method.

Mine-field maps

A total of about 624 mine-field map sheets at 1:5,000 will be produced at the end of May 1971.

CARTOGRAPHIC ACTIVITIES IN AUSTRALIA FROM 1 JANUARY 1967 TO 31 DECEMBER 1969

Paper presented by Australia[1]

INTRODUCTION

The purpose of this paper is to present a brief review of cartographic progress in Australia. The progress shown is a consolidation of the work carried out by federal and state agencies, the chief contributors being: (*a*) the Department of National Development; (*b*) the Department of the Army; (*c*) the Department of the Navy; (*d*) the Commonwealth Scientific and Industrial Research Organization; (*e*) the Department of the Interior; (*f*) the State Departments of Lands; and (*g*) the State Departments of Mines and Forests.

The text is brief. The maps in figures I (annex A)* to IX (annex H)* provide the reader with a better view of the situation than a voluminous text.

In the first part, comments are made under the headings of national geodetic survey, national levelling survey, aerial photography and topographic map coverage. These activities are carried out under the guidance of the National Mapping Council of Australia, and further information may be obtained from: The Director, Division of National Mapping, Department of National Development, P.O. Box 667, Canberra City, A.C.T. 2601.

A brief report on hydrographic charting is then presented by the Hydrographic Service, Royal Australian Navy. This is followed by notes on oceanographic and bathymetric surveys. Catalogues of Australian charts are available from: RAN Chart Agency, Garden Island, Sydney, N.S.W. 2000.

Reports on geological mapping, magnetic surveys, gravity surveys and radiometric surveys follow, and additional information may be obtained from: The Director, Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, A.C.T. 2601.

Soil maps, land classification surveys, climatic and water resources maps and national and regional thematic atlases are covered next, and enquiries may be directed to: Senior Assistant Secretary, Water, Power and Geographic Branch, Department of National Development, P.O. Box 850, Canberra City, A.C.T. 2601.

Finally, information on the report on vegetation and forestry surveys may be obtained from: Director-General, Forestry and Timber Bureau, Banks Street, Yarralumla, A.C.T. 2600.

NATIONAL GEODETIC SURVEY

The progress of the geodetic survey of Australia up to the end of the 1969 field season is shown in figure I (annex A).

Since 1 January 1967, 556 first-order astronomical stations were observed and 5,315 km of first-order traverse were measured. In addition, 6,365 km of high-precision traverse were measured to provide two base lines for the world geodetic triangulation network. High-precision traverses have reciprocal Laplace azimuths on every line, distances measured by MRA 4 tellurometer or laser 8 geodimeter, and astronomical latitude and longitude at every station. The high-precision measurement of the 3,164 km east–west base line from Culgoora in New South Wales to Caversham in Western Australia was completed in 1969 and the chord distance was forwarded to the American authorities. The measurement of the 2,300 km base line from Culgoora to Thursday Island in Queensland is scheduled for completion in 1970. These base lines, in conjunction with others in various parts of the world, will provide control for the United States world triangulation network. In addition, assistance was given in the associated BC4 camera programme.

The majority of map control for areas enclosed between the geodetic traverses continues to be supplied by aerodist and the airborne profile recorder (APR). Since 1 January 1967, 480 aerodist stations have been established and

* See pocket at end of volume.

[1] The original text of this paper, prepared by B. P. Lambert, Director of National Mapping, Department of National Development, Canberra, appeared as document E/CONF.57/L.42.

1,789 lines have been measured in Australia and the Territory of Papua and New Guinea. Additionally, 20,200 km of second-order tellurometer traversing have been measured for 1:100,000 mapping control.

Data is being collected for the determination of the geoid in Australia. A feature of the Australian geodetic survey has been the large number of Laplace and astro-geodetic stations that have been observed. These observations are continuing along the series of primary traverses and when they are completed a geoid contour map will be prepared. To strengthen the basic geoidal profile framework in areas where little astrogeodetic data is available, an additional 1,800 N values will be computed from gravimetric data. The geoid map will show 1 m contours of the geoid–spheroid separation (N) and is scheduled for completion in 1971.

Since 1966 ten more satellite-tracking stations in Australia were connected to the national geodetic network.

National levelling survey

The Australian continent has been covered with a network of levelling traverses forming loops of up to 1,500 km in circumference.

A programme of tidal readings at thirty-three gauges around the coastline of Australia was recorded between 1 January 1966 and 31 December 1968. The aim was to obtain continuous recordings for as many stations as possible for a common period of one year.

Most of the levelling was observed to third-order standards. A great deal of the levelling is done by private surveyors under federal contracts and supervised by the State surveyors-general.

The Australian levelling survey will be adjusted at the end of 1970 and some 160,000 km will be involved. The network will be split into five parts, which will be adjusted by the method of observation equations. The five separate parts will then be combined into a homogeneous continental net by condition equations involving over 650 junction points. A variance–covariance matrix will be computed for the whole of the continental network. As for the national geodetic datum, the origin for the Australian height datum will be the Johnston geodetic station in the middle of Australia where a special bench-mark has been established.

The determination of the Australian height datum, in terms of this bench-mark at the Johnston geodetic station, will most likely be obtained from a free adjustment of the whole net based on an arbitrary value at the origin. A block shift can then be applied to the whole net, the amount of which can be determined so that a best-mean fit is obtained at the tide gauges. Results of the adjustment will be available early in 1971 and figure II (annex B) shows the progress of the national levelling survey to 31 December 1969.

Air photography

Figure III (annex C) shows the present air photography coverage of Australia.

Air photography is generally undertaken by federal and state authorities for their own mapping purposes. Most state photography is at medium scales, and large-scale photography is flown for special projects. Many states are now flying large-scale colour photography.

Since 1967, 3·1 million km² of air photography in Australia were completed. Rephotography of Australia for federal purposes at a scale of 1:80,000 was commenced in 1960 and is scheduled for completion by 1973.

Air photographs are being used extensively for the Commonwealth 1971 population census. Some 87,000 km² of air photography will be used for census mapping and the location of census boundaries.

In 1969, 1,900 km of the north-eastern coastline of Australia were photographed at low tide with infra-red colour. Surveys of this nature provide information for the delineation of the low-water mark for mapping purposes and, in addition, provide information that is useful for the determination of petroleum exploration permit boundaries. A further 4,800 km of coastal photography is scheduled for 1970.

New Guinea

Air photography of the New Guinea mainland is about 80 per cent complete (see figure IV (annex C.1)). Progress in the mountainous areas is continually hindered by clouds. A contract was arranged for side-looking airborne radar photography (SLAR) of the gaps. The result will be an uncontrolled radar mosaic, which will consist of assembled radar imagery at a scale of 1:250,000.

Topographic map coverage

Federal programme

1:250,000 scale mapping

In 1968 the 1:250,000 scale planimetric series was completed for the whole of Australia. Revised editions continue to be published with the most recent information obtainable from new air photography and field inspection. In this revision particular attention is given to changes in roads, and the revised data is shown by a magenta overprint. In conjunction with the 1:100,000 national mapping programme, a new and contoured edition will be published at 1:250,000 scale as each map area is covered by the constituent six 1:100,000 scale maps. The new edition will be on the Australian geodetic datum and will show the Australian map grid in metres. Contours will be plotted at a basic interval of 40 m. The contours will be supplemented by relief shading.

1:100,000 scale mapping

The objective of the present national mapping programme is the coverage of Australia by 1976 with mapping at 1:100,000 scale with a basic contour interval of 20 m. In steep country the interval is 40 m. All maps are on the Australian geodetic datum and show the Australian map grid in metres.

There is both a civilian and a military edition in the series. In the civilian edition, the contours are supplemented by relief shading.

In addition to the national mapping programme, the Department of the Army publishes topographic maps at scales of 1:50,000, 1:25,000 and 1:10,000 over selected area of Australia.

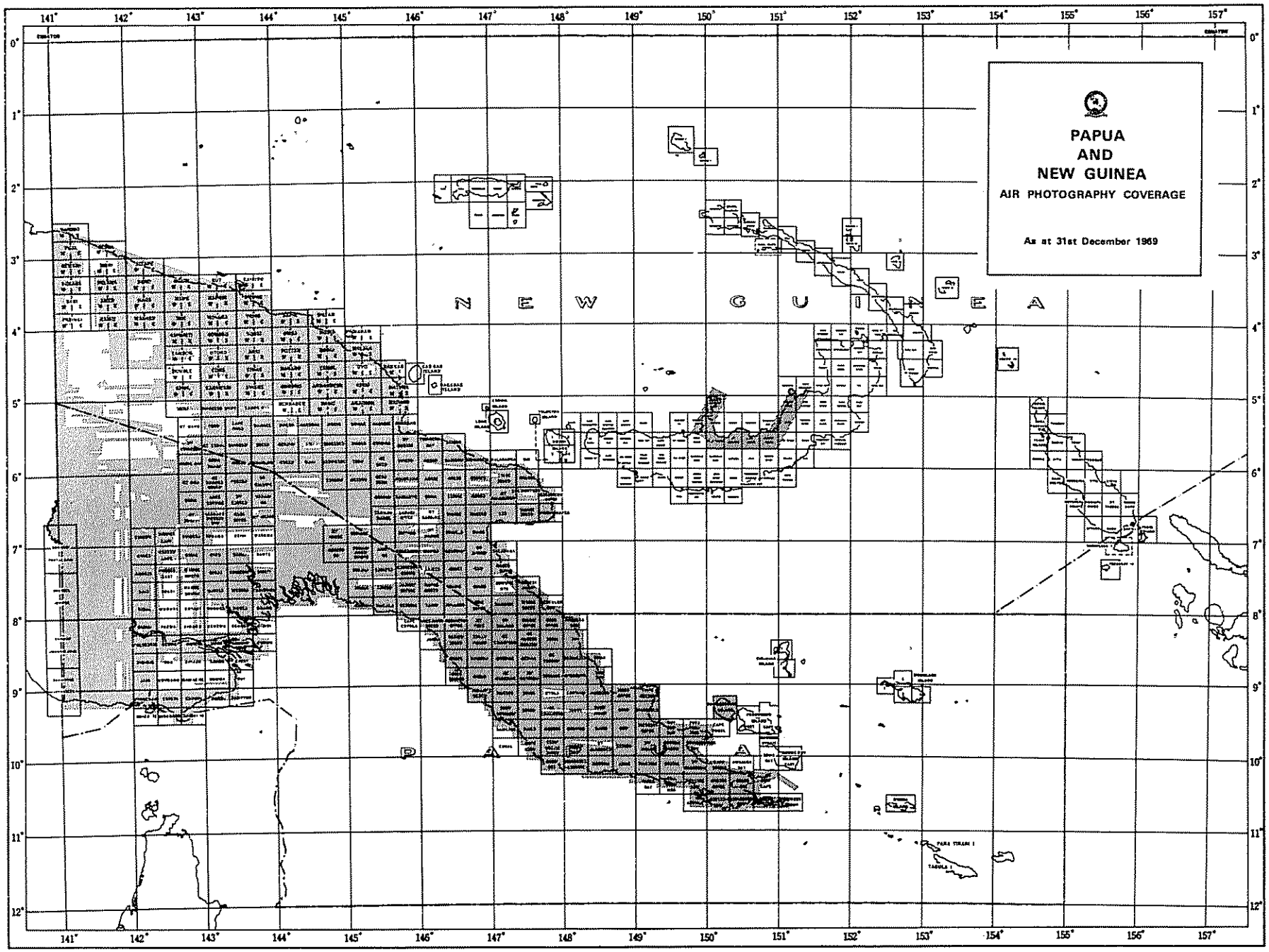


Figure IV. Air photography of the New Guinea mainland

Territory of Papua and New Guinea

Mainland Papua and New Guinea is covered with a 1:250,000 scale mapping series. A new edition at this scale will be published as each 250,000 map area is mapped at 1:100,000 scale.

Mapping of the Territory at a scale of 1:100,000 is in progress and is scheduled for completion in 1976. All maps are on the Australian geodetic datum and show the Australian map grid in metres. Relief is shown by contours at 20 or 40 m intervals. In addition, selected areas of the Territory are covered with 1:50,000 and 1:25,000 scale topographic mapping.

Planimetric mapping in the south-eastern portion of the Territory, at a scale of 1:50,000, is in progress. These maps are used mainly for administrative purposes and by land-resources-mapping authorities.

Mapping activities of the Australian states

Each Australian state has its own mapping authority to produce general topographic map coverage of its territories and for mapping required for specific administrative and developmental projects. The work is carried out by the Lands and Survey Departments under the respective state surveyors-general.

Federal and state mapping agencies, through the National Mapping Council of Australia, meet once a year to co-ordinate and correlate mapping on a national basis and to determine approved methods and standards of accuracy for the nation's geodetic survey and topographic mapping activities. All states actively participate in the national 1:100,000 scale mapping programme.

Standard topographic mapping of Queensland is carried out at 1:25,000 scale. Cadastral maps are published at various scales between 4 miles to one inch for country areas and 4 chains to one inch for urban centres. Shire maps are produced at scales of 2 chains, 5 chains and 10 chains to an inch.

New South Wales has a number of basic scales to meet different user requirements—1:4,000 scale with 5 ft or 10 ft contours for urban development; 1:25,000 scale with 10 and 20 m contours, together with a cadastral overlay, for more densely developed urban and non-urban areas; 1:50,000 scale with 10 and 20 m contours for areas of intermediate development; 1:100,000 scale uncontoured maps with cadastral detail for sparsely developed areas. Broadly, New South Wales will be covered with standard 1:25,000 scale mapping from the coast to the western side of the Great Dividing Range, with 1:50,000 scale mapping in the central division of the state and with 1:100,000 scale mapping in the western division.

In addition to work on the national 1:100,000 series, Victoria publishes a 1:50,000 scale cadastral series and a 1:25,000 scale and 1:5,000 scale series over selected areas of the state.

Tasmania is co-operating with the federal Government by providing complete coverage of the state with 1:100,000 scale mapping.

South Australia proposes to cover the entire state with standard 1:50,000 scale topographic mapping. Mapping for cadastral purposes is produced at scales of 1:100,000 and 1:50,000 and topographic/cadastral mapping at 1:10,000 and 1:2,500 scales.

Western Australia is aiming towards a fully integrated system of topo-cadastral mapping ranging from 1:100,000 to 1:500 with intermediate scales of 1:50,000, 1:25,000, 1:10,000, 1:5,000, 1:2,500 and 1:1,250. The 1:100,000 scale topographic series is compiled at either 1:50,000 or 1:25,000, and coverage of the state at 1:500,000 scale is continuing.

Automatic photogrammetry

Most mapping agencies in Australia now have machines in operation or on order that are capable of automatic or semi-automatic contouring and of preparing orthophotos.

For the 1:100,000 scale mapping programme, an area of approximately 3.8 million km^2 around the perimeter of Australia will be published either as line maps or lithographically presented orthophoto maps. The remaining 3.8 million km^2 in the interior will be compiled in the orthophotomap or controlled photomap form to 1:100,000 scale standards but will only be published as 1:250,000 scale line maps.

Laser airborne profile recorder

A laser profile recorder has been developed by the federal Government for the main purpose of providing vertical control for the national 1:100,000 scale mapping programme. Emphasis in design has been placed on compactness, light-weight rugged construction, ease of field operation and simplicity of field maintenance.

The limitations of radar profiling will be virtually overcome by the use of the laser system, which, with a beam of only 10^{-4} radians, will overcome the requirement for extensive datum areas and will enable positive ground heights to be obtained even in areas of open timber. The possibility of using this equipment to determine tree heights is being investigated.

Aeronautical charts

World aeronautical chart (WAC)—1:1,000,000 series

Forty-nine charts have been reprinted since 1967. There is complete coverage of Australia and New Guinea. The charts are continually revised, and many areas are currently being produced as fifth editions. The series was redesigned in 1967 and nineteen charts have been printed in the new format.

Visual terminal charts

This is a new series of charts at a scale of 1:250,000, specifically designed to assist pilots during airport approach. Topographic detail of visual importance to the pilot is emphasized, and aeronautical navigation information is shown in great detail.

Visual terminal charts will be produced only for airports where air traffic is dense. Seventeen charts are in the current programme.

International map of the world (IMW)

Provisional editions of the IMW sheets are printed concurrently with the corresponding world aeronautical charts by using a special black plate, with minor alterations to marginal detail, to overprint all other colours on the WAC sheet except the aeronautical overlay. Standard IMW sheets are also being produced as work permits; three sheets have been printed, and a further eight are in hand.

Geographical maps

In addition to the medium- and small-scale maps produced by the federal Government, the following geographical maps are also produced: (*a*) Australia, at scales 1:2,500,000, 1:5,000,000 and 1:10,000,000; (*b*) Papua and New Guinea, at scales 1:2,500,000 and 1:5,000,000; (*c*) Antarctica, at scales 1:10,000 and 1:20,000,000.
The maps are revised at four-year intervals.

Hydrographic surveys and charting

Since the last conference in 1967, hydrographic surveys have continued to be undertaken by the Royal Australian Navy (RAN) in accordance with "Hydroscheme 1965". This was a scheme of surveying priorities decided at a meeting in 1965 at which the major users of charts gave their views on surveying priorities. Figure V (annex D) shows how this plan has been followed between 1965 and the present. During the 1970–1980 period a concentrated effort will be made to chart all navigation routes around the Australian coast.

New ships

Approval was given for the building of a large oceanographic ship and a small hydrographic ship.

Chart production

During the years 1967–1969 the following numbers of new charts and new editions were published:

Year	*New charts*	*New editions and large corrections*
1967	25	13
1968	20	6
1969	20	3

Currently the Navy is publishing and maintaining 180 navigational charts.

Metrication of charts

The decision to convert all Australian charts from British units to metric units for all vertical measurement was made in 1969. The effect of this decision is to render all previously published charts of the RAN Hydrographic Office out of date.

To ease the work load, charts will be altered to metric units when they become due for a new edition for other reasons. New charts will be drawn using metric values.

Tide tables

Annual tide tables for Australian waters are now produced by the Hydrographic Office. The 1972 and later editions will be in metres.

Training

A Hydrographic School has been established in Sydney by the Royal Australian Navy for the training of junior officers and surveying recorders. Some foreign students are accepted at the school.

Oceanographic surveys

Reconnaissance geological mapping of the Australian Continental Margin to 500 m was started by the Federal Bureau of Mineral Resources in 1967. Ships' tracks form a grid of about 20 km spacing. Maps will be produced at a scale of 1:1,000,000 showing distribution of the sediment and rock types. To date, two cruises have been completed—one on the north-west Australian shelf and one in the Arafura Sea.

Multisensor marine geophysical surveys have been carrried out by the Bureau of Mineral Resources since 1965. Bathymetric, seismic, gravity and magnetic measurements have been made on ships tracks 16 km apart. Bonaparte Gulf, the Timor Sea and the north-west Continental Shelf have been mapped (see figures VII and VIII (annexes F and G)).

A survey of the Gulf of Papua and the Bismarck Sea is in progress. It is expected that about 15,000 line miles will be surveyed.

A geophysical survey of the entire continental slope around Australia is scheduled for completion by the end of 1972. The continental slope extends from a depth of 200 m to a depth of between 3,000 and 5,000 m.

Bathymetric surveys

The federal Government recently announced a 10-year programme for the bathymetric mapping of the Australian Continental Shelf. The survey is scheduled for completion by 1980, and a series of bathymetric maps at a scale of 1:250,000 will be produced. Initially, priority will be given to mapping reefs and islands of the Great Barrier Reef and defining coastlines and the physical edges of the Continental Shelf.

Geological mapping

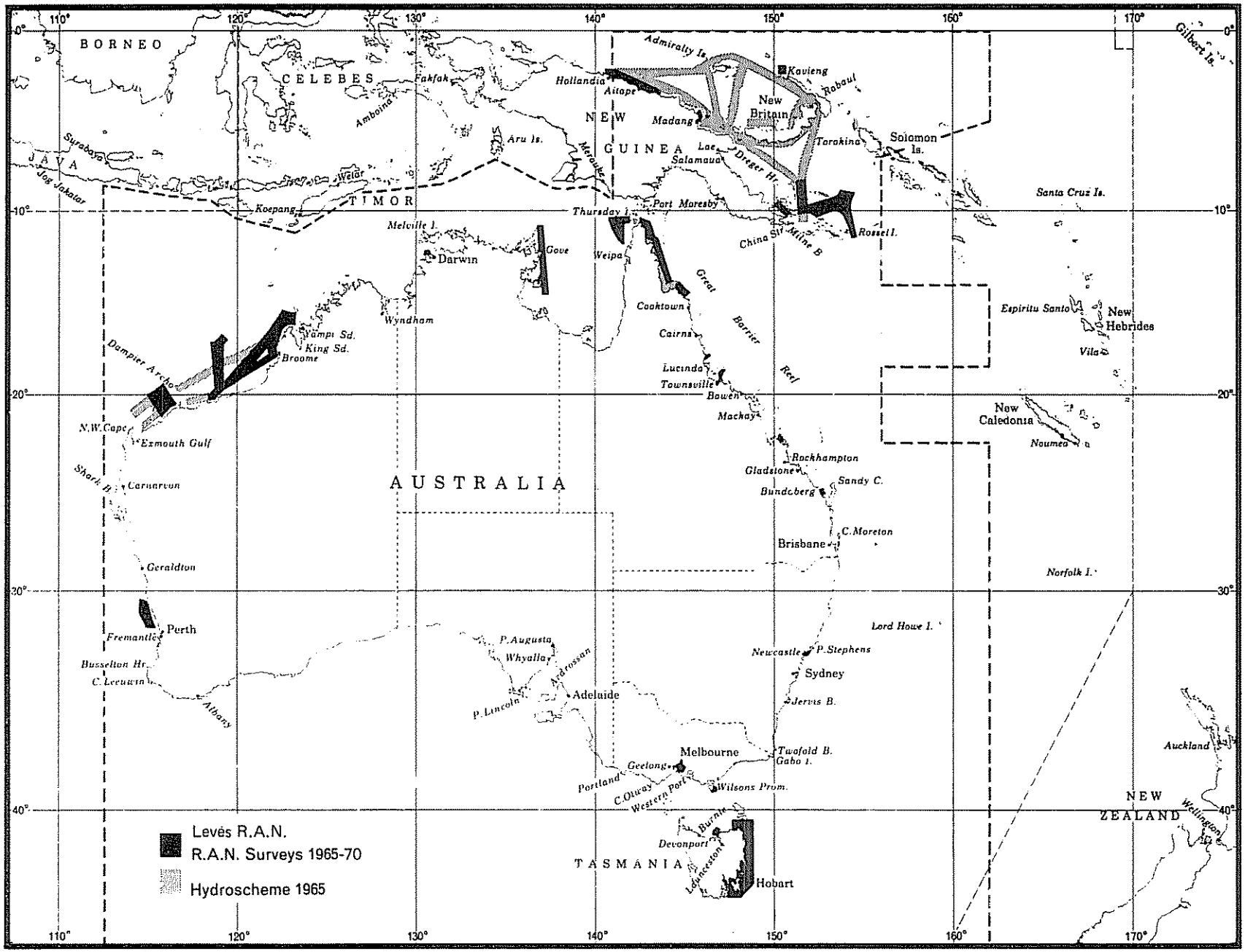
Geological mapping at a scale of 1:250,000 has been carried out by the Federal Bureau of Mineral Resources and the State geological surveys over the areas of the Australian continent and Papua/New Guinea shown in figure VI (annex E).

Air photographs are used to prepare photogeological maps before the field work. These photographs are also used for location and initial plotting of geological observations in the field. The final map is compiled on controlled planimetric base maps. Encouraging results have been obtained from the use of colour photography in some geological environments.

Magnetic surveys

Regional magnetic surveys have been made in Australia and the Territory of Papua and New Guinea over the areas shown in figure VII (annex F). Much of the work has been done by the Bureau of Mineral Resources, using contractors where appropriate.

Over the land masses and coastal areas the Bureau mainly uses its own aircraft, which are flown between 150



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Figure V. "Hydroscheme 1965"

and 600 m above ground level and at a line spacing from 1.5 to 3 km, depending on the geological conditions of the area. Navigation is mainly by aerial photography. The strength of the Earth's magnetic field is continuously recorded in analogue and digital form.

For the off-shore surveys, magnetic measurements are recorded continuously while the ship sails on a 16 km line spacing. Navigational aids include satellite Doppler and sonar Doppler methods.

The results of the magnetic surveys are reduced by computers and presented as magnetic profiles and contours on controlled planimetric base maps at 1:126,720 to 1:500,000 scale. Computer plotting is now being used for these maps.

Gravity surveys

Regional gravity surveys have been carried out in Australia and the Territory of Papua and New Guinea over areas shown in figure VIII (annex G). Most of this work has been done by the Bureau of Mineral Resources, much of it by contract.

Over land areas, helicopters are used for transport between ground stations, where gravity and barometric elevation are read mainly on an approximate 11-km grid. Air photographs are used for positioning. Elevation control is surveyed on ground traverses about 80 km apart. Gravity control is obtained from a national network of stations on a 250 km grid.

For the off-shore surveys, gravity measurements are recorded continuously while the ship sails on a 16 km line spacing. Navigational aids include satellite Doppler and sonar Doppler methods.

The results are reduced by the use of computers and presented as gravity contours at 1:500,000 scale on controlled planimetric base maps. Computer plotting of these contours is now being used.

Radiometric surveys

Radiometric surveys were carried out by the Bureau of Mineral Resources over the areas shown in figure IX (annex H).

The level of radioactivity is recorded by instruments in the Bureau's aircraft flown between 100 and 150 m above ground level and at a line spacing from 160 to 300 m. These surveys are usually made in conjunction with a magnetic survey.

The results of these surveys are presented as radiometric profiles, contours, and point-source anomalies on controlled planimetric base maps.

Soil maps

The major soil-mapping project completed in the period was the ten-sheet atlas of Australian soils (1960–1968, scale 1:2,000,000), prepared by the Division of Soils, Commonwealth Scientific and Industrial Research Organization (CSIRO) using the new Northcote soil classification. Each map is accompanied by a booklet that describes in detail each soil referred to in the map.

This material is being used by CSIRO to produce the Australian sheet for the FAO/UNESCO soil map of the world at 1:5,000,000 scale.

A number of regional soils maps at 1:1,000,000 and larger scales were published in the period as part of the land-classification surveys carried out in Australia and Papua/New Guinea by CSIRO's Division of Land Research.

Land classification surveys

The Division of Land Research of CSIRO has described and mapped the agricultural potential and land resources of some 2,165,000 km^2 of country in Australia and New Guinea. The preparation of these maps involves the extensive use of air photography, together with ground surveys by teams of specialists in geology, botany, climatology, soil science, plant biology and geomorphology.

Since 1966 seven land research series monographs have been published. These publications are scientific assessments of land for use mainly by agriculturists, foresters and engineers in broadly assessing and planning land use. The main maps embodying the results of these reconnaissance assessments commonly have "land systems" as their mapping unit. Land systems are areas of land with a recurring pattern of topography, soils and vegetation. Various ancillary maps are also published in these publications, on landforms, climate, soils, vegetation, pastures and the like.

Climatic and water-resources maps

Climate

The Federal Bureau of Meteorology has published a further six surveys in its series of regional climatic surveys. Maps of climatic elements form an important part of these publications. The Bureau has also published maps of average annual rainfall for the states of Queensland, Victoria and South Australia and for the Northern Territory, and an atlas of fifty-two maps of Australia (scale 1:12,500,000) on monthly and annual rainfall and evaporation.

Water resources

As reported in 1967, interest in water-resources maps is increasing, mainly in the preparation of state and national maps. Four maps of Australia at 1:5,000,000 scale are currently being prepared on behalf of the Australian Water Resources Council to summarize knowledge of groundwater resources. A map of surface-water resources at 1:6,000,000 scale, published in the atlas of Australian resources, has met in part a similar need for a summary on surface-water resources.

National and regional thematic atlases

Atlas of Australian resources

A further eight sheets have been published in the second series (i.e. second edition) of this atlas, which is prepared and published by the Geographic Section, Department of National Development. These sheets deal with minerals, water, crops and livestock, forests, electricity and roads. Work is well advanced on another five sheets.

Resources of New South Wales (N.S.W.)

The first five sheets of this loose-leaf atlas were published by the N.S.W. Department of Decentralization and Development in 1969. When completed, the atlas will consist of about twenty sheets of maps (at 1:3,000,000 and

smaller scales) with accompanying booklets, and some maps will also be available as wall maps at 1:1,500,000 scale.

Fitzroy region, Queensland, resources series

Seven of the twelve sheets of this series have been published by the Department of National Development since 1966 and the final sheet is in press. The sheets deal with an area of about 250,000 km^2, mostly at a scale of 1:1,000,000.

Burdekin–Townsville region, resources series

A similar series is being prepared for an adjoining Queensland region. Work is in progress on six sheets and publication of the map sheets and accompanying booklets should begin in 1971.

Vegetation and forestry surveys

In addition to the continuing and considerable volume of forestry surveys and maps by the State forest services and of natural vegetation by the Commonwealth Scientific and Industrial Research Organization as part of its land-classification surveys, several major general surveys of natural vegetation have been commenced since 1966.

The natural vegetation of much of Western Australia was mapped at 1:250,000 scale for the vegetation survey of Western Australia, and the first of seven sheets to cover the state at 1:1,250,000 scale will soon be published.

Other state-wide projects are the compilation of a vegetation map of New South Wales at 1:1,000,000 scale, to be published in the atlas "Resources of New South Wales", and a new map of Victoria. Another major project, now well advanced, is the reconnaissance mapping of northern Queensland at 1:1,000,000 scale by CSIRO.

These and many other recent and older surveys of natural vegetation, including many unpublished records and field observations, are being brought together to produce a new map of the whole continent at 1:6,000,000 for publication in the atlas of Australian resources. The initial map compilation is at 1:1,000,000 scale and a structural-floristic classification is being used.

CARTOGRAPHIC ACTIVITIES IN NEW ZEALAND, 1968–1970

Paper presented by New Zealand[1]

Introduction

This paper records progress in cartographic activities in New Zealand since the Fifth Conference.

The Department of Lands and Survey as the principal survey and mapping organization in the country undertakes the majority of survey and mapping work including control surveys, cadastral surveys of Crown lands, cadastral mapping, topographical mapping, special, general and thematic mapping including mapping for the Land Inventory Surveys and Resources Surveys and aeronautical charting.

Cadastral surveys of private land are carried out by private practising surveyors who also undertake some Crown cadastral surveys under contract.

The Department of Scientific and Industrial Research undertakes all geological soil survey, gravity and magnetic surveys and oceanographic work. Drawing office staff and base materials for these operations is provided by the Department of Lands and Surveys.

Some mapping operations related to forestry are undertaken by the New Zealand Forest Service. Hydrographic surveys and charting are carried out by the Royal New Zealand Navy, using shore control provided by the Department of Lands and Survey.

Progress to 1 July 1970 is shown in the following figures:

Figure I.	North Island, geodetic triangulation
Figure II.	South Island, geodetic triangulation
Figure III.	North Island, precise levelling
Figure IV.	South Island, precise levelling
Figure V.	Air photography coverage
Figure VI.	Topographical map coverage at 1:250,000
Figure VII.	Topographical map coverage at 1:63,360
Figure VIII.	Topographical map coverage at 1:25,000

[1] The original text of this paper, prepared by D. G. Francis, Department of Lands and Survey, appeared as document E/CONF. 57/L.44.

Surveying

During the period wide use has been made of the tellurometer, and the geodimeter has been introduced to further extend and refine the existing survey network to provide control for basic mapping and development schemes. A control survey in Fiordland using a ship-based helicopter and tellurometer equipment measured 280 miles of traverse in four days with a closing error of only one part in 80,000. Previous mapping in the area was 100 years old and included position errors of up to two miles.

There is an increasing demand for precise levelling data as height control for mapping and engineering projects and for checking the Earth's crustal movement. In a further effort to measure Earth movement adjacent to major fault lines, a Model 8 laser geodimeter has been purchased and used on special triangulation and crustal deformation surveys.

The Computing Branch has continued to use an Elliott 503 computer for adjustments to triangulation and control traverses, and has developed a variety of programmes to aid their work.

Survey control

Details of survey control are shown in the following table:

	1968	*1969*	*1970*
Triangulation (square miles)	298	2,710	2,104
Standard traverse (miles)	67	155	21
Precise levelling (miles)	153	287	283
Control traverses (tellurometer) (miles)	565	518	539

Photogrammetry

New Zealand now has complete coverage of aerial photographs, most of the recent work being done with

wide-angle or super-wide-angle lenses. Some successful tests with colour photography have been carried out for the New Zealand Forest Service and more mapping from colour photography is expected in the next few years.

The use of wide-angle and super-wide-angle photography has increased production and helped alleviate staff shortages. Basic mapping work was completed in the East Cape and Tararua Range areas of the North Island and in the South Island.

Experiments on scribing direct from Wild A9 and B8 plotters were carried out but found to be not fully satisfactory. Hot point scribing was also tried with little success. The present method is to plot the contours in pencil on a scribe sheet as a key for scribing by hand.

A comprehensive five-year mapping programme has been formulated to complete national coverage at one mile to an inch in 1973, and the effective and sequential flow of work is being maintained.

Photogrammetry was used to illustrate graphically the effects of the 1968 Inangahua earthquake.

Medium- and large-scale surveys have been completed for farm development, aerodrome construction, highway planning and construction and hydroelectric power investigation and design.

In 1969 first use was made of cross-sectional profile data obtained directly from photogrammetric procedures for quantitative calculations and highway design. This technique has been used several times since using an IBM 026 punch card system (which is also used for recording aerial triangulation) to record the digitized cross-sectional data from a Wild A7. Similar equipment is on order for a Wild A8.

	1968	*1969*	*1970*
		(square miles)	
New photography	29,368	23,895	18,588
Aerial triangulation	3,517	11,052	11,183
Special mapping	344	450	347
Basic mapping:			
1:25,000	99	544	662
1:63,360	7,851	9,210	7,810
Field work:			
1:25,000	1,176	86	6,701
1:63,360	11,431	16,764	15,950

Cartography

With the transition from reproduction by positive reversal to reproduction by polyester-based negative there has been a similar transition from vinyl to polyester drawing and scribing foils. However, positive reversal reproduction is still preferred when a number of screens are combined to the one plate.

Scribing negative for contacting to positive on polyester foil has largely replaced scribing for conversion to positive by dyeing. The use of scribing techniques has been extended into all phases of cartographic draughting.

Experiments are continuing in the use of colour separation photography of hand coloured originals. If successful, the method should save considerable drawing and checking time, particularly in the Land Inventory series.

The purchase of a new process camera has allowed greater flexibility in drawing for scale reduction and compilation methods.

Trials with etching peel-coat for masking have proved successful and should be a useful addition to our range of photo-mechanical techniques.

A pilot 35 mm microfilm system for the recording of survey plans has been instituted in Wellington District Office. Similar equipment is expected to be installed in other districts. A new design of one colour survey plan specifically for microfilm reduction is being studied.

Topographic mapping

Highest priority has been given to the completion of the 1:250,000 series which is expected this year and to the 1:63,360 series, particularly new full specification mapping.

Although eleven 1:25,000 sheets were published in 1968 none has been published since due to the lack of demand for mapping at this scale and the demands of the 1:63,360 programme.

The 1:500,000 series is undergoing a redraw as each sheet comes up for revision. This is due to the age of the originals, the new drawing techniques in use at present and the amount of accurate new information that has become available.

In 1968 a new format was adopted for the 1:63,360 series to replace that originally brought in about 1940. The map content remains the same.

General mapping

Work has continued on established map series and many new maps have been added to the range.

Seventy maps of representative basins have been undertaken for the National Water and Soils Conservation Organization, Ministry of Works. These show water catchment areas and will be published in a book and are part of New Zealand's contribution to UNESCO International Hydrological Decade 1965–1975. A new edition of the Descriptive Atlas of New Zealand is at the planning stage.

Cadastral mapping

The 1:63,360 cadastral series has continued to be published, national coverage being almost complete.

The production of large scale cadastral town plans has almost ceased due to a change in user requirement. Maps in this series will in future be made available as plan-prints from transparencies kept constantly up-to-date in district offices of the Department of Lands and Survey.

Land inventory mapping

The programme for land inventory mapping has accelerated though severely hampered by a lack of trained staff. One county has been published at 1:63,360 as a pilot scheme. The maps covering topography and land cover, geology, soils, potential pastoral use of soils, land tenure and land use were all well received. Drawing is well advanced on the maps of six counties, with a further two at printing stages.

National resources surveys

Seven maps of the Otago region were published in 1968. Maps of Hawkes Bay region and Wanganui region are at well advanced drawing stages. To date resources surveys of eight of the seventeen resources survey regions covering New Zealand have been completed.

Antarctic mapping

A further sixteen reconnaissance topographical maps at a scale of 1:250,000 were published over the period as well as twenty-seven special purpose maps.

Aeronautical charting

In the period under review a regular amendment and new-issue service has been provided for the ICAO aeronautical information publication which provides radio navigation charts and instrument approach and landing charts for aerodromes in New Zealand and the South Pacific.

There has been a trend to simplify the topographical background on approach and landing charts as the quantity of technical aeronautical information increases. A new style of FLIP visual landing chart is in the early stages of production and a mock-up has been prepared for a new series of three visual terminal charts. These charts are to enable visual flight to proceed through controlled areas.

New Zealand Forest Service mapping

Ten forest type (ecological) maps at 1:63,360 and forest class maps at 1:250,000 and other maps of forest conservancies at varying scales have been published.

Maps for scientific and industrial research

Twenty geological maps including five in the 1:63,360 series and six in the 1:250,000 series have been published. This completes coverage of New Zealand in the 1:250,000 geological series of twenty-seven sheets.

Forty-seven oceanographic maps and four geophysical maps were also published in the period under review.

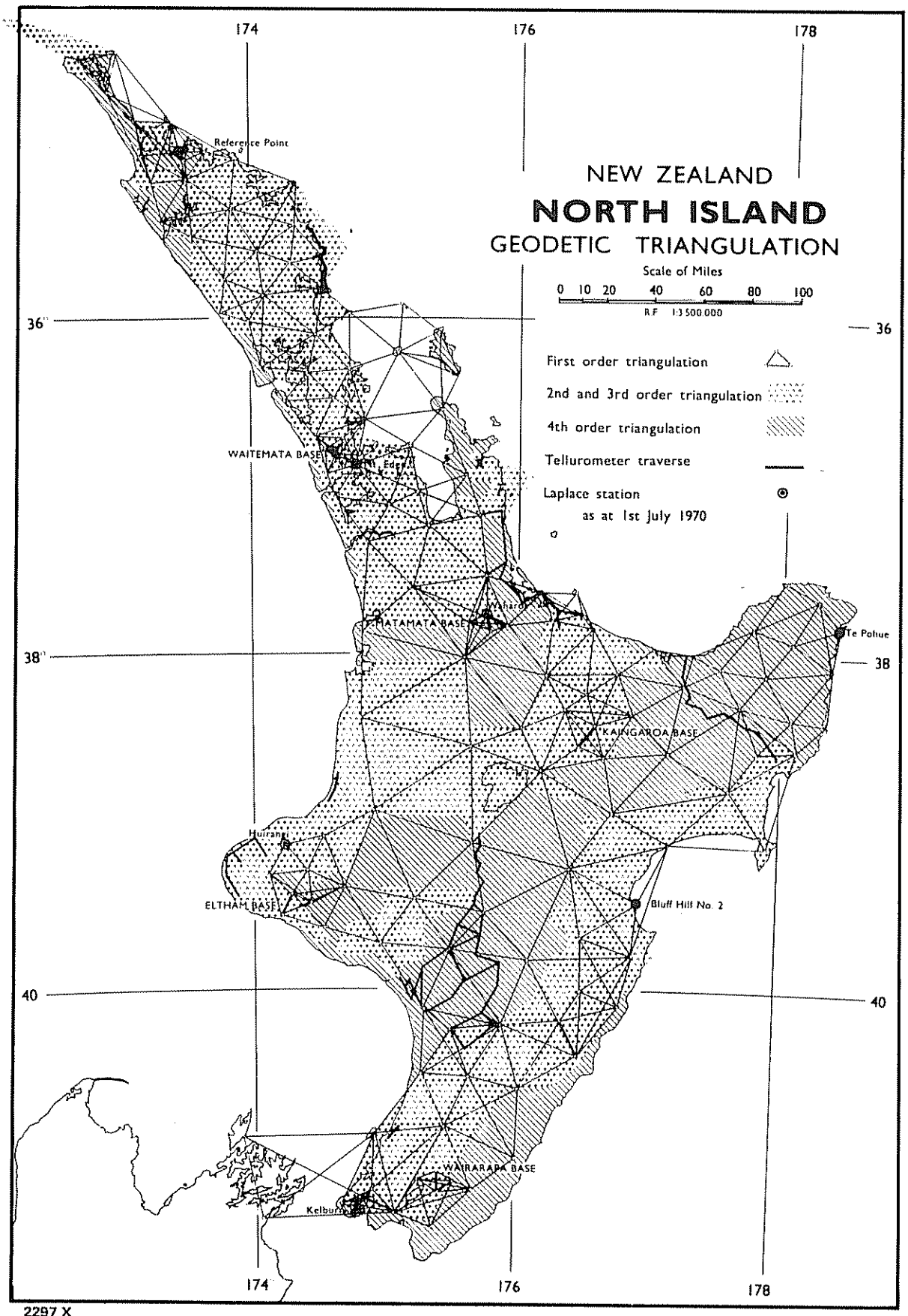


Figure I. New Zealand: North Island, geodetic triangulation

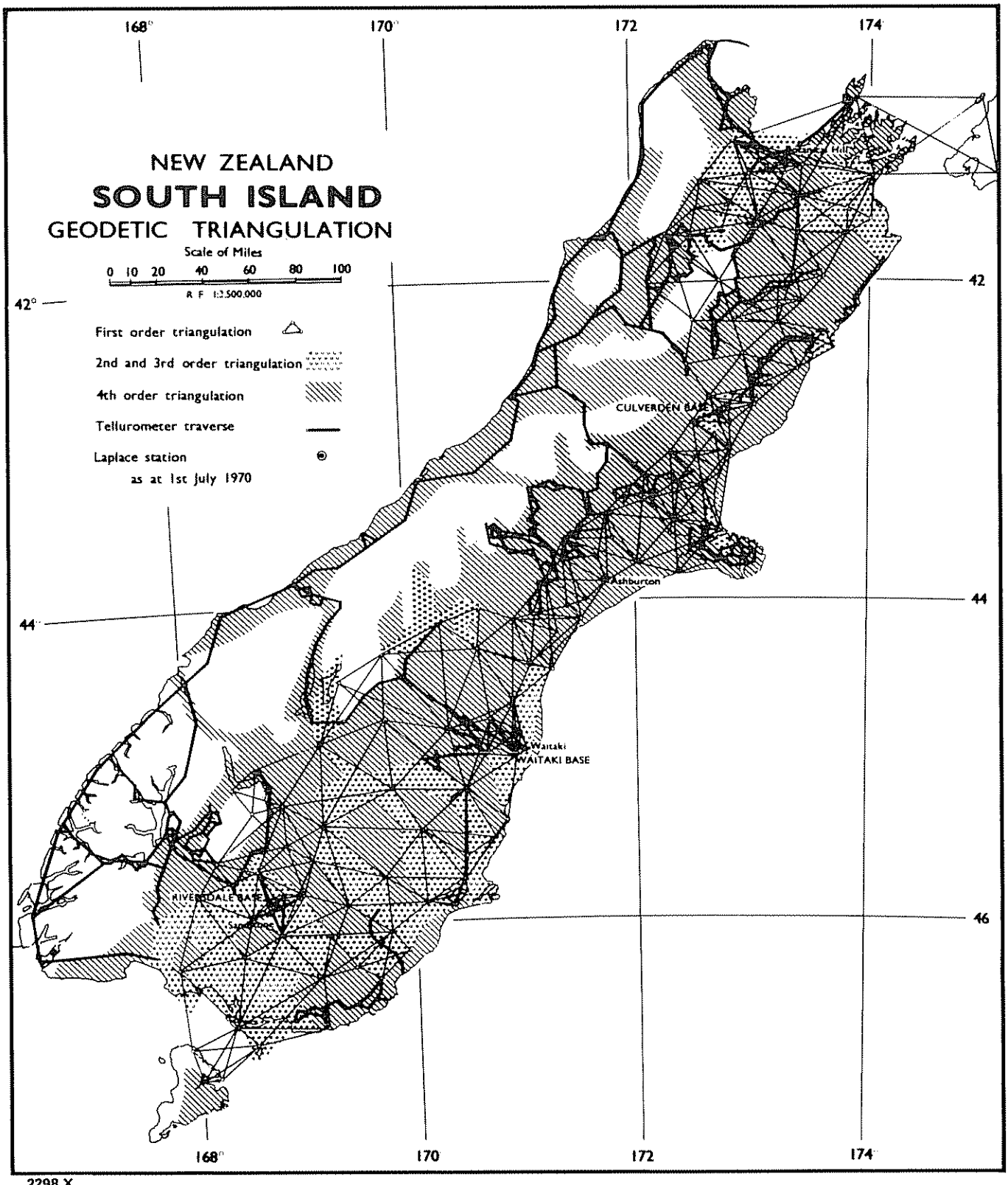


Figure II. New Zealand: South Island, geodetic triangulation

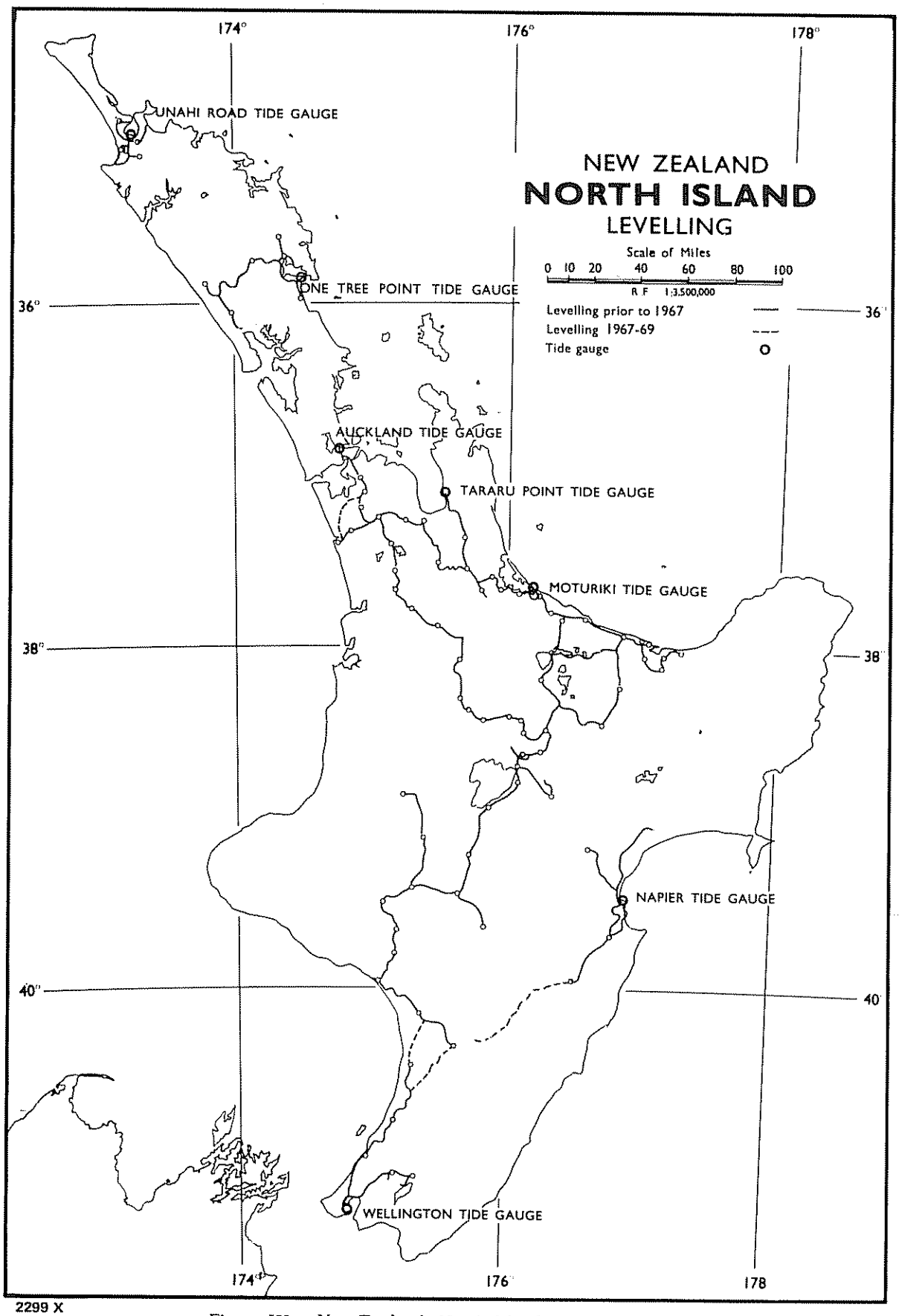


Figure III. New Zealand: North Island, precise levelling

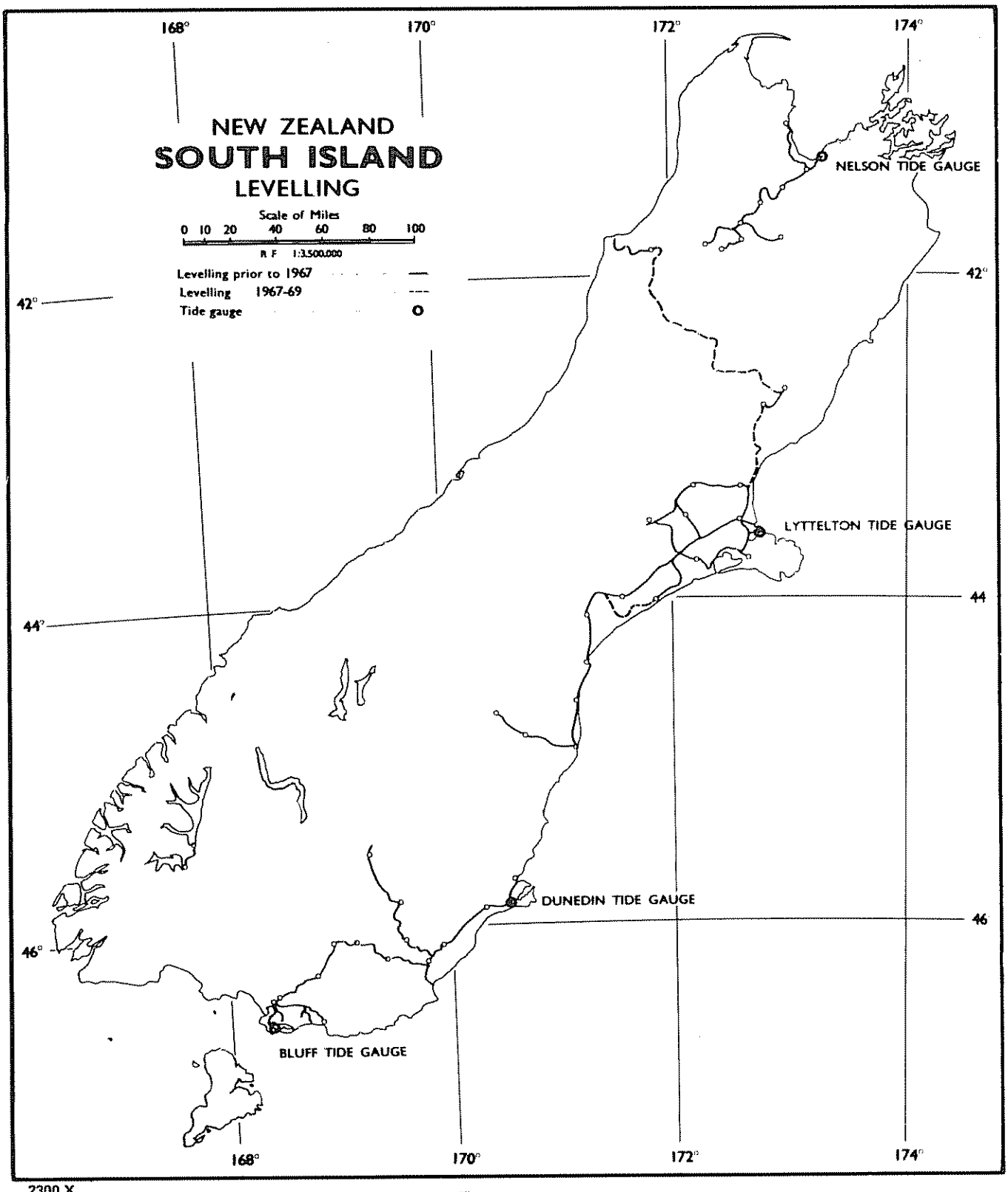
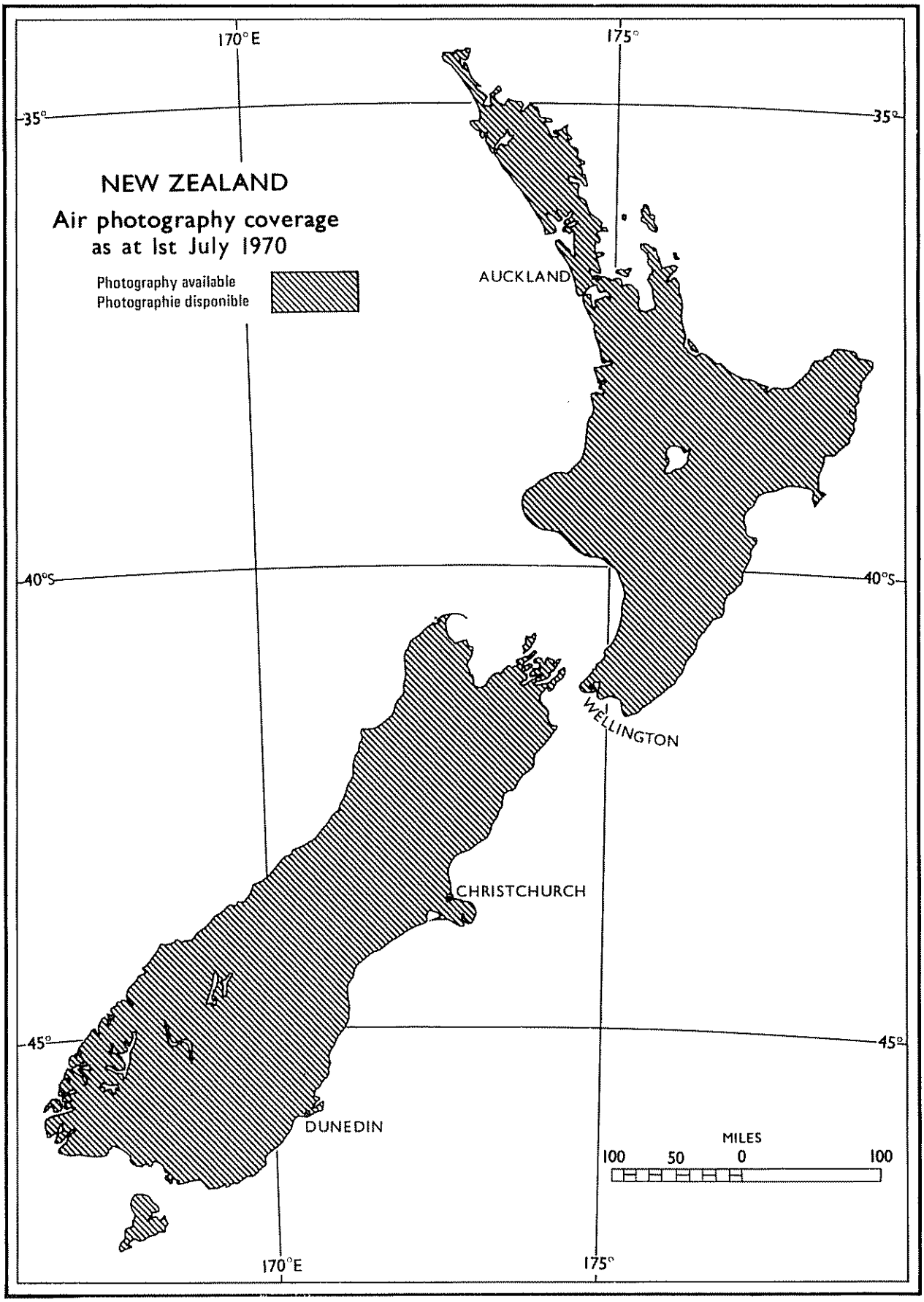


Figure IV. New Zealand: South Island, precise levelling



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Figure V. New Zealand: Air photography coverage as at 1 July 1970

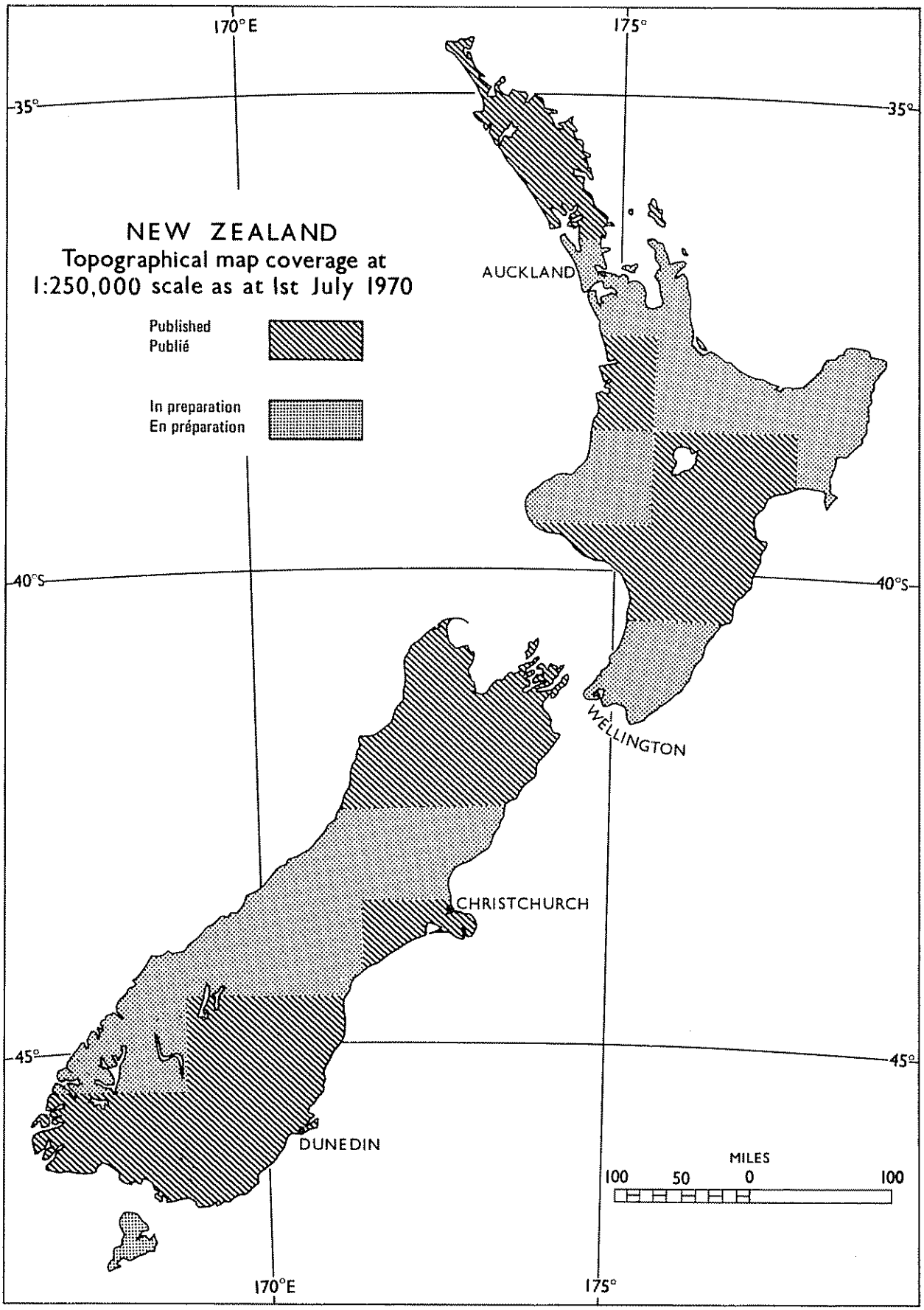


Figure VI. New Zealand: Topographical map coverage at 1:250,000 as at 1 July 1970

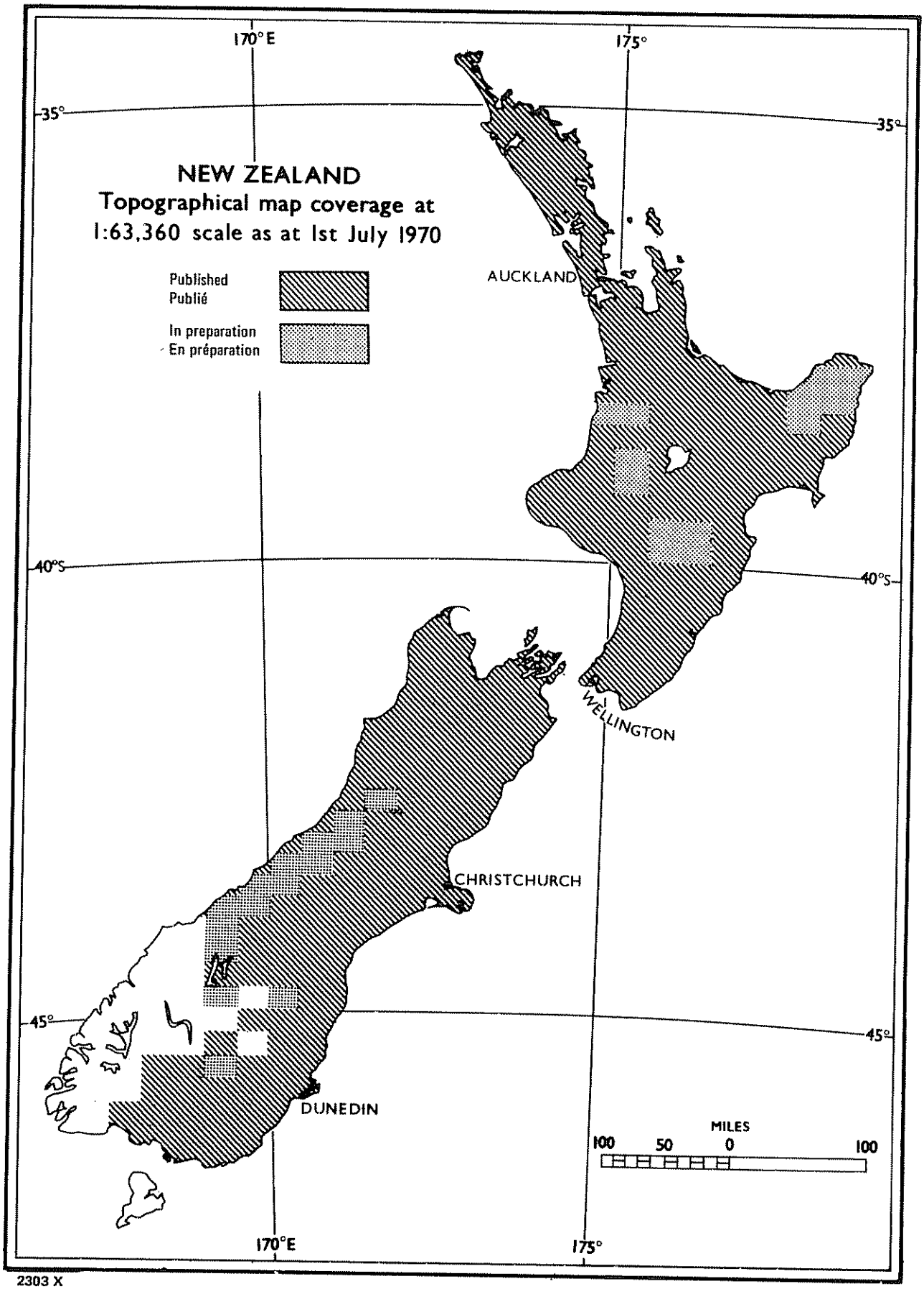


Figure VII. New Zealand: Topographical map coverage at 1:63,360 as at 1 July 1970

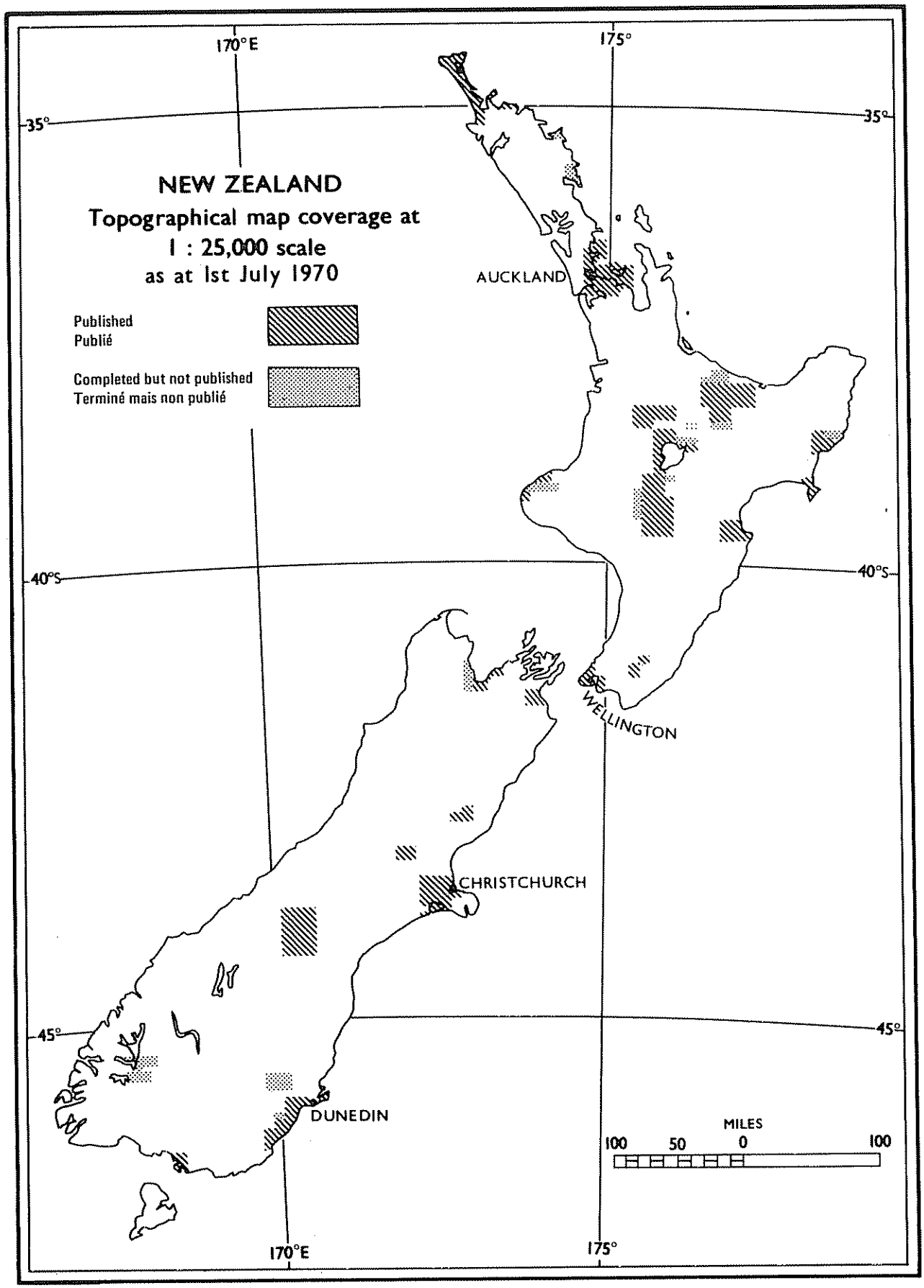


Figure VIII. New Zealand: Topographical map coverage at 1:25,000 as at 1 July 1970

CARTOGRAPHIC ACTIVITIES OF IRAN*

Paper presented by Iran[1]

INTRODUCTION

Prior to 1953 the National Geographic Organization (NGO) was the sole authority responsible for official production of surveys and mapping in Iran, but other unco-ordinated efforts existed to meet the needs of various government departments and private industry.

In 1953 the Plan Organization decided to establish a National Cartographic Centre (NCC) to co-ordinate surveys and mapping as needed for an increasing number and variety of development projects. The Centre would co-operate closely with the NGO.

Facilities for training staff at all levels for future needs were established within this new organization. The requirements of private organizations and other government departments as well as the Centre's own requirements were taken into account in preparing the training programme.

The survey, photogrammetric, cartographic and reproduction equipment needed for personnel training has been gradually acquired since 1953.

In an effort to supplement local training and keep abreast of new developments in techniques and equipment, selected staff have received advanced training at internationally recognized establishments. Visits to long-established organizations in the developed countries and participation in international technical congresses have also served to accelerate our progress.

The future needs of the country will be met by the following expanding organizations:

(*a*) The National Geographic Organization (which is responsible for all geodetic work and the production of the national small-scale basic map series);

(*b*) The National Cartographic Centre (responsible for cadastral mapping, large-scale mapping and surveys required for projects);

(*c*) The National Iranian Oil Company and the oil-exploiting and oil-producing companies (responsible for mapping at all scales as required for prospecting and exploitation of the oil fields);

(*d*) Private survey companies (whose facilities are at the disposal of NGO and NCC and whose technical capabilities are evaluated, classified and inspected by the two official organizations).

GEODESY

Triangulation and traverses

The main basis is a chain of triangulation 60 km wide linking the Iran/Turkey border in the north-west with the Iran/Pakistan border in the south-east and extending over a distance of 2,000 km. The chain follows the central mountain ranges, and all angle measurements were made with one-second-precision theodolites, each angle being measured sixteen times.

Five base lines, suitably distributed along the chain, were measured by geodimeter. The chain has been computed and adjusted on Laplace points in the international spheroid system. The chain is connected to a number of Shoran stations which have been used for control of the aerial photographic cover.

The national geodetic chain is also connected to a triangulation and traverse network covering the oil-prospecting company's "agreement area" in the south and measuring 250,000 km^2.

Current operations include an extension of the triangulation to the northern part of the country by a system of tellurometer traverses.

Levelling

The levelling network is based on tide-gauge observations at stations located on the southern coast at Bandar Abbas, Chahbar, and Genaveh. The network is evenly distributed throughout the country and comprises 8,000 km of second-, third- and fourth-order levelling.

Barometric levelling was attempted in the mountainous areas in the western part of the country, but the considerable height differences and meteorological conditions prevented satisfactory results. A system for carrying height measurements to the peaks from the low-altitude level lines by trigonometrical observations has now been adopted.

Geomagnetic and gravimetric measurements

Geomagnetics

A modern, fully equipped observatory has been established, which makes it possible to measure absolute values as well as variations. To date about forty well-set-out bases for absolute measurements have been established. The equipment includes:

1 Schmidt magnetic theodolite;
1 Askania earth inductor;
1 Askania variograph;
1 pulsation magnetograph;
1 H magnetograph, etc.

Gravity

Measurements were initially started in 1960 by using an Askania gravimeter, but since 1967 a La Coste and Rhomberg instrument has been used. To date some 800 first- and second-order bases have been established. Measurements began in the north-western province of Azerbaijan and are being extended to cover the entire country. Results are being adjusted by means of the Gauss–Vogler least-squares method.

More detailed accounts of these activities are given in reports 33, 35 and 48, which are available on request from the Iranian Geophysical Institute.

PHOTOGRAMMETRY

Aerial photography

The entire country had been covered during the period 1955–1957 at scale 1:50,000, the main purpose being the production of two general series of maps at scales 1:50,000 and 1:250,000.

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* Colour materials will be found in pocket at end of volume.

[1] The original text of this paper appeared as document E/CONF.57/L.60.

In 1965 a new general coverage was undertaken at scale 1:20,000 which should be completed this year and which is intended for land-reform mapping and other purposes.

Five aircraft (DC-3s and Aero Commanders) are generally used for aerial photography at scales ranging from 1:4,000 to 1:30,000, in connexion with many development projects throughout the country.

Terrestrial photography

Increasing use is being made of terrestrial photogrammetry in the preparation of large-scale maps for dam sites, archaeological studies and the like.

Table 1. Photogrammetric equipment in Iran

	1967	*1968*	*1969*	*1970*
Aircraft for photography:				
Government	1	1	1	—
Private	5	5	5	5
Cameras:				
Government	9	9	9	9
Private	—	—	—	—
Universal instruments:				
Government	4	4	4	4
Private	4	4	4	4
Precision instruments:				
Government	6	6	6	6
Private	12	11	11	11
Topographic instruments:				
Government	10	10	22	30
Private	9	9	9	9
Approximate instruments:				
Government	6	6	6	6
Private	3	3	3	3

Table 2. Photographic activities

Photo scale	*1968*	*1969*	*1970*	*Total*
		(km^2)		
1:4,000	4	—	114	118
1:6,000	41	950	—	991
1:6,500	895	4,896	2,434	8,226
1:7,000	45	1,200	—	1,245
1:7,500	—	280	375	655
1:10,000	1,823	5,853	5,460	13,136
1:20,000	30,810	275,000	125,300	331,110
1:25,000	3,294	—	—	3,294
1:50,000	—	—	158,000	158,000
	Length of photo strip (in km)			
1:10,000	393	967	333	1,693

Provision of photogrammetric control

The necessary control for orientation of stereograms for photogrammetric restitution is provided either by field surveys or a combination of field control and aerotriangulation adjusted in strips or blocks. Both the methods of aeropolygon extension and independent models for strip and block adjustment to ground control are used.

The survey methods used for providing control generally consist of triangulation or tellurometer traversing, or a combination of both.

The ITC (International Photogrammetric Training Centre, Delft, Netherlands) analogue computer system of block adjustment is extensively used for flat areas or irrigation works. For hilly or mountainous areas, a variety of computer facilities are available, including the IBM 1130, 1620, 7040 and 360/65. The programmes used for all kinds of adjustments were mainly those prepared by Dr. C. W. B. King for IBM.

CARTOGRAPHY

Drawing

Most maps are fair-drawn for reproduction by using scribing methods, and some pen-and-ink drawing is also practised. In some cases direct scribing on the plotting instruments is used. Letters and numbers are added to the maps by the usual printing methods, but stencilling or hand-lettering are occasionally used. Masking methods are often used for colour separation.

Printing

Scribed sheets are transferred onto zinc or aluminium plates and multicoloured final map sheets are produced on offset printing machines.

MAP PRODUCTION

General series

It is planned to cover the country with two map series at 1:50,000 and 1:250,000 scales. Some 2,650 sheets at 1:50,000, each covering an area of 15′ × 15′, are required to cover the entire country. As of July 1970, 295 sheets had been printed in six colours; 180 of them were completed during the past three years. In addition, some 138 sheets at 1:250,000 scale, each covering an area of 1° × 1° 30′ are required to cover the country. As of July 1970, fifty-eight sheets had been printed in six colours. The National Geographic Organization is responsible for these map series.

Project mapping

The National Cartographic Centre produces a wide variety of maps at different scales (from 1/200 to 1/50,000) for the study, planning and execution of hydroelectric and irrigation schemes, transmission-line networks, urban development, mineral exploration, pipelines, highways and so on.

Table 3 indicates the scope and extent of activities of the National Cartographic Centre in the past three years.

Table 3. Project mapping

Scale	*1968*	*1969*	*1970*	*Total*	*Number of colours*
		(km^2)			
1:2,500 and larger	680	300	340	1,320	1–3
1:5,000	6,740	—	770	7,510	2–5
1:10,000	2,850	1,930	1,370	6,150	1–3
1:20,000	2,970	10,750	6,480	20,200	2–4
1:50,000	25,200	56,000	20,200	101,400	4

Strip maps at 1:2,000 scale and longitudinal profiles are prepared for high-voltage transmission-line routes. Distances covered to date include 251 km in Gilan, 828 km in Azerbaijan, 461 km in Mazanderan and 1,413 km in the western part of the country, a total of 2,953 km.

Table 4 shows the number of maps produced for road studies since the last conference.

Table 4. Number of road-study maps produced since March 1967

Region \ Scale	1:50,000 10 km width (km)	1:5,000 200 m width (km)	1:2,000 200 m width (km)
Kermanshahan	646	—	638
Ilam	262	—	256
Hamadan	381	—	529
Gilan	—	110	214
Mazandaran	316	—	203
Gorgan	—	393	133
Fars	—	—	100
Kerman	—	—	200
TOTAL	1,605	503	2,273

CADASTRAL MAPPING

As a basis for cadastral mapping, aerial photography at scale 1:6,500 to 1:7,500 is first carried out. Each photograph is enlarged and rectified to 1:2,500 scale, based on ground control.

The rectified enlargements are then taken to the area to be settled or resettled and, in consultation with local elders and owners, the boundaries of each plot are determined, marked on the enlargements, numbered and entered on the register. With this information, maps are produced which include all the main topographic details in addition to the cadastral data.

The maps are then annotated with the information collected on the photo enlargements and the plots are measured. Title deeds are then issued to all the property owners.

The National Cartographic Centre plans to produce a complete series of cadastral maps based on the above-cited 1:20,000 scale photographic coverage.

Table 5 outlines the cadastral work completed in the past three years.

Table 5. Cadastral work completed in Iran, 1967–1970

Region	Area (ha)
Zabol	220,000
Fowman	90,000
Zayendeh-Rud	7,000
Sefid-Rud	40,000
Minab	25,000
Land reform	42,000
TOTAL	424,000

PHOTO-INTERPRETATION

In addition to the normal process of photo-interpretation required for general mapping, the available aerial photographic coverage is used for other purposes, in particular photogeology and forest surveys.

Several photogeological studies were carried out in recent years, and in the case of forests work was restricted to the Caspian Sea coast. The Engineering Department of the Ministry of Natural Resources carried out photography at scales 1:50,000, 1:10,000 and 1:5,000 for inventory, classification and measurement of trees. The data thus obtained are used for reafforestation, conservation and development of related industries.

GEOLOGICAL MAPPING

The production of geological maps in Iran is the responsibility of the Geological Survey Institute. The National Iranian Oil Company and the Iranian oil-producing companies have made a significant contribution to this work in the areas in which they operate.

The history of geological mapping in Iran may be divided into three periods:

(*a*) 1950–1957. Initially, geological mapping was based on the available topographic maps at 1:250,000 and 1:247,440 (0.25 inch to 1 mile), from which a geological series at 1:500,000 covering the western parts of the country was produced. Additional series at 1:1,000,000 and 1:2,500,000 were subsequently prepared.

(*b*) 1957–1962. During this period more reliable maps at 1:100,000 and 1:250,000 were produced by using 1:250,000 aeronautical approach charts as base maps and photogeological interpretation of the new 1:50,000 photographic coverage, together with geological survey information from all available sources. An area of 200,000 km^2 was therefore covered by detailed and reliable mapping, and a further area of 400,000 km^2 was covered by more general geological maps.

(*c*) 1962–1970. In certain areas the existing geological maps were further upgraded during this period, on the basis of good available topographic maps and additional geological information.

Field control surveys were carried out and simple photogrammetric processes such as radial triangulation were applied in order to extend geological mapping into areas not yet covered by accurate topographic maps. Geological maps at 1:500,000 and subsequently at 1:100,000 scale have been produced for these areas. About one-third of Iran has thus been covered with geological maps at various scales. An extensive programme is now planned for extending the geological coverage and upgrading existing mapping so as to meet the growing needs of the country.

TRAINING FACILITIES

A training school in all subjects related to surveying and mapping was established in 1954. It functioned until 1958, and during that four-year period 78 surveying engineers, 208 surveying technicians and 120 cartographic draughtsmen were trained and qualified.

The school was reopened in 1965 with an expanded curriculum, and to date an additional 59 surveying engineers, 259 surveying technicians and 42 cartographers have been trained and have graduated.

The subjects taught include geodesy, aerial surveying, photogrammetry, cartography, map reproduction, geophysics and geology, as well as related subjects such as mathematics, theory of errors, physics and optics. In addition, instruction in foreign languages is given to equip the students for further education and subsequent practical applications.

ACTIVITIES OF THE AFGHAN CARTOGRAPHIC INSTITUTE FOR THE PAST FIVE YEARS

Paper presented by Afghanistan[1]

About one year after the beginning of the nationwide activity for mapping the area of Afghanistan by the Afghan Geological Survey of the Ministry of Mines and Industries, the Afghan Cartographic Institute (ACI) was established under the Prime Ministry in 1958. About six years later the Aerial Photography and Mapping Office of the Afghan Geological Survey was joined to ACI, and immediately after the ACI was transferred under the direction of the Ministry of Mines and Industries. Since then, in addition to the results of the nationwide mapping activity of the Afghan Geological Survey, the following was accomplished from the mapping point of view:

Photogrammetry

The flight crew was trained for a short period with USAID help and it finished the large-scale photography, at scales 1:15,000 to 1:10,000, of the upper Kabul and Harirud valleys, the Kunduz–Khanabad area, some parts of the Helmand valley, part of the international highway between Kabul and Herat, and other cities of Afghanistan. The area covered measures 621,000 ha and was taken in 9,412 negatives of 24 × 24 cm format with 60 per cent overlap and 15 per cent sidelap. The required copies of contacts and enlargements, about 140,000 pieces, were printed for the projects concerned. Indexes and the required corrected photomosaics of the cities of Kabul, Herat and Kandahar and of the Kunduz–Khanabad area, were made at scales 1:5,000 and 1:10,000. The 1:10,000 scale maps with 2 m contour interval were prepared for the upper Kabul valley and the Herat and Kunduz–Khanabad areas in 168 double sheets by A5, A7, A8 and B8 plotting machines, and for these projects fourteen personnel were completely trained in plotting. 1:5,000 scale maps of the cities of Kabul, Herat and Jalalabad were completed and that of Kandahar is in preparation. Plans at scales of 1:400 to 1:5,000 of the local areas were drawn up by plane-tabling for different purposes.

Geodesy

The reconnaissance and marking of the first and second order of the greater loop of Afghanistan was completed, as well as the observation of 65,850 km², which represents about six-sevenths of the total area of the loop. The greater loop of the first-order level, 2,321 km², was completed and is being computed for preliminary adjustment. Other smaller loops of first-, second- and third-order level were also completed as needed. Basic levelling benchmarks for reference and checking in future projects were surveyed and marked. The work for a Doppler station was started in Kabul.

Reproduction

The map at scale 1:250,000 of Afghanistan in five colours was completed and printed. About forty maps at 1:100,000 scale and ninety maps at 1:50,000 scale were prepared for colouring by tracing and retouching, and the maps at scale 1:50,000 prepared by retouching have already been printed in five colours. The multicoloured map of the world at 1:40,000,000 scale was reproduced, and the negatives for the map at 1:20,000,000 scale were made available with the help of the Asia Foundation.

The smaller scale maps of Afghanistan, from 1:5,000,000 to 1:1,300,000, were completed and printed. These include the road map showing distances and economic, geological, archaeological and demographic data, and touristic maps of Afghanistan. Over 250,000 copies of ozalid printing, contact printing of aerial photography and photomosaics, and photo and line indexes, etc., were printed. The printing of an atlas of the provinces of Afghanistan was almost completed.

Moreover, D. G. Francis' *Fundamentals of Cartography* (350 pages) was translated by Din Yaqubi and printed. Mr. Yaqubi also translated almost all the operating manuals for the existing technical equipment of the ACI. A more complete glossary[2] of the geographical names was also completed and printed according to the alphabetical order in the system of transliteration of the ACI. One of the nineteen country maps at scale 1:500,000 was printed.

Future work programme

Large-scale aerial photography and mapping of areas is needed. Completion of Doppler geodetic work. Preparation of large-scale maps for the remaining cities of the country. Completion of the first-, second- and third-order triangulation and levelling networks of the entire area of the country. Completion of the 1:500,000 and 1:1,000,000 map series and the 1:50,000 and 1:100,000 colour map series of Afghanistan. Revision of maps.

[1] The original text of this paper, prepared by A. Yaqubi, President of the Afghan Cartographic Institute, Kabul, appeared as document E/CONF.57/L.61.

[2] A sample of the glossary was submitted to the participants of the Conference as an annex to this paper. For copies of this glossary requests may be made to the Afghan Cartographic Institute, Kabul, Afghanistan.

CARTOGRAPHIC ACTIVITIES IN MALAYSIA

Paper presented by Malaysia[1]

Introduction

Cartographic activities in Malaysia must necessarily keep up with the surge of economic, industrial and development activities in the country. The gigantic and widely known rural development programme alone, the aim of which is to provide land for the landless, provides the bulk of the work-load in cadastral surveys as well as other cartographic activities.

The Director of National Mapping, Malaysia (concurrently the Director General of Survey of West Malaysia) is

[1] The original text of this paper appeared as document E/CONF.57/L.62.

responsible for topographical and geodetic surveys besides the production of maps in Malaysia for military and civilian purposes. This heavy responsibility has, however, been alleviated through the assistance of two United Kingdom Government survey organizations in the mapping of East Malaysia, viz.:

(i) The Directorate of Overseas Surveys (DOS) whose assistance is provided under the United Kingdom Technical Aid Programme of the Ministry of Overseas Development;

(ii) The Directorate of Military Surveys of the Ministry of Defence whose assistance through the Assistant Director of Survey (AD Survey) Far East Land Forces, has been mainly in connexion with military operations by United Kingdom and Commonwealth Forces under defence treaty obligations.

Triangulations

In West Malaysia where an adequate network already exists, no further primary or secondary triangulation activities were undertaken.

In East Malaysia, the existing triangulation network has been further broken down (mainly by electronic distance measurements), partly to provide ground control for mapping and partly to extend the control network for cadastral survey purposes. The rapid completion of this work owed much to the availability of helicopter support as some areas are almost inaccessible by foot. Four secondary and fifteen tertiary points were established by conventional triangulation observations in Sarawak.

The Directorate of Military Surveys recently undertook a further extension of the first order tellurometer traverse in the Third Division of Sarawak near the Indonesian border. Ten new stations were fixed. The Directorate of Overseas Surveys in the process of fixing ground control points for 1:50,000 mapping established several new tellurometer traverse stations. The tellurometers of the Land and Survey Department of Sarawak were used extensively during the past three years in breaking down control for mapping and general cadastral purposes. Altogether, one first-order, 60 second-order and approximately 250 third-order stations were fixed by tellurometers.

Some 700 stations (at approximately half mile intervals) for standard traverse controls were established by geodimeter.

Connexion between the triangulation systems of West Malaysia and Thailand

This was completed by a joint Malaysian/Thai/AD survey team with the AD survey undertaking a reconnaissance survey subject to approval by the other two teams, the training in the use of electronic distance measurement equipment and the correlation and calculation of the results of the task. Nine stations were occupied, three stations fixed and 612 miles of tellurometer traverses measured. The aims of this joint task were:

(*a*) To connect the first-order triangulation of Thailand at selected points to the first-order triangulation of West Malaysia at selected points using triangulation and electronic distance measurements. Separate measurements were taken by Malaysian and Thai teams in order to provide training for future tasks;

(*b*) To train surveyors of three nations on a joint geodetic project using electronic distance measurement equipment.

The task was carried out in three phases: Reconnaissance (3 August to 2 September 1967), tellurometer measurements (25 September 1967 to end of January 1968) and angular measurements (4 October 1967 to May 1968). Normal field checks were carried out during field work but final computations and adjustments were processed by an electronic computer in the United Kingdom and completed in October 1968.

Comments and recommendations

The project was well executed and fully met the initial requirements and, in the absence of any evidence of discordance, the plethora of observations and the variety of observation conditions lend strength to the solution. However, it was recommended that a more comprehensive adjustment be undertaken to make the best use of the present work.

Levelling

The object was to extend the present precise levelling network as new lines of communications are opened. In West Malaysia a total of 175 miles of precise levelling was carried out during the period under review, principally between Grik and Butterworth.

Gravity survey

Ten new gravity stations were established in Sarawak in the course of carrying our first-order tellurometer traverse.

Air photography

West Malaysia

As West Malaysia had a complete photo cover for standard mapping as recently as 1967, further coverage to the extent of 2,000 square miles were flown at various scales ranging from 1:10,000 to 1:30,000 for revision purposes and for special purpose mapping for other Government and statutory bodies.

Sarawak

The Land and Survey Department of Sarawak using a chartered aircraft and its own Wild RC8 camera covered an area of 45,000 square miles at scales ranging from 1:5,000 to 1:30,000. This photography is being used for the 1:50,000 mapping by the Directorate of Overseas Surveys (DOS) and for large scale mapping by the Land and Survey Department, Sarawak. Other photography was taken for land-use mapping, road location, forest inventory and the revision of town maps as requested by other departments in Sarawak.

Sabah

Under phase 1 of the Sabah forest inventory project (aerial survey) 75 per cent of the whole of Sabah (approximately 22,500 square miles) was photographed at 1:25,000 scale with the Department's own RC8 camera and a hired aircraft.

Map compilation

In Malaysia the basic scales and projections of topographical maps are as follows:

	Series	Scales	Projections
West Malaysia	L8010	1:25,000	Rectified Skew Orthomorphic
East Malaysia	L7010	1:63,360	Orthomorphic
	T735	1:50,000	Orthomorphic

Series L7010 and T735 of the basic map series are designed to serve both military and civilian users, while series L8010 is designed to meet the needs of rural development and other planning purposes.

Series L8010

This series forms the basic mapping of the L7010 series. All topographical map sheets are compiled at this scale. There are 708 map sheets of which 115 sheets have been published during the period under review. The size of a sheet is 21 × 24 inches, the size being so chosen that six sheets of this series will fit in the sheet line of one map sheet of the L7010 series.

Series L7010

This series, derived from the 1:25,000 compilation sheets, is considered the standard series of West Malaysia. It is fully coloured, gridded and contoured at 50 and 100 ft vertical intervals.

There are 153 sheets in this series and of these thirty-four sheets have been published during the period under review. The number of sheets remaining to be published is twenty-seven. The over-all size of the sheet is 18.7 × 25 inches but a few sheets have different dimensions.

Series T735

This is the standard mapping series of East Malaysia. There are 340 map sheets in this series. The old uncontoured sheets are now steadily being replaced by the fully coloured and contoured editions. To date 107 fully contoured and coloured sheets have been published.

The contour interval is 100 ft with provision for 50 ft supplementary contours at certain intervals, and also 250 ft contours in very steep country.

Series L5010

Series L5010 (1:250,000) was designed to replace the older series L501 (1:253,440). This series is compiled from the standard series L7010 and series 1501 (JOGS). There are fourteen sheets in this series of which ten sheets have been published.

Town maps

All town maps of West and East Malaysia are drawn to the same specifications.

West Malaysia

L808 (1:10,000) and L905 (various scales) are the town series of West Malaysia. These are fully coloured, gridded and contoured at 25 ft vertical intervals. The L808 series consists of forty-five map sheets, of which only one sheet has been published so far. The other sheets are now in various stages of compilation. Series L905 has forty-three sheets in all, each sheet being of one town. During the period under review, five sheets were published.

East Malaysia

Series T931 covers the towns of East Malaysia. There are eight sheets of various scales in this series, one sheet for a town. All sheets have been published.

State maps

The state maps of the thirteen states of Malaysia have been published at various dates. These maps were compiled by the cadastral division of the survey department in each state. They show details of communications, drainage patterns, administrative boundaries, alienated lands, forest and other reserves and other details of interest. In general, three versions of state maps are published, viz :

(*a*) Contoured, uncoloured and ungridded;
(*b*) Contoured, coloured and ungridded;
(*c*) Contoured, coloured and gridded.

The publication scales vary from state to state.

Thematic and special-purpose maps

Besides undertaking the heavy burden of publishing its own cadastral and topographical maps, the directorate also compiles and publishes the following thematic maps at various scales for other government bodies, such as Civil Aviation, Postal, Census, Mines, Irrigation, Railways, Geological, Agriculture, Forestry, National Electricity Board and Federal Land Development Authority (FLDA).

Notable contributions were the preparation of detailed plans showing spot heights at close intervals for big irrigation schemes such as the Muda and the Besut irrigation projects, and detailed contour plans for FLDA land schemes for planning and development purposes.

The principal maps printed were:

(*a*) Aerodrome obstruction charts for Penang Airport and Subang International Airport at Kuala Lumpur. A detailed plan with 5 ft contours for the Subang Airport complex;

(*b*) Twelve election maps for the Election Commission showing parliamentary and state constituencies;

(*c*) Nine land alienation, soil suitability, mineral potentialities and forest productivity maps for the Economic Planning Unit of the Prime Minister's Department;

(*d*) Four maps—master plan, soil survey, land form and land classification—of the huge Jengka Triangle Project undertaken by the Federal Land Development Authority (FLDA);

(*e*) Six schematic reconnaissance soil maps, one forest productivity and one schematic forest type maps for the Ministry of Agriculture and Co-operatives;

(*f*) Three geological maps, and one map showing active mining fields for the Ministry of Lands and Mines;

(*g*) Census maps consisting of census district maps, and enumeration block maps for the Department of Statistics in connexion with the 1970 Census.

National atlas

This is a joint project undertaken by the Language and Literature Agency Malaysia (Dewan Bahasa dan Pustaka), the geography department of the University of Malaya, and the Directorate of National Mapping.

Table 1. Map sheets produced by the Central Drawing Office and the Photo-Lithographic Division March 1967–July 1970

Name of map or series	Central Drawing Office		Photo-Lithographic Division			
	Number of new map sheets completed	Number of map sheets revised	Number of new map sheets printed	Number of revised map sheets printed	Number of map sheets reprinted without revision	Total number of copies printed
Series L7010 and L707—1:63,360	37	21	34	14	112	3,304,538
Series L8010—1:25,000	115	12	107	12	—	869,750
Series T735—1:50,000	4	—	4	—	—	65,800
Series L5010 and T503—1:250,000	3	—	4	—	4	369,750
Series L905 and T931—Town maps and L808 various scales	5	—	8	—	—	153,500
Miscellaneous maps and charts	310	8	310	8	—	5,330,298
TOTAL	474	41	467	34	116	10,093,636

Table 2. Map sheets produced by the Directorate of Military Surveys and the Directorate of Overseas Surveys, March 1967–July 1970

Mapping agency	Number of map sheets published					Number of map sheets reprinted
	T735	T503	T931 and L905	L5010	Misc. maps	
Directorate of Military Surveys	75	12	1	1	8	33
Directorate of Overseas Surveys	32	—	—	1	—	—
TOTAL	107	12	1	2	8	33

Table 3. Photogrammetric equipment available in Malaysia, March 1967–July 1970

Name of equipment	With Directorate of National Mapping	With Lands and Surveys Department, Kuching	With Lands and Surveys Department, Sabah	Total
Wild A7	1	1	—	2
Wild A8	2	1	2	5
Wild B8	4	2	3	9
Multiplex	4	—	1	5
EK5A or EK3D	1 (5A)	1 (5A)	1 (3D)	3
PUG Point transfer	1	1	1	3
SEG V Zeiss rectifier	1	—	—	1
EMI Logetronic printer	1	1	—	2
Contact printer	2 (Zeiss)	1	1 (Zeiss)	4
Film processor	2 (Wild)	1	2 (Zeiss & Wild)	5
Enlarging Camera	1 (De Vers)	2 (Klimsh super) (Omega)	1 (Wild)	4
Wild RC8 air camera	2	1	1	4
Zeiss film viewer	1	—	1	2
Zoom stereoscope	—	1 (Bausch & Lomb)	—	1
TOTAL	23	13	14	50

Work commenced in 1966 and to date 72 out of 102 map pages have been printed. The target date for the publication of first edition (Malaysian language) is July 1971.

Map production

The Topographical Division of this Directorate is responsible for the trigonometrical and topographical survey of the country and the periodic revision of such data as may be found necessary from time to time. The map reproduction component consists of the Central Drawing Office and the Photo-Lithographic Division. Assembly, scribing or fair drawing, colour separation, annotating, and masking are done in the Central Drawing Office, while all camera work and printing are done in the Photo-Lithographic Division. (See tables 1 and 2 above.)

Electronic computer

In order to cope with a huge cadastral survey computation back-log of some 400,000 lots involving approximately 2 million theodolite station points, an IBM 1130 electronic computer system was installed in January 1970 with data-processing commencing almost immediately.

The results achieved have been gratifying. The output up to the end of August 1970 was 28,672 lots (excluding lots not acceptable owing to bad closures).

Photogrammetry and map-printing equipment

Additional equipment acquired since the last report:

(*a*) Photogrammetry:

2 Wild B8;
1 Wild PUG 3 point transfer device;
1 Contact printer (Zeiss).

(*b*) Map printing:

Roland offset printing machine (single colour)—size 18 × 24 inches;
Roland ULTRA RZU V offset printing machine (double colour)—size 35 × 49 inches;
Vacuum contact printer;
Vacuumatic paper counting machine;
Offset dampening roller cleaning machine;
Ministar Combi plan printing machine;
2 Densitometers (Gretag and Eel);
Enlarger Variscop 60 (Agfa);
Morisawa type-setter machine.

CARTOGRAPHIC ACTIVITIES IN THAILAND

Paper presented by Thailand[1]

Cartographic activities in Thailand is one of the governmental activities assigned to different agencies. The responsibility for conducting ground and air surveys for the preparation of land maps of the Kingdom, for carrying out geodetic and geophysical activities and for training cartographic personnel has been assigned to the Royal Thai Survey Department, Supreme Command, while the production of navigation charts and hydrographic surveys and conducting of oceanographic activities have been assigned to the Hydrographic Department, Royal Thai Navy, Ministry of Defence.

Cadastral surveys in Thailand are the responsibility of the Department of Lands, Ministry of Interior. Special-purpose maps, such as geological, soil and statistical maps, are compiled by various governmental authorities dealing with those activities, namely, the Departments of Mineral Resources and Land Development and the National Statistical Office; they are issued mainly by the Royal Thai Survey Department.

Progress in cartographic activities in Thailand since the last conference may be summarized as follows.

Aerial photography

Since the last conference one Wild RC 9 aerial camera was acquired by the Royal Thai Survey Department. Two fully equipped photographic aircraft, the Aero Commander 500 A and the Beech Craft Queen Air A 80, were provided to all Thai government agencies whenever aerial photography was called for.

Aerial photographs were taken for twelve national development projects carried out by six agencies; the total coverage comprised 78,286 km^2.

Difficulties attributable to the shortage of pilots, surveying navigators and camera operators were overcome during the period under report. Some of the Royal Thai Survey Department personnel were given an opportunity to further their studies in these fields with the assistance of the Netherlands Government, while others were locally trained by the Department itself with the assistance of the United Nations Civil Aviation Centre and the Royal Thai Air Force.

The most recent aerial photography activities in Thailand began in September 1966 and were completed in December 1969 with the assistance of the United States Government, in accordance with the joint Thai–United States Mapping Agreement. The entire area of the Kingdom was covered, and the purpose of this operation was to serve as a basis for map compilation in the area below 7° north latitude and for the map-revision programmes in the remaining area of the country. To date, all of Thailand has been covered with three sets of aerial photographs at 1:40,000, 1:60,000 and 1:50,000, taken in 1952–1957, 1962 and 1966–1969, respectively.

Geodetic survey

Triangulation

Considerable progress on the geodetic survey of Thailand has been made by the Royal Thai Survey Department since the last conference. The first-order triangulation net was established, comprising thirty-seven stations in the north-eastern part of the country. The result is a complete network of basic horizontal controls for the country.

[1] The original text of this paper appeared as document E/CONF.57/L.65.

Another important geodetic operation during the period under report was the geodetic junction established between Thailand and the Federation of Malaysia. The first-order triangulation net linking the Nakhon Si Thammarat base line in Thailand to the Kota Baharu base line in Malaysia was established from October 1967 to April 1968. The task was performed by survey parties consisting of personnel from the Royal Thai Survey Department and the National Mapping Service of Malaysia, with the assistance of the United Kingdom survey team from the Survey Far East Land Forces in Singapore. Four stations, three of them in Thailand, were established by triangulation and checked by combining trilateration and tellurometer observations. Computation of observations was carried out by the Military Survey of the United Kingdom, and the results were quite successful in strengthening horizontal controls along the borders of both countries.

During the period under report, the following geodetic instruments were purchased: three Wild T3 theodolites and two AGA model 6 geodimeters.

Astronomical observations

First-order astronomical observations were conducted in Thailand by the Royal Thai Survey Department since the last conference. Five additional Laplace stations were established; two of them were located at each end of the Lampang first-order base line, and one on the United States Earth satellite triangulation station at Chiang Mai airport. The Wild T4 universal theodolite was purchased during the period under report.

Levelling

The Royal Thai Survey Department continues to extend its levelling programme every year. During the period under report, first-order levelling was carried out in the northern, eastern and southern parts of the country at a distance of 1,724.5 km, and 154 BMPs, 696 BMSs and three BMTs were established. The levelling instruments needed to perform this work were purchased.

Mapping activities

The main task of the Royal Thai Survey Department in the mapping field is to revise and recast the existing 10 × 15 inch format of the L708 map series at 1:50,000, which is the base map of the country, into the L7017 series of 15 × 15 inch format. The L708 map series covering approximately 94 per cent of the Kingdom has been revised and recast, while the maps for the remaining area below latitude 7° north down to the Thai–Malaysian border, has been in the stereocompilation stage to be conformed with the L7017 series. These programmes received partial assistance from the United States. So far 14 per cent of the projected area has been covered. It is hoped that the new series will cover the entire country by September 1973.

During the period under report the Royal Thai Survey Department produced, with the assistance of the United States, temporary pictomaps at 1:25,000, covering the area between 7° north latitude down to the Thai–Malaysian border. This series will no longer be used when the new L7017 series is completed.

Another mapping project carried out exclusively by the Department consisted in producing 1:25,000 topographic maps for an area of vital interest, especially for security and training purposes. These maps will comprise about 160 sheets.

The 1:12,500 city map production is part of the long-range programme of the Department. Under the Thailand–United States Joint Mapping Agreement, ninety-nine sheets were prepared during the period, covering fifty-three *changwats* (provinces), forty-four *amphoes* (districts) and two *tambons* (subdivisions of districts). By the end of 1971, all seventy-one *changwats* (provinces) throughout the country should be covered at this scale.

The application of photogrammetric techniques to mapping has been in great demand, and the Department hopes to increase its qualified personnel in this field. With the assistance of the governmental and non-governmental organizations, the Department has sent four officers to attend courses at the International Training Centre in the Netherlands; one to the University of Melbourne, Australia; and another to the Swiss School for Photogrammetric Operators.

Map reproduction

Since the last conference about 2.8 million maps have been issued, 67 per cent of which are of various scales and types, compiled and revised by the Royal Thai Survey Department. The remainder, which have been printed for other governmental agencies, are mainly those of the special-purpose type. The increase in the number of press runs needed to cope with the increasing demand of multi-colour special maps explains the decrease in the number of copies by comparison with the last period under report.

Reproduction equipment has been purchased, the most important item being a reproduction camera. With regard to personnel training, the Department obtained considerable assistance from both governmental and non-governmental agencies abroad, which enabled it to send an officer to attend the reproduction course at the United States Coast and Geodetic Survey, Washington, D.C., and another to attend the offset press operation and reproduction equipment repair course at Fort Belvoir, United States. A third officer will be trained at Kummerley and Frey, A.G., in Switzerland.

Geophysical activities

During the period under report, the Department conducted field observation operations for land-gravity and geomagnetic surveys so as to increase the number of stations.

Land gravity survey

A total of 141 base stations were re-observed in the north, north-eastern and eastern parts of the country. The expansion of gravity survey stations was based on those base stations; some 995 stations in the central, eastern and southern parts of the country were therefore observed during the period under report, and fifty new stations were set up.

To accelerate the improvement of gravimetric work, the Royal Thai Survey Department sent one officer to attend a training course in gravity and astronomy at the United States Coast and Geodetic Survey and purchased a La Coste and Rhomberg gravimeter during the period.

Geomagnetisim

There is still no magnetic observatory in Thailand for the time being. Geomagnetic surveys were conducted in order to increase the number of stations. Observations

were made in sixty-one stations throughout the country during the period. Single or double stations were set up 80 to 120 km apart or at every degree of the geographic grid. This improvement programme was made possible through the purchase of an Askania magnetometer. An officer was sent to the Askania factory for training, and another attended the seismology and geomagnetism course at the United States Coast and Geodetic Survey.

National resources atlas and topical maps

Since the last conference two new editions of the national resources atlas were issued by the Royal Thai Survey Department, consisting of volumes II and III (volume I had been presented at the last conference). Volume II contains six new topical maps with English text. The seventeen topical maps contained in volume III include thirteen revised topical maps from previous editions and four new topical maps with text in Thai and in English. Data used in the preparation of those maps and texts were collected from various governmental agencies concerned.

Education for mapping and surveying

Although survey engineering courses have recently been offered at universities and other higher education institutes in Thailand, the Survey School under the direction of the Royal Thai Survey Department is the only one which provides a complete mapping and surveying course. The school has been given the responsibility of training cartographic personnel to meet the requirements of all governmental units.

During the period under report, a two-year course in basic surveying and mapping and a five-year course in advanced mapping and surveying were given at the Survey School. In addition to these regular courses, five refresher courses for junior and senior officers and two professional courses were organized so as to acquaint the staff of the Department with the new techniques.

Assistance in the form of scholarships and fellowships has been given for these educational and training programmes to the Department by various governmental and non-governmental agencies in the United States of America, the Netherlands, the Federal Republic of Germany, Japan and Switzerland.

Hydrographic surveys

In the past three years the Hydrographic Department carried out hydrographic surveys, mainly in coastal areas and harbours, in order to issue nautical charts and with a view to the development of coastal industrial districts. A total area of 5,000 square miles was surveyed and the results were used to compile two new charts and revise twelve others.

Aeronautical chart production

The Hydrographic Department produced eleven world aeronautical charts at 1:1,000,000, in accordance with the regulations of the International Civil Aviation Organization. The original plates of aeronautical charts Nos. 2677 and 2678 were corrected and issued. Aeronautical charts at 1:500,000 for the same area are planned in the next programme.

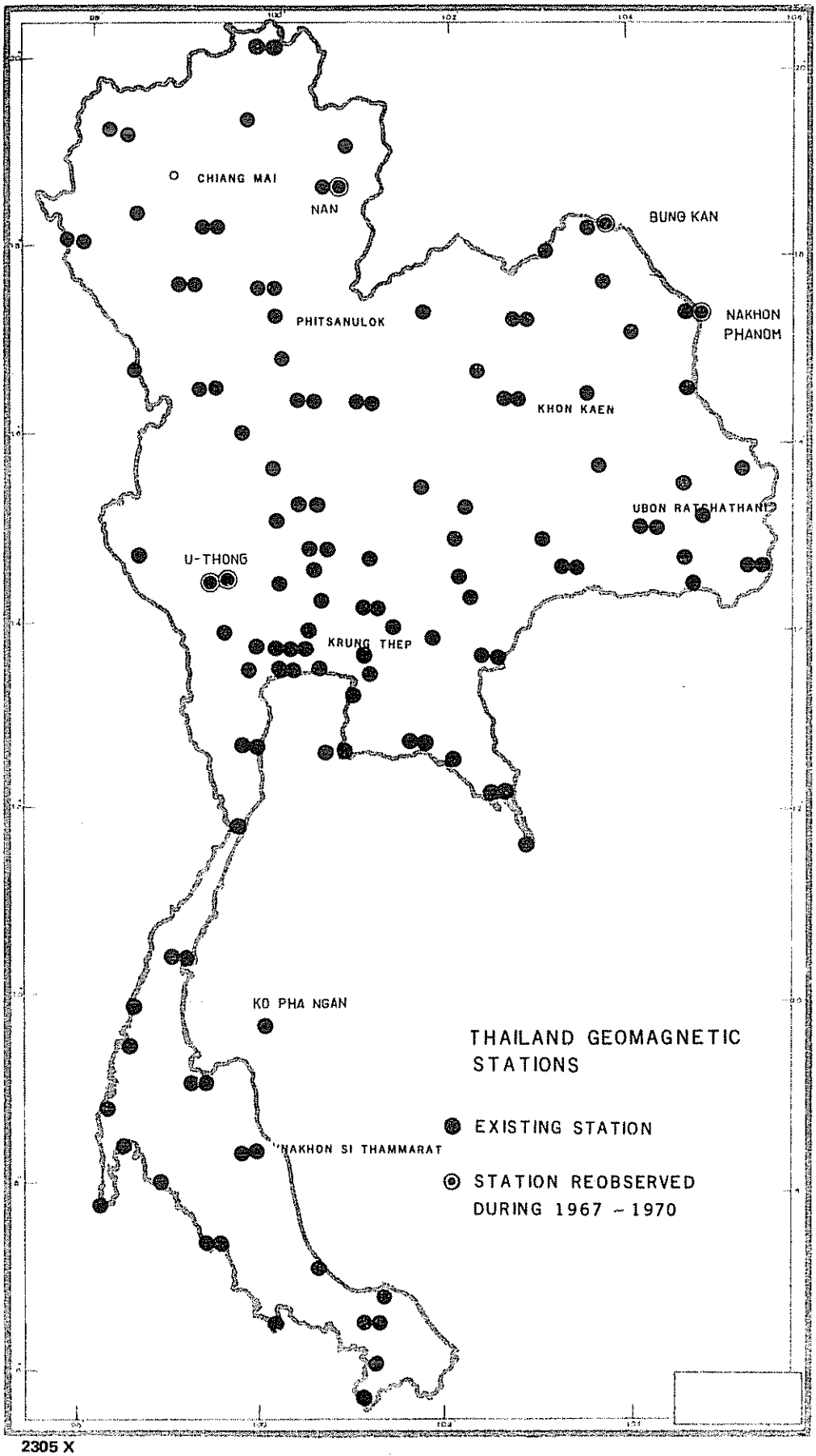
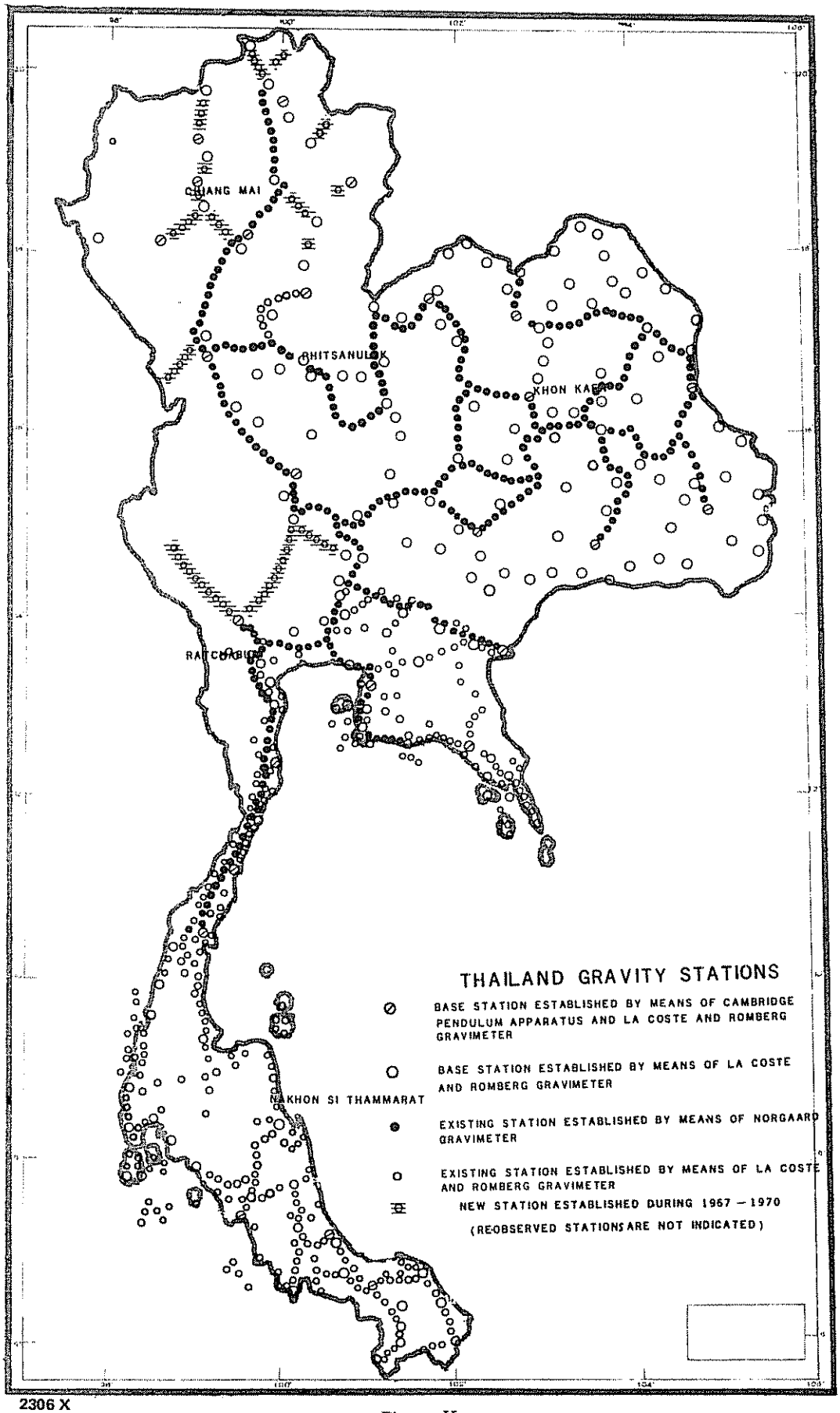

CHIANG MAI
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KO PHA NGAN
NAKHON SI THAMMARAT
THAILAND GEOMAGNETIC STATIONS
EXISTING STATION
STATION REOBSERVED DURING 1967 - 1970
2305 X

Figure I



2306 X

Figure II

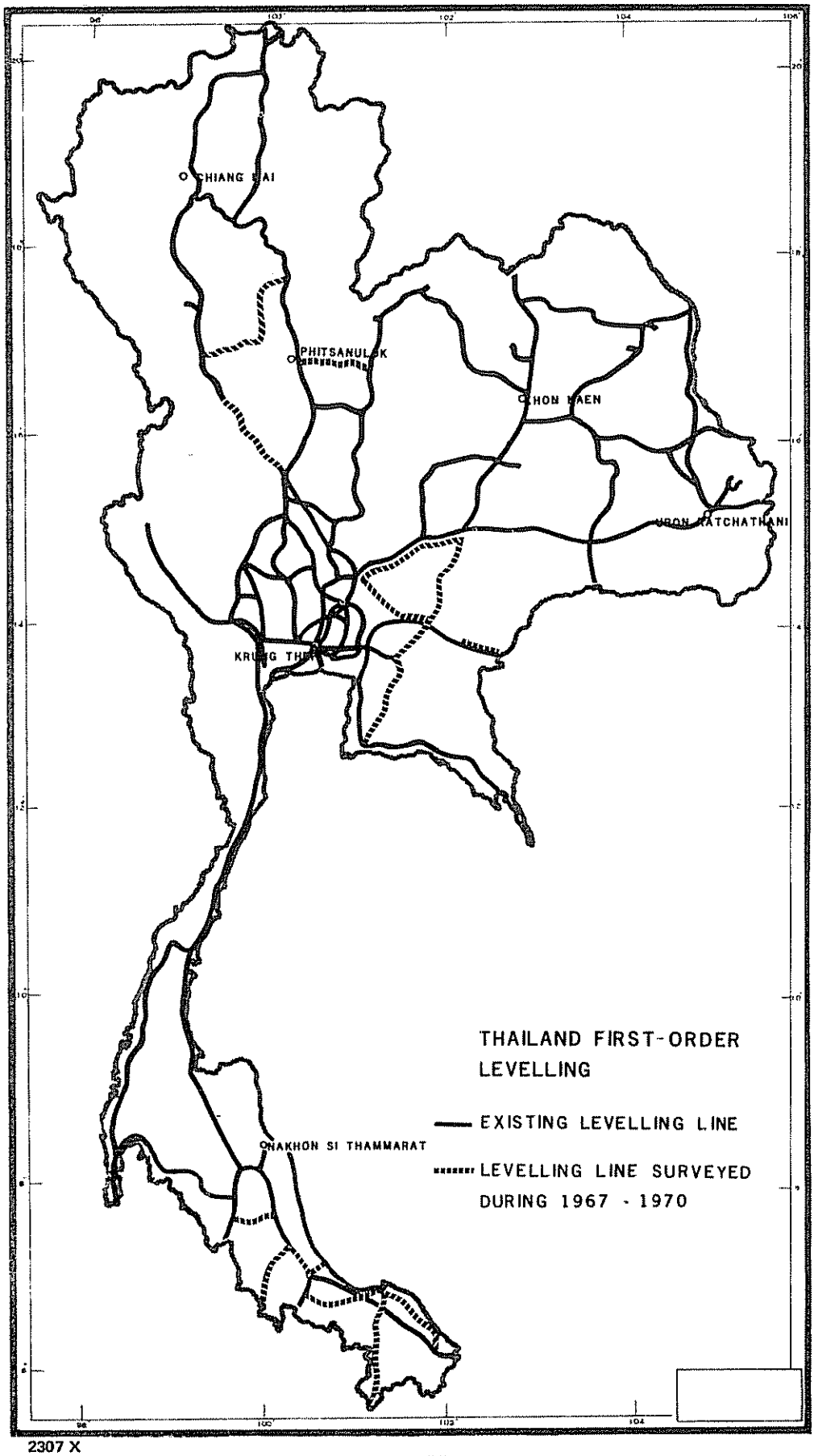

CHIANG MAI
PHITSANULOK
KHON KAEN
UBON RATCHATHANI
KRUNG THEP
NAKHON SI THAMMARAT
THAILAND FIRST-ORDER LEVELLING
EXISTING LEVELLING LINE
LEVELLING LINE SURVEYED DURING 1967 - 1970
2307 X

Figure III

CARTOGRAPHIC ACTIVITIES IN INDONESIA, 1967–1970

Paper presented by Indonesia[1]

MAPPING ORGANIZATIONS

Several organizations are engaged in surveying and mapping activities in Indonesia: the Army Topographic Service is responsible for medium- and small-scale mapping and geodetic control; the Cadastral Service, for land titles; the Naval Hydrographic Service, for hydrographic charting; and other agencies do technical mapping for their own purposes.

With a view to using national funds for mapping and natural resource activities efficiently and economically, the Government established, by presidential decree No. 83/1969, a national co-ordinating body for surveys and mapping (BAKOSURTANAL) on 17 October 1969. This national agency is responsible for co-ordinating the planning of mapping and of natural resource surveys among several organizations; it also acts as a clearing-house for mapping materials and related information and for data on natural resources.

GEODETIC ACTIVITIES

Trilateration

During the period covered by this report a first-order traverse was carried out and an aerodist net was measured in western Kalimantan (Borneo) over an area of about 65,000 km². The traverse consists of thirteen stations with a total length of about 730 km. The sides were measured with a tellurometer RMA 3 and the angles with Wild T3 instruments.

The aerodist net consists of forty-six points connected by 107 measured distances. It is tied to the above-mentioned traverse and it is supposed to be of third-order precision. These surveys were part of a mapping project at 1:50,000 scale under way in western Kalimantan.

Geodetic astronomy

First-order longitude, latitude and azimuth were measured at three Laplace stations in western Kalimantan with a DKM 3A instrument. Moreover, eight second-order astro-stations were fixed to provide ground control for mapping of a tidal rice-culture project in southern Kalimantan.

Gravity survey

Gravity observations were carried out at thirteen stations in western Kalimantan by using a La Coste and Rhomberg instrument. This gravity net is connected to the gravity station in Kuching (Sarawak).

Levelling

Second- and third-order levelling were carried out in Java and southern Sumatra for irrigation projects, and in western Kalimantan to determine the initial height of the traverse mentioned earlier under trilateration.

Triangulation

Triangulation surveys were conducted in the Nusa Tenggara island chain; five primary and three secondary stations were fixed. The angles were measured with the Wild T3 instrument.

International Map of the World on the Millionth Scale

Twenty-four out of twenty-nine sheets were issued in a preliminary edition (four colours); five sheets had already appeared previously according to specifications.

Revision of topographic maps

Twenty sheets at 1:25,000 and sixty sheets at 1:50,000 were revised during this period.

[1] The original text of this paper appeared as document E/CONF.57/L.71.

HYDROGRAPHIC ACTIVITIES IN INDONESIA, 1967–1970

Paper presented by Indonesia[1]

The possibility of off-shore mining of oil and other products, the rapid development of fisheries and the increase of maritime transport in Indonesian waters has required the collection of extensive hydrographic and oceanographic data on Indonesian waters.

GEOPHYSICAL SURVEY

Oil companies that have concessions for exploration have already completed a geophysical survey of almost all Indonesian waters, particularly the continental shelf. In accordance with the concession agreements, the results of the survey will be temporarily classified.

Research institutes have also conducted geological and geophysical studies, such as the UNESCO shipboard training course in May 1969 aboard the SS *Jalanidhi* in the South China Sea, under Professor H. S. Haile, Head of the Department of Geology, University of Malaysia.

OCEANOGRAPHY

From 1966 to 1970 the following regular marine investigations to collect oceanographic data were completed:

1. Operation Baruna II (East Indonesian waters, May–June 1966);
2. Tjenderawasih Expedition (Arafura Sea, May 1967);
3. CSK Expedition (South China Sea, August–October 1967);
4. CSK Expedition (Sulawesi Sea, November–December 1967);
5. Arafura Expedition (Arafura Sea, December 1968);

[1] The original text of this paper appeared as document E/CONF.57/L.72.

6. FAO Expedition (Molucca Sea and Banda Sea, February–April 1968);

7. Java Expedition (Java Sea, September 1968);

8. Operation Baruna III (Banda Sea, March–May 1970).

Hydrography

Since more and bigger tankers and cargo ships are the rule, they have had to use the navigation channels as much as possible to the extent that safety of navigation was still guaranteed.

An accurate hydrographic survey for depth sounding and positioning and water characteristics with the aid of modern electronic instruments makes it possible to ascertain the useful depth of a channel. The most important hydrographic surveys carried out during the period 1966–1970 were as follows:

1. Survey of Belawan Channel (for dredging);

2. Straits of Rupat, Bengkalis and Dumai (to build an oil harbour);

3. Kidjang Strait (dredging to allow passage for bauxite cargo ships);

4. Tjilatjap (dredging to allow passage for iron-ore cargo ships);

5. Sumur (to build a ferry harbour);

6. Seputih (to fix anchoring area);

7. Teluk Kelabat/Bangka (for a navigation channel);

8. Indramaju (for flood control);

9. Tjirebon (harbour survey);

10. S. Pakning (harbour survey);

11. Djamuang (for upgrading the western channel of Surabaja);

12. Malacca Strait (to allow passage for tankers with 21 m draught).

Cartography

Indonesian charts of territorial waters consist of 358 sections, 60 of which were revised during the period under consideration. Nearly all charts need to be revised, but only a small part of the total area has been resurveyed recently owing to lack of funds.

Printing of the charts has also raised difficulties. Although the Hydrographic Office has had Roland two-colour and Dufa offset machines since 1965, for various reasons they are not yet in operation.

Other activities

(*a*) Collection of data for a geodetic system covering both Indonesia and Malaysia; (*b*) works to ensure the safety of navigation for large-tonnage ships, particularly in the Malacca Strait and South China Sea; (*c*) water pollution prevention.

AERIAL SURVEY ACTIVITIES IN INDONESIA

Paper presented by Indonesia[1]

Introduction

In 1960 the Government of Indonesia established the Aerial Survey Institute. One year later the Institute became a State enterprise, and changed its name to P. N. Aerial Survey (PENAS).

For aerial survey operations PENAS uses two C-47 and two B-25 aircraft equipped with Wild RC-8 and Fairchild T-11 aerial cameras. In 1970 two Cessna 402-B aircraft were added, equipped with aerial cameras and airborne geophysical survey instruments. Aerial survey operations will therefore expand significantly in the years ahead.

Aerial photographic coverage

Prior to and during the Second World War some parts of the country had been photographed by the Dutch and Allied Forces. These aerial photos were used in the preparation of topographic maps and for other military purposes. They included a valuable and complete set of negatives of West Irian and surrounding islands, covering an area of about 187,921 km^2 at scale 1:40,000.

Several other areas were photographed from 1950 to 1960, but most of the negatives were not clearly identified, except for a few that covered an area of 12,250 km^2 and were filed in the library.

During the first five years of the post-war period the use of aerial photos was limited mainly to civil mapping and geological exploration. During the period 1965–1967, surveying activities decreased because of political and economic conditions.

With the beginning of the first five-year development plan in 1969 and because of the opportunities given by the Government to foreign investors, particularly for the development of oil, mining and other resources, aerial surveying activities increased considerably. Like all developing countries, Indonesia lacks the basic maps needed for development, and this has brought about increased efforts in the field.

The largest number of aerial photographs was taken in 1969, when more than 220,000 km^2 were photographed at various scales, mostly in black and white, although in some cases colour and false-colour photography were used. During the first eight months of 1970 aerial photos were taken of almost 188,000 km^2; it is estimated that the total area covered for 1970 will be higher than for 1969.

The total land area of Indonesia measures about 1.9 million km^2 and the aerial photos cover only 772,000 km^2 so far. At times the same areas have been photographed twice at different scales and for different purposes. The aerial photos taken so far therefore cover about 30 per cent of the country's total area.

Aside from conventional aerial photography, Indonesia has been using the modern lateral-radar technique for the past year. Five oil companies and one copper-mining

[1] The original text of this paper, prepared by M. Fargani, P. N. Aerial Survey Institute, Djakarta, appeared as document E/CONF 57/L.79.

Airborne geophysical survey activities in Indonesia

Year	Location	Contractors	Exploration	Approximate total area in km²	Approximate distance in km
1962–1963	South-east Kalimantan	Government Steelwork	Iron ore	47,000	7,000
1963–1964	Central Sumatra	Panam Oil Co.	Oil	21,000	7,000
1964	Central Sumatra	Caltex Co.	Oil	89,375	13,000
1965	Tandjung, Kalimantan	Shell/Permigan	Oil	21,276	14,469
1966	Northern Sumatra	Pertamina	Oil	12,000	10,000
1967	Bunju, Kalimantan	Pertamina	Oil	12,000	10,000
1967	Mahakam, Kalimantan	Pertamina	Oil	15,000	11,000
1969	Djambi, Sumatra	Total Oil	Oil	27,000	9,000
1970	Western Sumatra	Rio Tinto	Copper	38,400	32,000
1970	Halmahera	Indeco	Nickel	15,600	17,498
1970	Central Celebes	?	Nickel	14,300	—

company are using radar photos at 1:225,000 for exploration purposes.

Airborne geophysical survey

The airborne geophysical survey method has been applied in Indonesia since 1962. These surveys have been used for mining explorations: iron ore in Kalimantan (1962–1963), nickel in the Celebes and Halmahera islands (1970), oil in Kalimantan and Sumatra (1963–1969) and so on.

In the last few years airborne geophysical activities have expanded in Indonesia. This year it is expected that 32,000 km will be covered for copper exploration in western Sumatra and 17,498 km (aeromagnetic surveys) for nickel exploration in Halmahera. In central Sulawesi (Celebes) and other islands in eastern Indonesia airborne geophysical surveys will be carried out before the end of the year.

The total area of the regions covered by airborne geophysical surveys exceeds 300,000 km². It is hoped that in the near future use of the data resulting from these operations will increase owing to the requirements of the mining concerns now operating in Indonesia. More than thirty foreign oil companies and more than six foreign mining companies are now planning to prospect in Indonesia.

Summary

During the last four years aerial photographs have been used more extensively in surveying and mapping because of mineral resource exploration. More than half of the aerial photos are used in geology and mining; the rest is used for agriculture and resettlement projects (20 per cent); engineering projects (10 per cent); forestry (10 per cent); and miscellaneous (less than 10 per cent).

Like aerial photography, the airborne geophysical survey plays an important role in oil and mineral exploration; it is especially effective for dense forested areas, swamps and shallow coastal waters.

In the next decade the various methods of aerial surveying will be used more frequently in Indonesia simply because it is the best means to collect basic data which are now generally inadequate or almost non-existent.

CARTOGRAPHIC ACTIVITIES IN THE REPUBLIC OF VIET-NAM

Paper presented by the Republic of Viet-Nam[1]

Introduction

Generally speaking, the cartographic activities of the Republic of Viet-Nam are the responsibility of the National Geographic Department, which at present comes under the Ministry of National Defence.

This report on cartographic activities deals with progress in the following areas: (*a*) Geodetic surveys; (*b*) Topographic mapping; (*c*) Special- and general-purpose maps; (*d*) Efforts to promote the wider use of maps; and (*e*) Organization of a cartographic documentation centre.

Geodetic surveys

In view of present conditions, the National Geographic Department is unable to make very much headway in field surveys. Nevertheless, in the last three years sixty-three first- and second-order geodetic stations have been set up and more than 400 km of precision levelling have been completed.

Triangulation and traversing

A first- and second-order triangulation covering the Saigon–Bien-Hoa region as far as the coast in the Vung-Tau area was completed in 1967. This network was based on two old first-order points whose position was confirmed and on three base lines measured by an MRA2 tellurometer. The network as a whole was adjusted by the method of least squares.

In 1958, the National Geographic Department launched a large-scale long-term programme for the purpose of re-equipping the Mekong Delta with a coherent and accurate geodetic network. Since the Delta is completely flat, it was decided to employ the traversing method, by using MC-8 electronic length-measuring instruments for distances and Wild T3 theodolites for angles. With United States assistance, most of the stations are being equipped with

[1] The original text of this paper appeared as document E/CONF.57/L.81.

100-ft BILBY geodetic beacons; other traverse points are installed on high structures, such as belfries, water-towers and the tops of buildings. Laplace position fixes are being considered for junction points and terminal stations, and will be the subject of studies in the near future. Pending general adjustment of the network as a whole, traverse control points are being calculated provisionally by plane co-ordinates for immediate use in stereopreparation work.

Levelling

The National Geographic Department is continuing its levelling programme at an annual average of about 200 km. The network in question extends along all the *routes nationales* and most of the other main roads. Lower-order traversing has been done to determine the altitude of traverse stations and stereopreparation points.

Photographic coverage

During 1968 and 1969, photographic missions for cartographic purposes were carried out for the entire territory of the Republic of Viet-Nam. They comprise two different coverages.

(*a*) Normal 1:50,000 coverage by Planigon cameras with a focal length of 151.306 mm, which has been used for several purposes: map revision, forestry classification, studies of soils and mineral resources;

(*b*) 1:25,000 coverage by cameras with a focal length of 12 inches. This has proved very suitable for identification and rice-field distribution work, which is being done in connexion with the Agrarian Reform Act of the Republic of Viet-Nam;

(*c*) Large-scale photography (1:10,000 and 1:8,000) of populated areas and along highways has also been done with Zeiss cameras (Pleogon A, 153 mm focal length) and Fairchild (Goerz Planigon, 6 inch focal length). These have been used in preparing large-scale topographic maps and in infrastructure projects (highways and airfields), as well as in agricultural water projects.

Topographic mapping

Revision of maps at 1:50,000

The basic cartographic coverage of 1:50,000 for the whole of the territory of the Republic of Viet-Nam was completed in 1965. Revision was started in 1967; aerial photography is primarily used for bringing details up to date, and the revision sheets are then checked and supplemented by ground surveys. So far, sixty revised sheets (21 per cent of the territory) have been published.

Topographic mapping at 1:25,000

To meet national cartographic requirements, the National Geographic Department is preparing more detailed and precise maps of the more populated areas; the 1:25,000 mapping programme was established in 1965, with priority for coastal areas and urban centres. So far, fifty-one sheets have been published.

Town plans and large-scale maps

Most of the large towns of the Republic of Viet-Nam are mapped at a scale of 1:10,000. Town-mapping remains a part of the National Geographic Department's long-term programme aimed at the 1:10,000 mapping of all urban centres.

A programme of large-scale maps up to 1:5,000 was established in 1968 to provide an accurate topographic basis for town-planning and development projects. These maps, which are prepared by photogrammetric methods and contain all planimetric details plotted to scale, cover rectangular sections of 4 × 6 km.

The large-scale mapping applies to the following areas:

(*a*) Saigon–Bien-Hoa: thirty-eight sheets at the 1:5,000 scale have been plotted with 1 m contour intervals and spot heights to within 0.25 m; twelve sheets relating to the capital, Saigon, are now in process of publication;

(*b*) Tay-Ninh: nine 1:10,000 scale sheets, with 1 m contour intervals have been issued in three colours;

(*c*) Vung-Tau: nine 1:10,000 scale sheets, with 5 m contour intervals and intermediate contours of 2.5 m on the plain have been issued in three colours;

(*d*) Tan-An–My-Tho: twenty-three 1:10,000 scale sheets linking the Saigon area to two major urban centres in the south, Tan-An and My-Tho, are planned; nineteen sheets have been plotted and seven of them are being prepared for publication.

Special- and general-purpose maps

The following special- and general-purpose maps have been issued to date:

1:250,000 road maps: 9 sheets;

1:500,000 administrative and road maps: 12 sheets;

1:500,000 South Viet-Nam river navigation maps: 2 sheets;

1:500,000 geological maps with explanatory text: 22 sheets;

1:1,000,000 Republic of Viet-Nam administrative map: 1 sheet;

1:1,000,000 Republic of Viet-Nam vegetation map: 1 sheet;

1:1,000,000 general soil map with explanatory text: 1 sheet;

1:2,000,000 general physical map: 1 sheet;

1:2,000,000 ethnolinguistic map: 1 sheet;

1:2,000,000 geological map: 1 sheet;

1:2,000,000 economic map: 1 sheet.

At the request of the Civil Aviation Department, the National Geographic Department is collecting the necessary documentation for the preparation of the five sheets of the ICAO 1:1,000,000 World Aeronautical Chart relating to the territory of Viet-Nam.

Promoting the wider use of maps

Wide dissemination of maps to the public has also been one of the National Geographic Department's main concerns. Bookshops in most large towns are invited to act as agents for the sale of maps to the public.

A *Revue Géographique*, the first issue of which appeared in April 1969, is to carry articles relating to mapping methods and the activities of the Department. It also contains articles for the general public concerning the use of maps, aerial photographs and other cartographic materials.

This publication has had an immediate effect: the number of maps sold to the public has steadily increased by several thousand copies as compared to previous years. Encouraged by this result, the Department has decided to

continue the publication of the *Revue Géographique*, with two issues a year; No. 4 is being prepared for publication on 1 November, the country's national holiday.

Cartographic documentation centre

Efforts are under way to organize a cartographic documentation centre as part of the Department. At present the centre has some 80,000 maps and plans of all types and at different scales covering the territory of Viet-Nam and the world, as well as various cartographic documentation ranging from survey sheets to proof copies of maps. All of this material has been carefully inventoried and is being classified.

With the formation of this centre, the National Geographic Department hopes to make available basic cartographic material for study to the public in general and to technicians in particular; moreover, it expects to have close relations with the cartographic services of other countries for the exchange of documents.

SURVEYING IN HUNGARY

Paper presented by Hungary[1]

Large-scale surveying started in Europe in the nineteenth century in response to national requirements. It was then that cadastral surveying also began in Hungary. In 1867, following the Hungarian war of independence (1848–1849), national surveying headquarters were established in Buda and remained there until the end of the Second World War. With industrialization and the development of agriculture Hungarian surveying also underwent changes.

Hungary today has a well-developed ground-control network and map system and an effective surveying organization. The uniform and co-ordinated execution of surveying activities in the country is assured by up-to-date legislative and technical measures. Refresher courses are offered at various educational establishments.

The State surveying organization establishes and maintains the geodetic ground-control nets, carries out the surveys and generally fulfils all requirements arising in the field.

The National Office of Lands and Mapping is dependent on the Ministry of Agriculture and Food. The Surveying Institute, the Budapest Geodetic and Cartographic Establishment, the Cartographic Establishment and the Pécs Geodetic and Cartographic Establishment are all under the control of the National Office, as are the nineteen county and the 100 district land offices. The tasks of the Surveying Institute are as follows: (*a*) research and development in the field of surveying; (*b*) documentation and map services for the entire country; and (*c*) contract negotiations and quality control of basic surveying work. The other three establishments carry out the work related to the geodetic ground-control networks and the preparation of the basic cadastral and topographic maps. The Cartographic Establishment produces educational, tourist and other maps in its own printing plant.

The activities of the land offices include surveying, land registration and land use. Surveying comprises provision of county and district surveying data and map services; introduction of map changes; recording and maintenance of ground-control points; and co-ordination and control of surveying work, including special-purpose surveys.

The Geodetic Research Laboratory of the Hungarian Academy of Sciences is located in Sopron. Its research staff is engaged in basic geodetic research as well as development and control of surveying instruments. The main special committees operating within the Academy of Sciences are the Hungarian National Committee of the IUGG, the Geodetic Scientific Committee, the Subcommittee on Instruments and the Subcommittee on Satellite Geodesy.

The Geodetic and Cartographic Society of the Association of Hungarian Scientific and Technical Societies plays an important role in developing specialized knowledge of surveying. The Society comprises nine sections, thirteen permanent and *ad hoc* committees, and several regional organizations. Its activities are closely co-ordinated with those of the National Office of Lands and Mapping.

The Hungarian geodetic instrument industry exerts considerable influence on Hungarian surveying. The Hungarian Optical Works contributes in large measure to the development of State surveying through its manufacture of theodolites, tacheometers, automatic levelling instruments, gyrotheodolites, gyroscopes and electronic range-finders.

Many surveyors also work in other fields, such as mining, hydrological services, forestry, planning and building.

The most important surveying activities are carried out by the State with funds made available to the National Office of Lands and Mapping. The State's most important responsibility in the field of surveying is the establishment and maintenance of the ground-control network and basic map system.

Hungary today has up-to-date horizontal and vertical ground-control nets which were established after the Second World War. A new fourth-order horizontal ground-control net is currently being set up. Thirty per cent of the country's territory has been covered.

The higher-order levelling network requires only maintenance and some supplementary work. We are now planning to set up a high-precision levelling network that will be suitable for investigating the vertical movements of the Earth's crust.

With regard to the basic map, cadastral maps are available for the country's entire territory. These maps are regularly brought up to date (to the extent of 63 per cent for uninhabited areas, 56 per cent for inhabited areas and 90 per cent for vineyards). Our task now is to establish the bases for new technical and economic large-scale maps at 1:1,000, 1:2,000 and 1:4,000 scales, so as to modernize their contents and unify the projection system and the scales.

Topographical maps at 1:10,000 scale have been compiled for more than 50 per cent of the country's territory,

[1] The original text of this paper, prepared by I. Joó, Director, Geodetic Department, National Office of Lands and Mapping, Budapest, appeared as document E/CONF.57/L.86.

and topographical maps are also being prepared at 1:25,000 scale. Topographical maps covering the entire territory at scales of 1:25,000, 1:50,000 and 1:100,000 should be available by 1974.

A sizable team of well-qualified specialists was a basic prerequisite for the development of Hungarian surveying. Training of surveyors is conducted in four types of schools. Technicians are taught in four secondary schools. The course lasts four years and ends with a final examination. The students become technicians after one year of practical work. Surveyors are trained at the Junior College of Surveying in Székesfehérvár. This course lasts three years and ends with a State examination. Surveying engineers are trained at the Budapest Technical University; the programme lasts five years. A two-year refresher course is offered at this university to graduates with a few years' experience. Another course of this type will be offered in 1971 on geodetic automation.

Technical developments in Hungarian surveying may be outlined as follows. Between 50 and 60 per cent of horizontal ground-control points are determined by modern tellurometers and geodimeters. Gyroscopic theodolites are also used to a large extent.

Topographical surveying at 1:10,000 scale is carried out exclusively by photogrammetric methods, and so is 80 per cent of large-scale cadastral surveying (1:1,000 to 1:4,000).

Electronic computers and data-processing machines have been introduced in Hungarian surveying, but further development is necessary.

Basic research is conducted mainly in physical geodesy, satellite geodesy, surveying calculations and other theoretical problems, with a view to (*a*) studying the possibility of making greater use of air photographs and photogrammetric methods for surveying and extension of ground-control networks; (*b*) using tellurometers, geodimeters and electronic computers more frequently and more economically to extend and improve the horizontal ground-control network; (*c*) establishing control lines for more precise measurement of movements in the Earth's crust, developing measuring methods and evaluating the results of measurements; and (*d*) developing satellite geodesy, establishing a satellite observatory for geodetic purposes and applying the results of the observations to the ground-control network.

Various scientific and other publications provide information on the activities, research findings and technical developments of Hungarian surveying. The National Office of Lands and Mapping and the Geodetic and Cartographic Society jointly issue a bimonthly publication entitled *Geodézia és Kartográfia*.

Special research studies on surveying appear in the following publications: *Acta Geodaetica, Geophysica et Montanistica; MTA Föld—és Bányászati Tudományok Osztályának Közleményei* (bulletin of the Geological and Mining Section of the Hungarian Academy of Sciences); *Bányászati Lapok* (*Mining Review*); and in the scientific bulletins of Budapest Technical University and Miskolc Technical University for Heavy Industry.

Hungarian surveying maintains favourable international relations. Hungary is a member of the following international organizations: IUGG, IAG, FIG, SIP, COSPAR, the Committee for Planetary Geophysical Research and INTERKOSMOS. These operate within the system of multilateral co-operation established by the socialist countries' academies of science.

We hope that the Conference will further the development of co-operation among surveyors of different countries, disseminate information on Hungarian surveying activities and promote the exchange of professional experience.

CARTOGRAPHIC ACTIVITIES IN THE PHILIPPINES

Paper presented by the Philippines[1]

Like other developing countries, the Philippines has to programme its funds carefully to set priorities designed to maximize the economic development of the country. Cartography is used for the purpose of attaining these objectives.

CHARTING AND MAPPING

The Board of Technical Surveys and Maps (BTSM), with the co-operation of the co-ordinated agencies, has prepared the topographical maps of metropolitan Manila at scales of 1:10,000 in eleven sheets and 1:25,000 in two sheets and the land-use map of the same area at a scale of 1:25,000 in two sheets. The area covers approximately 880 km^2. These maps are for general circulation and are readily available to the public.

Topographical maps of the Philippines at scales of 1:50,000, 1:250,000 and 1:1,000,000 continue to be available to the general public. The revision of topographical maps is programmed and co-ordinated by the BTSM. New prints will be undertaken during the fiscal year 1970–1971. Topographical base maps at scales of 1:1,000,000, 1:2,000,000 and 1:5,000,000 are now made available to government agencies for the preparation of various economic maps.

The Presidential Advisory Council on Public Works and Community Development, with the assistance of various surveying and mapping agencies, has completed the preparation of a water resources atlas of the Philippines. This atlas is limited in its distribution to certain government agencies and political subdivisions and has been prepared essentially for local consumption only to meet urgent needs of political subdivisions in their various economic and development activities.

The Bureau of Mines has completed the preparation of reproducibles of the geological map of Marinduque at a scale of 1:50,000 in six sheets. The geological maps, scale 1:1,000,000, the surface water resources maps, scale 1:1,000,000, and the soil cover maps, scale 1:1,000,000, are also available to the public.

[1] The original text of this paper appeared as document E/CONF. 57/L.94.

Status of nautical charts

The Bureau of Coast and Geodetic Survey (BC&GS) continued the compilation, maintenance, verification, printing and sale of 169 nautical charts of the country. These charts comply with international standards and are available to the general public. To date, they have seven aeronautical charts at scales of 1:1,000,000 and 1:500,000 which are available to the public and landing charts for local airports which may be procured through the Civil Aeronautics Administration. These aeronautical charts are joint efforts of the Civil Aeronautics Administration and the Bureau of Coast and Geodetic Survey and comply with ICAO standards and specifications. They are maintained by the Bureau of Coast and Geodetic Survey.

Status of other mapping activities

The mapping requirements of various agencies have been met by the preparation of a limited number of maps which are made available for government use only and to support the principal governmental functions of these agencies. Preparation of large-scale maps of urban areas are under consideration to support the resources inventory studies of these areas which are needed for a well-planned economic development and the control of industrial pollution.

SURVEYING

Control surveys

The country has horizontal and vertical control data but these are mostly of second-, third- and fourth-order accuracy, are mainly in coastal regions and have been executed to support hydrographic survey activities. There is a revised project to extend these controls inland.

Hydrographic surveys

The Bureau of Coast and Geodetic Survey has continued to expand the gathering of hydrographic data. It has made about 6,900 statute miles of sounding lines which cover an area of about 750 square statute miles. The surveys include hydrographic and oceanographic surveys of Manila Bay, Laguna de Bay, Cavite Harbour and important harbours of the country. The data gathered have been utilized and incorporated in the maintenance of the various nautical charts prepared by the Bureau.

Aerial photography

The Land Authority has completed 40 per cent of the aerial photography of the Philippines. This project includes the aerial photography of the western, central and southern parts of Luzon, most of Palawan, the whole of Panay, 80 per cent of Occidental Negros and about 90 per cent of Mindano Islands. The Bureau of Forestry, in co-operation with the Philippine Air Force and the private sector, has been supervising the aerial photography of various forest areas in Mindanao. The aerial photographs are made available to the public upon proper representation through the Department of National Defence.

The Reconnaissance and Development Survey of the Laguna de Bay Development Project has been completed and preparation of detailed development plans are progressing satisfactorily. The National Irrigation Administration (NIA) and the Bureau of Public Works (BPW) are undertaking the irrigation project of the Upper Pantabangan watershed area and work on the preparation of necessary maps and construction plans is progressing satisfactorily.

The Reforestation Administration surveyed and reforested 76,104.43 ha of forest lands with a perimeter of 80,446 km. It has also completed the ground survey of another 69,169 ha preparatory to reforestation work.

The Bureau of Mines has surveyed and submitted for verification 170,208 ha of mining claims and has approved 32,634 ha of such surveyed claims.

Cadastral mapping and surveys

These are handicapped by the lack of an adequate horizontal and vertical control system in the inland areas. Plans are being made to encourage aerial photography surveys and the use of aerial photographs in order to expedite completion of cadastral surveys, the issuance of proofs of real estate ownership and to encourage economic development programmes.

The Bureau of Lands which is in charge of cadastral surveys has accelerated the issuance of land patents and the executions of cadastral surveys to implement the land reform programme of the country. It has issued about 300,000 patents covering about 589,800 ha and has verified surveys of about 420,000 lots. In spite of these results, the country needs to accelerate the execution of cadastral surveys further to maximize economic development.

The Bureau of Soils has made soil surveys of 7,486,003.8 ha. This completes the soil surveys of all the provinces of the country. The reports on these surveys have also been completed and the Bureau is undertaking the printing of these reports together with the proper soil classification maps. Reports on some provinces are being revised to conform with results of the recent surveys made. The Bureau of Soils has prepared reproducibles of soil maps of Camarines Norte and Ilocos Norte on a scale of 1:250,000 and printing of these maps will be undertaken as soon as funds are released. The Bureau has soil maps for all provinces but these are limited in quantities and intended for local consumption only.

ANNEX

During the three-year period (1967 to 1969) the Bureau of Coast and Geodetic Survey accomplished the following:

	1967–1969
Triangulation:	
Miles (statute)	129.9
Area in square miles	1,148.82
Geographic positions	117
Topography:	
Miles (statute) of shoreline surveyed, plane table	161.82
Air photo compilation	10.8
Area surveyed in square statute miles, plane table	241.82
Air photo compilation	1.6
Wire drag:	
Miles (statute) of wire drag	49.9
Area in square statute miles	3.25
Tide and currents:	
Number of tidal stations occupied	7
Number of current stations occupied	17
Number of bench-marks established	32
Hydrography:	
Miles (statute) of sounding lines	1,995
Area in square statute miles	112.95
Oceanography:	
Number of stations occupied	54
Levelling:	
Miles (statute), first order	81.62
Number of bench-marks established	13
Magnetics:	
Number of stations occupied	4
Tagline:	
Miles (statute)	29.7
Area in square statute miles	13
Traverse:	
Miles (statute)	71.8
Base measurement:	
Miles (statute)	3.59
Reconnaissance:	
Miles (statute) along axis of arc	75.8
Area in square statute miles (first order)	1,740.85

CARTOGRAPHIC ACTIVITIES IN INDIA, 1967–1970

Paper presented by India[1]

The Survey of India is the chief cartographic organization of the country. During the period under report the continuous activities of the department included geodetic, geophysical and topographical surveys and mapping; surveys for development projects connected with irrigation, power, communication, flood control and forests; special surveys for cantonments, soil conservation and geological investigations; aeronautical mapping for the preparation of landing and approach charts; preparation of various navigational charts for aviation, demarcation of internal and external boundaries and various other surveys required for the country. The department is also responsible for planning and co-ordinating aerial photography and publication of tidal, trigonometrical and levelling data for the country.

GEODESY

Control work

The Geodetic Branch carried out first-order triangulation for extending the geodetic framework in the country to the high hills covering an area of about 9,400 km². Further, in order to provide accurate planimetric control, about 9,400 km² of geodetic triangulation (including 2,300 km² of trilateration) has been done for various development projects connected with steel plants, irrigation, dams and Earth stations for a communication-satellite project.

A total of about 4,000 linear km of both forward and backward high-precision and precision levelling was completed. In addition, about 4,400 linear km of secondary levelling was done in connexion with various irrigation and other projects.

GRAVITY SURVEYS

15 km national gravity net

In pursuance of the national programme of establishing a 15 km mesh of gravity stations throughout the country, about 800 gravimetric stations were established in various parts of the country. In addition, twenty-four trigonometrical stations were occupied for gravity observations in the Koyna region for the study of crustal movements due to the recent earthquake.

5 to 10 km gravity net

As a part of the national programme for providing a 5 to 10 km net of gravity stations in specially selected areas of geological significance in the country, 1,437 gravimetric stations were established in Gujarat, Madhya Pradesh and Maharashtra. This work is still in progress.

Earth tides

Thirty-one-day, half-hourly gravity observations for Earth tides were carried out with the LaCoste and Rhomberg gravimeter at Bangalore, Jabalpur, Abu and Shillong, and their 29-day harmonic analyses were also carried out.

Standardization of gravity data

Standardized gravity anomalies on various hypotheses, viz free air, Bouguer and isostatic, were computed for 876 stations for use in the isostatic and other geophysical studies in the country. Two technical papers (Nos. 13 and 14) giving the co-ordinates, heights and standardized gravity data comprising observed values of gravity and various anomalies, viz free air, Bouguer and isostatic, were also completed and are now being published.

TIDAL SURVEYS

At present the Survey of India carries out tidal predictions for forty-one ports between Suez and Singapore. In

[1] The original text of this paper appeared as document E/CONF. 57/L.95.

order to obtain the necessary data on which to base these predictions and determine an improved mean sea level on which to base the India Geodetic Level Net, the Survey has been carrying out systematic tidal observations at twenty-one ports by operating and maintaining tidal observatories equipped with automatic tide gauges. In addition, short-period visual observations with tide-gauges are also being carried out at more than 100 minor ports to supplement the tidal data of our coasts for navigational and port-development purposes.

Self-registering tide-gauges are being manufactured locally in the department's instrument repair workshop.

GEOMAGNETISM

Observations at repeat stations and field stations

In order to collect data for the preparation of magnetic charts required by the department and other agencies, as well as to fill gaps in the distribution of repeat stations throughout the country, magnetic observations for the three elements, viz horizontal force, vertical force and declination, were carried out at 126 repeat stations and 75 field stations in various parts of the country. Prior to 1967, the repeat stations throughout the country were 200 to 300 km apart; at present they are only 130 to 140 km apart. The total number of repeat stations is now 151.

Eleven field stations were reoccupied in the Koyna region for the study of crustal movements due to the recent earthquake.

Magnetic observations in the Bay of Bengal

A start has been made in magnetic observations of total force on the water surface in the Bay of Bengal with a proton magnetometer. The observations were made at 167 points.

Magnetic observatory at Sabhawala (Dehra Dun)

The magnetic observatory at Sabhawala (Dehra Dun), which had started functioning in 1964, continued to function satisfactorily. This is the only magnetic observatory in the northern part of the country, and it is useful for controlling field observations in this region and studying the secular change in the magnetic elements. The data are being published in annual bulletins.

GEODETIC ASTRONOMY

Latitude observations by the Talcott method were made with a Zenith telescope throughout the period under report in order to study the latitude variation at Dehra Dun. Two groups of seven to eight pairs of stars were observed twice a week. Astro-fixes were made on six off-shore islands to obtain mapping control. Observations to determine both components of the deflection of the vertical were carried out at 183 stations. Laplace azimuth observations were made at twenty-five stations.

PHOTOGRAMMETRY

Photogrammetry was introduced in the department only in 1950. Thanks to the skill and hard work of the officers, the period of experimentation and adjustment was brief, and the department now surveys a very large area every year by using photogrammetric methods. The department now has a large number of first-, second- and third-order precision instruments.

During the period under report, the following areas were covered by photogrammetric surveys:

Scale of map	*Area in km²*
1:50,000	149,000
1:150,000 to 1:50,000	33,000
1:5,000	54
Aerial triangulation	160,000

PHOTO-INTERPRETATION

In order to develop the technique of photo-interpretation, an Institute was set up at Dehra Dun in 1966 under the aegis of the Survey of India by agreement between the Netherlands and the Indian Governments. The Institute now comprises four divisions, i.e. photogrammetry, forestry, geology and soil science. Its aims are (*a*) to provide specialized training in the use of aerial photographs for twenty students at a time in each of the three disciplines, forestry, geology and soil science; (*b*) to provide advanced training and research facilities for a total number of about fifteen students in the above disciplines; (*c*) execution by the staff and advanced trainees of pilot schemes in forestry, geology and soil science, and related surveys; (*d*) to act as a consulting organization for expert advice.

On successful completion of the long course, students are awarded a diploma; those who take the short course receive a certificate. The main course lasts one year and has been designed as a synthesis of various theoretical subjects, including practical work both in the field and in the laboratory. The short course lasts six months and is designed especially for engineers and scientists engaged in ravine reclamation (separate course).

Progress to date

The first session was started in April 1966 and we are currently holding the fifth session. So far 107 students have been trained in the long course and 13 in the short course.

Research and consultancy

The Institute provides consulting services to the departments of the Central and State governments on problems connected with natural resources. A member of the staff has also developed a stereo slope finder that will prove of considerable help to photo-interpreters in various disciplines. Slopes and dips can be measured with a mean square error of 1.5 degrees and the determination of each slope takes 2 to 3 minutes.

Photo-interpretation as a technique has gained wide acceptance by various agencies and departments of the Indian Government, such as the Geological Survey of India, the Oil and Natural Gas Commission, the Forest Department, the Ravine Reclamation Board and the like.

CARTOGRAPHIC EDUCATION

On 24 February 1967, the Pilot Production and Training Centre was set up at Hyderabad under the United Nations Development Programme with a view to developing and imparting education in the theory and practice of cartography at the primary and advanced levels. The Centre will also produce pre-investment project maps and cartographic data in increasingly diversified fields, through the optimum utilization of men and modern technological

equipment and instruments, in order to meet the requirements of the various development projects in the country.

These instruments and equipment involving foreign exchange are being received through the United Nations project manager. The project has since been renamed Centre for Survey Training and Map Production, comprising (*a*) the Pilot Map-Production Plant and (*b*) the Survey Training Institute.

The Pilot Map-Production Plant, when fully operative, is expected to be sufficiently production-oriented. The Survey Training Institute has prepared a comprehensive syllabus to train about 400 students at a time. The Pilot Map-Production Plant comprises a number of field and photogrammetric units. The syllabi, training programmes and facilities are being improved and modernized to provide training in all modern surveying techniques.

Four foreign experts, including the project manager, are at present working in this project. Their Indian counterparts in this organization have been trained abroad in photogrammetry, advanced geodesy, cartography, reproduction techniques and instrument maintenance and repair techniques.

The Indian counterpart of the project manager is the senior director of the Centre, while the Surveyor General of India is the Indian Government project representative.

Map compilation

The Survey of India adopted the metric system in 1957. The basic scale of topographic mapping is 1:50,000, except in developed areas, where the scale is 1:25,000. From these maps, standard 1:250,000 scale sheets are compiled for each degree square. Geographical maps (CIM series) at 1:1,000,000 scale are compiled covering the entire country. Some other maps maintained by the Survey are: 1:1,000,000 aeronautical maps of India and adjacent countries; a 1:1,000,000 map of each state; a 1:2,500,000 road map of India; a 1:3,500,000 railway map of India; a 1:4,000,000 political map of India; a 1:4,000,000 physical map of India; and a 1:2,500,000 wall map of India and adjacent countries.

In addition to the above, various types of aeronautical maps and charts were prepared to meet the diverse requirements of aviation. The data for these maps and charts were revised by rapid verification survey of a very large area with existing topographic maps and aerial photographs. Sixteen different series of maps and charts were prepared, among which are (*a*) the IAF (Indian Air Force) operational survival map at 1:1,000,000; (*b*) the IAF operational aeronautical map at 1:1,000,000; (*c*) the IAF tactical navigation chart at 1:3,000,000; (*d*) the IAF jet navigation chart at 1:2,000,000; and (*e*) the IAF operational navigation chart at 1:1,000,000.

Special maps

A large number of maps at scales varying from 1:1,000 to 1:20,000 were prepared to meet the requirements of special projects: power, irrigation, tunnel alignments, flood control and the like. Many municipal and city guide maps at 1:10,000 and 1:20,000 scales, and approach and landing charts (ICAO) at various scales were also prepared.

Map printing

The Survey of India has three map-printing and one letterpress printing establishments. Details of the maps printed are given below:

Series	*Type of map*	*Number*	*Total number of copies*
i	Topographical maps at 1:25,000 to 1:250,000 scales	791	3,398,542
ii	Geographical maps at 1:1,000,000, 1:2,000,000, etc.	152	803,861
iii	Special maps at various scales	7,136	3,166,924

Miscellaneous

Cadastral surveys in India are carried out by the State survey departments. The framework for cadastral surveys is generally connected to the national framework of geodetic and topographical triangulation. The scale in different States varies from 64 inches to 8 inches per mile. Efforts are now being made to introduce uniformity in survey methods, map scales and symbols used by various States, and to use metric equivalents in all cadastral surveys. The hydrographic survey of coastal areas is carried out by the Naval Hydrographic Office. The National Atlas Organization is responsible for the preparation of atlases.

SURVEYING AND MAPPING IN THE UNION OF SOVIET SOCIALIST REPUBLICS

Paper presented by the Union of Soviet Socialist Republics[1]

In the last few years the national geodetic service of the USSR continued its surveying work to meet the demands of civil engineering and agriculture.

Mapping has been carried out for the new industrial regions of Siberia and the Far East. Large-scale topographical surveys for the purpose of land development have been completed in Central Asia, Kazakhstan, in the Caucasus and other regions of the country.

At the same time map revision was achieved for the central and southern regions of the country, and the geodetic control network was extended to the most important industrial regions and the large cities.

Geodesy

Ground operations for the establishment of the national astrogeodetic network have been completed. In its present form, the Soviet geodetic network is a very complex achievement. It is subdivided into four orders of accuracy. The first-order triangulation was constructed in the form of polygons as an astrogeodetic network and is intended for scientific investigations to determine the form

[1] The original text of this paper appeared as document E/CONF. 57/L.102.

and dimension of the Earth, as well as to provide the system of co-ordinates for the entire country. The second-, third- and fourth-order networks provide the necessary density of geodetic points.

The astrogeodetic levelling data and the gravimetrical determinations serve to establish the astrogeodetic network. These data make it possible to determine both the plumb-line declinations and the reference ellipsoid height above geoid for projection of the geodetic control system into the assumed reference surface.

The construction of the first-order triangulation in the form of polygons in the USSR has been going on for decades, since the territory is so vast. A characteristic trait of this primary triangulation is that its construction as well as the means used to achieve it are uniform.

Astrogeodetic network polygons are formed by chains which generally consist of linked triangles. These triangulation chains are developed from base lines, at the ends of which the astronomical co-ordinates and the azimuth (Laplace stations) are determined. The length of the triangulation chains in most areas of the country is about 200 km. First-order traversing by means of electro-optical range-finders is sometimes substituted for the triangulation chains.

The degrees of accuracy for the first-order triangulation are as follows. The mean square angular error is ± 0.60 second, taking into account triangle discrepancies, and ± 0.65 second if the adjustment data for the triangulation chains are considered. The accuracy of the base lines is no less than 1:300,000, the average being 1:500,000. The astronomical-longitude error does not exceed ± 0.03 second, the mean square error in the Laplace azimuths being about 1.1 second. The mean square longitudinal chain displacement is ± 0.55 m; the transversal displacement is ± 0.96 m; and the relative error in azimuth is 1.15 second. The mean square error in distance transmission over 5,000 km along a single chain of the astrogeodetic network before its adjustment is ± 7 m.

A continuous secondary triangulation network, rigidly connected to the primary one, is a component part of the astrogeodetic network of the country. The second-order networks are placed on the sides of the first-order triangles and on the Laplace azimuths determined at the polygon vertices.

The secondary triangulation consists either of continuous nets of triangles, where the sides measure 13 km in length on the average, or of polygonal traverses measured with electro-optical range-finders.

Base lines are measured over every fourteen to twenty triangles in the triangulation network as a whole, and the Laplace station observations are made at the centre. The mean square angular error calculated from triangle discrepancies is ± 0.75 second.

Although the accuracy of the secondary triangulation is slightly below that of the primary one, the former is constructed more rigidly. The strength of the secondary triangulation is so great that after free-network adjustment the mean square error of the sides was found to be about 1:400,000 and the azimuth error ± 0.5 second.

The USSR astrogeodetic network data comply with the requirements established by the International Geodetic Association in 1930 at its fourth general assembly at Stockholm, and in 1963, at its thirteenth general assembly, at Berkeley.

A considerable portion of the USSR territory is covered by a high-precision levelling network, the over-all length of which is about 350,000 km. The total length of the first-order levelling completed after 1945 exceeds 40,000 km.

According to a preliminary evaluation of the accuracy, the first-order levelling is characterized by an accidental mean square error of ± 0.25 mm per km and a systematic mean square error of ± 0.05 mm. For the second-order levelling, these values are ± 1.2 mm and ± 0.17 mm, respectively.

Under the new high-precision levelling programme 50,000 km of new levelling and 25,000 km of first-order relevelling are to be completed in the next 10 years. The second-order levelling network is planned on a much larger scale; it is located mainly in the mountainous areas and in the northern and eastern parts of the country.

The relevelling data are widely used for investigation of current vertical movements in the Earth's crust. The maps of these movements in the Ukraine, the Caucasus, the central Russian plain, the Baltic republics and some other areas have been established on the basis of the relevelling data. An example of recent work is the map of the vertical movements of the Earth's crust caused by the Tashkent earthquake on 26 April 1966.

In accordance with this new programme, the levelling lines will cross regions of oil, gas, coal and ore deposits, and large artificial reservoir areas, as well as zones of tectonic and seismic activity in the Caucasus, central Asia, Kazakhstan and the Baikal lake region.

Relevelling is planned along the first-order lines established from 1945 to 1965, as well as along many second-order traverses previously established.

A strict schedule is followed in expanding the levelling networks: relevelling is performed within periods not exceeding 15 to 25 years. In some regions it is planned to carry out the first-order levellings and the relevellings in less time so as to relate the levelling data more accurately to a specific period.

Technical progress in the geodetic industry closely follows general developments in science and technology, especially electronics, automation and the precision instrument industry. Plants producing geodetic instruments have in recent years been equipped with new and improved apparatus and machinery.

Experimental models of the "Kwartz" range-finder having an optical quantum oscillator as a light source were built in 1968–1969. Operating experience has shown that these range-finders can measure lines of from 25 to 30 km in length in the day-time with an error of about $+(1\text{ cm} + 2 \cdot 10^{-6})$.

Serial production of the CDG-3 range-finders started in 1970. A gallium arsenide transistor diode is the light source in this type of range-finder. The power consumption of the CDG-3 is less than 5 W, and with it lines of 1.5 to 2 km can be measured with an error of less than 2 cm.

The theodolite auxiliary unit DNK-02 for measuring distances has been put into production; a gallium arsenide diode is also used. The optical block of the unit is fitted to the telescope of the theodolite. Its power consumption is less than 3 W.

A new experimental model of the "Luch" radio range-finder with a 3 cm band and external antenna was developed in 1966. Operating experience has shown that

lines of from 50 to 60 km can be measured with the Luch, with an instrumental error of about 2 to 3 cm and with no need to build geodetic towers.

More modern types of theodolites have been developed, in accordance with national standards; they will soon be produced commercially. The new T05, T-1 and 3T1 theodolites for high-precision triangulation have been tested; they will also be produced commercially. Serial production of the T-2, T-5, T-10 and T-30 theodolites has begun.

The new high-precision astronomical instrument TA 05 and the TA 1, which is less accurate but more portable, are being developed. The DN-04, DNR-06 and DN-10 dual-vision range-finders developed in 1967 and later improved, are now being produced commercially.

Levelling instruments of different orders of accuracy are being perfected, mostly in connexion with the design of self-levelling units.

Topography

Mapping in the USSR has been mainly performed by means of aerial survey methods with the help of techniques and technology developed by Soviet scientists, designers and workers in producing organizations.

Automatic cameras AFA-TE, statoscopes, radar altimeters, gyroscopic stabilizers and radio-geodetic systems are used in aerial surveying operations. High-efficiency instruments are available for printing aerial photos; stereocomparators; two types of universal photoplotting instruments: the stereograph (SD), designed by Prof. F. V. Drobyshev and the stereoprojector (SPR), designed by Prof. G. V. Romanovsky; phototransformers, engraving devices and other office equipment. Photogrammetric devices and instruments produced by Karl Zeiss-Jena (German Democratic Republic) are widely used in office operations. Efficient topographic mapping techniques for different physiographical conditions and at various scales have been developed, analytical aerotriangulation programmes with digital computers, rational organization schemes for field and office operations, and so on.

The main result of the activities of the National Topogeodetic Service in the last decade has been the completion of mapping of the territory of the USSR at the basic national scale of 1:100,000. At the same time, during the 1950s, mapping at from 1:10,000 to 1:25,000 was undertaken by units of the National Geodetic Service. With respect to large-scale survey operations, the work carried out for the cadastre is especially noteworthy. Extensive map revision has also been done.

Large-scale mapping of the most important industrial and agricultural regions, and assistance provided to various civil engineering and prospecting operations have required restructuring and technical re-equipment of the production units of the topogeodetic service.

The principal aim of the scientific investigations is the development and improvement of the aerial photo-topographical methods of surveying so as to reduce as much as possible the most labour-consuming and expensive field operations in observations of the ground-control points. For determination of the co-ordinates of projection centres, an aircraft radio range-finder has been developed and tested in the last few years that makes it possible to measure the distances between the aircraft and two ground stations with a mean square error of about ± 1.5 m at a distance of 300 to 400 km.

For increasing the accuracy of measurements, high-precision stereocomparators with automatic delivery of the results on printed or punched tape have been developed. These instruments make it possible to take measurements with a mean square error of from 1 to 2 microns. The computation programme makes it possible to take into account the errors of photocamera records.

For large-scale mapping, special universal air photo stereoscopic instruments have been developed which ensure highly precise automatic recording of the co-ordinates.

For obtaining orthophotomaps, special instruments are being constructed which make it possible to obtain orthophotographs automatically by using information recorded in the process of relief drawing.

Compilation methods for large-scale maps (1:10,000 and 1:5,000) are constantly being improved. New methods of map revision are being developed

Special attention has been given to problems of combining field and office photo-identification in the preparation and revision of large-scale maps, in the use of colour and infra-red aerial photos, application of orthophotomaps and numerical maps.

Cartography

The cartography of the USSR is closely connected with the problems of economic development, prospecting and rational utilization of natural resources, precise location of the means of production, and so on. The cartographic service aims to provide a great variety of cartographic documents, such as thematic scientific reference maps of the USSR and other countries. All previously collected statistical and other data regarding investigation of natural and labour resources, economics and transport, lands and vegetation, utilization of the soil in agriculture, and so on, are gathered in the most legible and practical form for comparative purposes.

In addition to the cartographic service units the following organizations take part in the development of new thematic maps, as well as in the collection and control of the documents: the institutes of the Academy of Sciences of the USSR, those of the Soviet Union republics and the specialized institutes of the other ministries and departments.

Another large group comprises mainly reference and geographical maps, political maps and maps of the administrative divisions of the USSR, of the republics, territories, provinces, as well as the maps of foreign countries, raw materials and so on. These are mostly maps in wide demand that are systematically revised and re-issued in large quantities.

One outstanding cartographic undertaking is the production of training maps, produced jointly by the Academy of Pedagogical Sciences and the Ministry of Education. Training maps have recently been produced on plastic plates or on paper coated with a transparent film to prevent wear and tear and making it possible to draw on them with coloured pencils.

Considerable work is done on the compilation and editing of topical, reference and training atlases. Their compilation is carried out jointly with specialists from other organizations.

About 25 million copies of training maps and atlases, 10 million copies of administrative division maps and more than 100 types of tourist maps are produced yearly in the USSR.

Among the principal cartographic publications of the last few years, the following are worthy of special note:

Atlas of the USSR	1969
Tectonic map of Eurasia and of recent tectonic movements in the USSR	1968
Geographical atlas for high-school teachers	1969
Atlas of automobile roads of the USSR	1968
Small atlas of the world	1968
Railways of the USSR	1968

A major cartographic undertaking is the geographical map of the world at 1:2,500,000, compiled by the cartographic and geodetic services of the USSR, Bulgaria, Hungary, the GDR, Poland, Czechoslovakia and Romania.

The surveying and geodetic services of the USSR aim to meet the growing requirements of the country's economic, scientific and educational services for geodetic, topographical and cartographic materials.

CARTOGRAPHIC ACHIEVEMENTS AND FUTURE PLANS IN LIBYA*

Paper presented by Libya[1]

Introduction

Libya covers an area of more than 1.75 million km² of North Africa and is inhabited by almost 2 million people. The estimated annual rate of population growth is about 3.8 per cent, which is rather high. However, in a vast country like Libya with relatively large natural resources a quick population growth may be acceptable. Growth of population is a helpful factor in developing the country and utilizing the natural resources with utmost efficiency.

At present the main source of national income is crude oil. It represents about 70 per cent. Developments along every line and facet of productivity are needed. As a matter of fact, plans have already been put into effect for increasing cultivated land, the exploitation of other minerals in addition to oil, the establishment of new industries, the redistribution of the population in fast-growing cities, towns and villages, and the construction of new highways, airports, harbours and many other projects for the education, health and welfare of the Libyan people.

It is an established fact that all development projects require good basic and detailed up-to-date mapping of the country and of the different factors of these various projects. This has been realized by the Libyan Revolutionary Government and a strong up-to-date survey and mapping department is being established with a preliminary annual budget of more than $1 million. The actual expenditure for mapping in Libya for the fiscal year 1969/1970 is over $4 million. It is expected to be doubled in the present fiscal year and in the future.

The photogrammetric plotting method has been used extensively in mapping Libya. The use of orthophotomaps is also planned for the very near future in the country.

Surveying achievements

Ground control in Libya

Libya was completely covered by horizontal control points by the Italians during the period between the two world wars. These were based on the Bessel ellipsoid. Most of these horizontal control points unfortunately were destroyed. A triangulation network was completed in the late 1950s and early 1960s of the northern coastal region of the country, which covers about 5 per cent of the total area. The new network is based on the international ellipsoid and connected to the European Datum through Shoran ties. The grid system used is the UTM. Plans have been made to check the existing triangulation network, rebuild the main stations, recover the lost ones, and intensify the network generally. Some 7,100 km of levelling lines have been completed in the same period and cover all the heavily populated areas as well as those areas of national interest from the point of view of resources. Altogether these levelling lines cover about 75 per cent of the total area of the country. Unfortunately no first-order levelling lines have been completed.

Temporary tidal stations were used as vertical datums for the second-order lines of levels established. More tidal stations are planned to create further vertical datums and to co-operate with international studies of the variation of the mean sea level. No definite date has been set for the establishment of these tidal stations because of the urgency of other more important surveying projects.

Tellurometer traversing fills many gaps in the main coastal network. A few traverses have been extended to the south into the Fezzan area and to Cyrenaica in the east.

Aerial photographs

The whole country was covered by small-scale aerial photographs on a scale of 1:60,000 in the 1950s by a number of specialized aerial photographic companies. Portions of the southern part of the country were covered by medium-scale photographs of 1:40,000. Furthermore, large-scale photographs on a scale of 1:15,000 to 1:6,000 cover scattered areas in the country amounting to about 5 per cent of the total area.

Cadastral surveying

Cadastral surveying of property location and demarcation is currently not well advanced. The classical graphical method is being loosely applied. A new analytical system is under development where photogrammetric techniques would play an important role. Nevertheless, a good property surveying system requires good basic surveying not only in the form of good horizontal and vertical ground control but also in the form of good town planning and township division system. Local and master plans for 154 villages and 28 cities have been carried out in the past five years. An area close to 500 km² is shown on

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* Now the Libyan Arab Republic.

[1] The original text of this paper, prepared by M. M. Unis, Director, Survey Department, Tripoli, appeared as document E/CONF.57/L.103.

50 × 50 cm sheets of 1:1,000 topographic maps with one-metre contour interval. The town-planning project requires about 1,900 sheets. Low-altitude flights were flown in order to produce the large-scale photographs needed for the town-planning project.

Engineering surveying

Because of the great strides in development in the country, a large number of highways, pipelines, power lines, sewage systems and dams are under construction by private firms and some government agencies. The surveying required for these engineering projects is mostly done by the organizations concerned and no details are at the disposal of the Survey Department at this time.

Mapping

Small-scale mapping

Libya is covered by a group of small-scale map series. The whole country is covered by 1:1,000,000 world series maps. A large portion of the country is also covered by 1:400,000 planimetric maps which were made by the Italian Government prior to 1939. The coastal belt of Libya is covered by fifty-eight 1:250,000 topographic maps. The last series is considered up to date and was completed by the United States Army Map Service. A number of 1:100,000 map series for different parts of the country also exist. However, most of these are obsolete due to the use of the old grid system or of rough planimetric nature. In addition to the above-mentioned small-scale maps a number of aeronautical and marine charts exist.

Medium-scale mapping

The coastal belt of the country is covered by a series of 1:50,000 topographic maps made in the early 1960s and compiled by photogrammetric means. This series is considered the most recent and reliable medium-scale topographic maps of the area.

Large-scale mapping

A few old series of 1:25,000 topographic maps for scattered portions of the country are available. Moreover, 1:5,000 and 1:2,500 maps of the cultivated and settlement areas are in existence. Maps on a scale of 1:1,000 are available for almost all villages and towns of Libya. Large-scale maps of Libya may cover about 5 per cent of the total area of the country.

Standard romanized names

Efforts have been made in order to reach standard romanized names for all the surveyed objects in Libya. These efforts have yielded acceptable names for the cities and villages which are covered by the town-planning programme. It is true that this programme in Libya is in its infancy, but efforts are going ahead in order to achieve an agreed system of names. These efforts will be incorporated in our map revision programme and the revised map series will carry the new standard romanized names in the very near future. A number of government agencies in Libya will co-operate in this programme.

Future plans

As the Libyan Survey Department, in Tripoli, was established only in the late 1960s and is still becoming established, and because of the vast area of the country and the huge amount of surveying required for it together with the relatively high labour cost, there are plans to equip the department with up-to-date survey instruments and to staff it with highly qualified personnel. There is a tendency to use EDM devices for the establishment of ground control and wide use of photogrammetric methods for mapping with emphasis on orthophotomaps in particular areas. Electronic computation seems to be a must in order to complete as much as possible of the badly needed work for development projects in the shortest possible time.

The existing horizontal control system, besides being revised and made permanent, will be intensified. Extension of horizontal control will be carried out in the southern part of the country in the form of electronic traversing with adequate astronomical control. Wherever possible, relatively wide-range trilateration will be established in the south.

A minimum of three tidal stations will be reconstructed and run systematically for a good period of time. A vertical datum thereafter will be adopted and the whole levelling net will be readjusted.

Superwide-angle photographic missions are planned for the production of small-scale topographic maps (1:250,000) during the next ten years for the southern part of the country.

Standard photographic flights are also planned for the coastal area in order to produce medium-scale (1:25,000) maps, and for particular areas large-scale maps of 1:5,000 and larger will be made.

An analytical cadastral system, through the use of low-flight standard photographs, will be adopted. On the other hand the use of orthophoto maps will be introduced in the country for the first time, most probably as a substitute for the required topographic maps used in reconnaissance of large engineering projects.

New editions of the existing 1:50,000 and 1:250,000 topographic maps will come out in the very near future and will show Arabic and standardized Roman names.

CARTOGRAPHIC ACTIVITIES IN CANADA

Paper presented by Canada[1]

INTRODUCTION

This report summarizes cartographic activities in Canada. Responsibility for activites in geodesy, topographical mapping, aeronautical charting and map production for the federal Government is assigned to the Surveys and Mapping Branch of the Department of Energy, Mines and Resources, while activities in hydrography and oceanography are undertaken by the Marine Sciences Branch of the same Department. The survey organizations in each of the provinces are generally more limited in resources and range of operations and their programmes are designed to meet their specific needs. Cadastral surveys are carried out by private practising surveyors operating under regulations set by the legislatures of the provinces in which they reside.

GEODETIC SURVEY OPERATIONS

In Canada the Geodetic Survey is responsible for the establishment and maintenance of the national frameworks of primary horizontal and vertical control, the establishment of mapping control as required by the national mapping programme and the maintenance of a national survey control data bank.

Horizontal control

The horizontal control network now includes some 5,400 stations in 23,600 miles of work. The more southerly areas of the country have been covered with first-order nets established by conventional procedures, while the northern areas of the country have been covered with Shoran trilateration, of which the average side length is about 200 line miles. In more recent years Aerodist, the airborne tellurometer system, has been used to establish high-order horizontal control and control for 1:50,000 scale mapping in northern areas, where there is a high level of resource exploration activity.

A programme of establishing second-order traverse grids in the metropolitan areas to provide control for municipal surveys and co-ordinate systems was completed in 1970. This programme, which was begun in 1962, has seen control networks established in fifty-nine different municipalities.

The period 1967–1970 has seen the emphasis in effort change from the establishment of new networks to the strengthening and densification of existing control in areas of economic importance and development, mainly in eastern Canada. Additional effort has been spent in improving the scale of existing networks by the measurement of lines by tellurometer and improving the azimuth by adding Laplace stations to existing networks. During the past three years forty-three new Laplace points have been established, nine old stations have reobserved and reciprocal observations have been made on six lines. We now have a total of 204 Laplace stations and 700 primary deflection stations.

The joint Canadian–United States North American satellite triangulation project, started in 1964 and suspended in 1966, has been reactivated. It is expected that four of the Canadian stations will be reoccupied in 1970–1971 and 1971–1972 to improve the accuracy of the Canadian work, and to make connexions to Alaska, Greenland and Bermuda.

Aerodist activities for the period 1967–1970 have added ninety-nine first-order and thirty-eight second-order stations with control being provided for over 1,500 1:50,000 scale map sheets covering an area of 443,000 square miles.

Vertical control

In the four-year period 1967–1970 the Geodetic Survey ran 7,800 miles of new first-order levels, relevelled 2,100 miles and established 7,800 new bench-marks. The country-wide network now includes 55,100 miles of first-order levels, 16,700 miles of second-order levels and 31,600 bench-marks.

A trans-Canada level line was started in 1966 and is expected to be completed in 1971, with a total length of 3,900 miles. The levelling required for the re-evaluation of the international Great Lakes datum was started in 1968. Six hundred miles have been completed and it is anticipated that the remaining 400 miles will be completed in the next two years. This project is using parallel-plate micrometer and metric rods, with the allowable discrepancy between forward and backward levelling of 3 mm $\sqrt{K}$.

The programme to establish deep bench-marks to improve the stability of bench-marks in some areas was started in 1967. The deep bench-marks consist of two separate pipes, one inside the other, driven to refusal. Two hundred of these bench-marks have now been installed; the average depth is 41 ft, the maximum depth 204 ft.

A programme of establishing grids of vertical control in municipalities has been continued. Projects in seventeen cities have been completed during the past four years, bringing the total to thirty-four. Several special level lines have been run to aid development projects in areas of northern Canada. These have all been carried out to assist in hydro-development and stream-diversion projects.

Research and development

A study of the possibilities of using the gyrotheodolite in geodetic work has recently been completed. It has been determined that the gyro measures astronomic azimuth. With all due precautions regarding stability of set-up, adequate warm-up, observing routine and number of observations it is felt that the MoM GiB-2 can establish astronomic azimuth with a standard error of about 1 second.

A useful computer programme entitled GALS (Geographic adjustment by least squares) had been developed and is in use for both production and investigational work. The programme is comprehensive; it computes the least-squares adjustment of any combination of triangulation and traverse surveys and produces accuracy analysis of the survey. It is written in basic Fortran IV and can be readily adapted to any large electronic computer.

[1] The original text of this paper, prepared by J. I. Thompson, Assistant to the Director, Department of Surveying and Mapping, Ministry of Energy, Mines and Resources, Ottawa, appeared as document E/CONF.57/L.113.

Topographic and general-purpose mapping

Canada has three principal topographic mapping series at scales 1:250,000, 1:50,000 and 1:25,000. The 1:250,000 scale coverage of the country, which was recently completed, comprises 919 maps and is used for general planning and administrative purposes. The 1:50,000 scale maps have been produced for the more settled areas and in more remote areas where there are programmes for the development of natural resources. Approximately 4,850 maps have been produced covering approximately 39 per cent of the land area of Canada. The largest scale, 1:25,000, will be available only for the more densely populated areas, and the majority of the metropolitan areas has been covered.

Map coverage at scale 1:125,000 is produced from information at larger scales for limited areas of Canada where there is a special need. Approximately fifty maps are available and forty others are in production. Work on the International Map of the World on the Millionth Scale series is continuing. Eleven maps covering more densely populated areas in southern Canada have been published and another twenty are in production. A wide range of general-purpose maps have been published as well as special series such as electoral-district, bilingual-district and national-park maps.

Activities since the last conference have been directed to the production of new maps in the more northerly areas in support of the development of natural resources, with an increasing amount of effort being expended on revision and remapping in the more densely populated areas of the country, and to the maintenance of published and special-purpose maps and their limited extension as required.

In recent years there has been a great increase in the demand for photo-mapping products produced by orthophoto instruments and rectifiers. A wide variety of experimental photomaps have been produced to meet these requests and include products at scales 1:25,000 and 1:50,000 based on 1:50,000 scale mapping, photomaps at scale 1:250,000 based on the published maps at that scale and a planimetric series at scale 1:50,000 produced of remote areas, using the published 1:250,000 scale topographic maps as a base.

Other research includes the continuance of investigations for an aerotriangulation adjustment system specifically adapted to Canadian requirements and intended to handle large blocks of aerial photography and accommodate heterogeneous and randomly distributed control. Other projects include an investigation into the accuracy of Aerodist-controlled photography and research into the determination of more accurate representation of isobaric surface in order to increase the effectiveness of altimetry systems.

A major breakthrough in the field of orthophoto instrumentation has been made by the firm of Hobrough Limited, Vancouver. This firm has invented and constructed a prototype instrument capable of scanning an entire model in less than 15 minutes. The firm is now conducting extensive tests on the instrument and it is anticipated that it will prove successful.

Aeronautical charts

Coverage of Canada is available at scales 1:50,000 and 1:1,000,000 in two series of pilotage charts designed as aids to visual navigation. Various plotting charts of Canada and the Pacific and Atlantic Oceans are produced at scales 1:250,000 to 1:6,000,000.

Radio-navigation charts, instrument-approach-procedure charts and related supporting publications are published and regularly maintained. Radar-surveillance charts and controller charts are also produced to provide air-traffic controllers with *en route* and terminal flight information.

Work has started recently on the conversion of the present 1:1,000,000 scale pilotage charts series to a new format. This new series will comprise nineteen charts, replacing the sixty-six charts of the present series. The cycle for revision of the Enroute series of flight information publications was changed from a 35-day period to the ICAO 28-day cycle early in 1970.

Canadian Hydrographic Service

Canada possesses the world's longest coastline, its greatest navigable fresh-water system and a vast continental shelf covering 1,425,000 square miles. Annually, 190 million tons of cargo moves through Canadian waters. Eight-hundred thousand pleasure craft are registered in Canada.

Since 1883, hydrographic surveys of Canada's coastal and navigable inland waters have been continually in progress, and they have been the Canadian Hydrographic Service's responsibility since 1911. Today, the Service maintains over 1,000 navigation charts and distributes more than 300,000 each year to commercial shipping, the fishing industry and national defence, to industry exploiting the resources of the continenal shelf and to recreational boaters in both Canada and the United States of America.

Some interesting features of the Canadian Hydrographic Service's work are: (*a*) a continuing programme of special charting focused on the exploitation of the continental shelf's resources to publish natural resource, bathymetric and superficial geology charts; (*b*) conversion of charts to the metric system; (*c*) charting the polar continental shelf by helicopter-supported sounding through the ice and by Hovercraft surveys in open water; (*d*) development of equipment to automate field-survey and chart-production techniques; (*e*) production of folded strip charts designed for recreational boaters; (*f*) a continuing programme of chart-revisory surveys; and (*g*) conversion to the negative scribing technique. The Service now scribes the complete chart, including the soundings.

Oceanography

The Marine Sciences Branch has a responsibility to provide assistance and expertise where and when required to a large community of Canadian marine interest that will benefit the Canadian economy in resource development and environmental programmes. The services provided range from the continual provision of tidal and water-level data and the archiving and retrieval of oceanographic data through the Canadian Oceanographic Data Centre and the world data centres in Washington, D.C., and Moscow. Research studies and surveys in geophysical, geological and chemical oceanography are carried out from major centres of oceanographic activities at the Bedford Institute, Dartmouth, Nova Scotia; Ottawa, Ontario; and Vancouver, British Columbia, on the west coast. Their international interests are being highlighted in the voyage of the Canadian S.S. *Hudson* around the Americas and an increased priority for Pacific Ocean studies.

CARTOGRAPHIC ACTIVITIES IN THE PORTUGUESE OVERSEAS PROVINCES

Paper presented by Portugal[1]

TIMOR PROVINCE

The Portuguese province of Timor is composed of the eastern part of the island of the same name, Atauro Island and the enclave of Oe-Cussi.

Surveying and mapping are carried out in this province by a geographical mission.

Geodesy

The triangulation of Timor was completed before March 1967 and the purpose of subsequent geodetic activities has been to cover the province with precision-levelling and gravity-surveying networks.

Levelling

The precision levelling network, which covers 1,359 km, is made up of sixteen lines arranged in six circuits, marked by 1,069 beacons.

During the period referred to by this report, the following levelling projects were carried out.

(*a*) Reconnaissance and beaconing operations covering 576 km;

(*b*) Line measurements in both directions covering 129 km;

(*c*) Reconnaissance, beaconing and line-measuring operations covering 338 km.

Wild N III levels and Invar levels were used in the measuring operations.

Gravity surveying

The gravimetric network of Timor consists of a basic network, with summits situated at eleven airfields in the province, and a first-order network comprising a total of 237 summits, twenty-five of which are situated at Oe-Cussi and twenty at Atauro Island.

The gravity value of the principal NP-36 levelling marker, situated at Baucau international airport, will be adopted as the "datum" of the gravimetric network. This value will be determined by the Darwin pendulum station by reference to the world gravimetric network.

During the period of this report, observations were carried out in almost all of the first-order stations of the network. A Worden gravimeter of the type used in surveying was used for the gravity observations.

Cartography

The 1:50,000 map of Timor was constructed on the Universal Transverse Mercator Projection and consists of thirty-six to thirty-seven sheets printed in six colours in a $15' \times 15'$ format with contours at 25 m intervals. The survey was made by photogrammetry with the use of vertical aerial photographs taken at a scale of about 1:30,000. The field work for the map consisted of geodetic triangulation, cartographic triangulation and traversing and photographic and toponymic reconnaissance. The photogrammetric work consisted of aerial triangulation and plotting.

The purpose of the aerial triangulation was to provide photogrammetric data for the compilation of the map, in support of classical ground surveys. The aerial triangulation was determined as follows:

(*a*) Primary aerial triangulation—consisting of spatial aerial triangulation of framing strips based on three groups of four or five ground-control points with known co-ordinates;

(*b*) Secondary aerial triangulation—consisting of spatial aerial triangulation of photographic coverage strips using the co-ordinate control points established by the primary aerial triangulation.

The aerial triangulation was done with a Wild A7 Autograph fitted with a Wild EK5 electric co-ordinatograph and a Wild SL15 card-punch. Planimetric errors were calculated and adjusted by the Van der Welle method with the use of an electronic computer. Altimetric errors were adjusted graphically. The accuracy obtained for the aerial triangulation was as follows: mean planimetric error ± 4.1 m; mean altimetric error ± 2.2 m.

In view of the tolerances allowed for the map—namely, a mean planimetric error of ± 10 m and a mean altimetric error of $\pm(3+10t)$ m (where t = tangent of angle of inclination)—the scale (1:50,000) and the magnitude of the contour intervals, it can be seen that the results obtained clearly exceed those required for the map.

The plotting was done pair by pair and reproduced on the co-ordinatograph at the scale of the published map. The contours were scribed directly from the autograph with a sapphire point on to a "Stabilene" sheet while other details were drawn on a polyester base sheet. The drawing was done on "Stabilene" sheets, with colour separation, by the scribing method.

All the sheets of the 1:50,000 map have been published. The following work was done on this map during the period covered by this report: (*a*) plotting and drawing of 17 sheets; (*b*) printing of 36/37 sheets.

Another map of Timor, at a scale of 1:500,000 has been prepared by reduction from the 1:50,000 map and is being printed.

A 1:500,000 geological sketch map of Timor has been published and included in the "Cours de Géologie d'Outre-Mer".

PORTUGUESE STATE IN INDIA

Removed from the full and effective exercise of Portuguese sovereignty since December 1961.

MACAO PROVINCE

A 1:20,000 hydrographic chart of Macao, Taipa and Coloane has been published.

[1] The original text of this paper appeared as document E/CONF. 57/L.115.

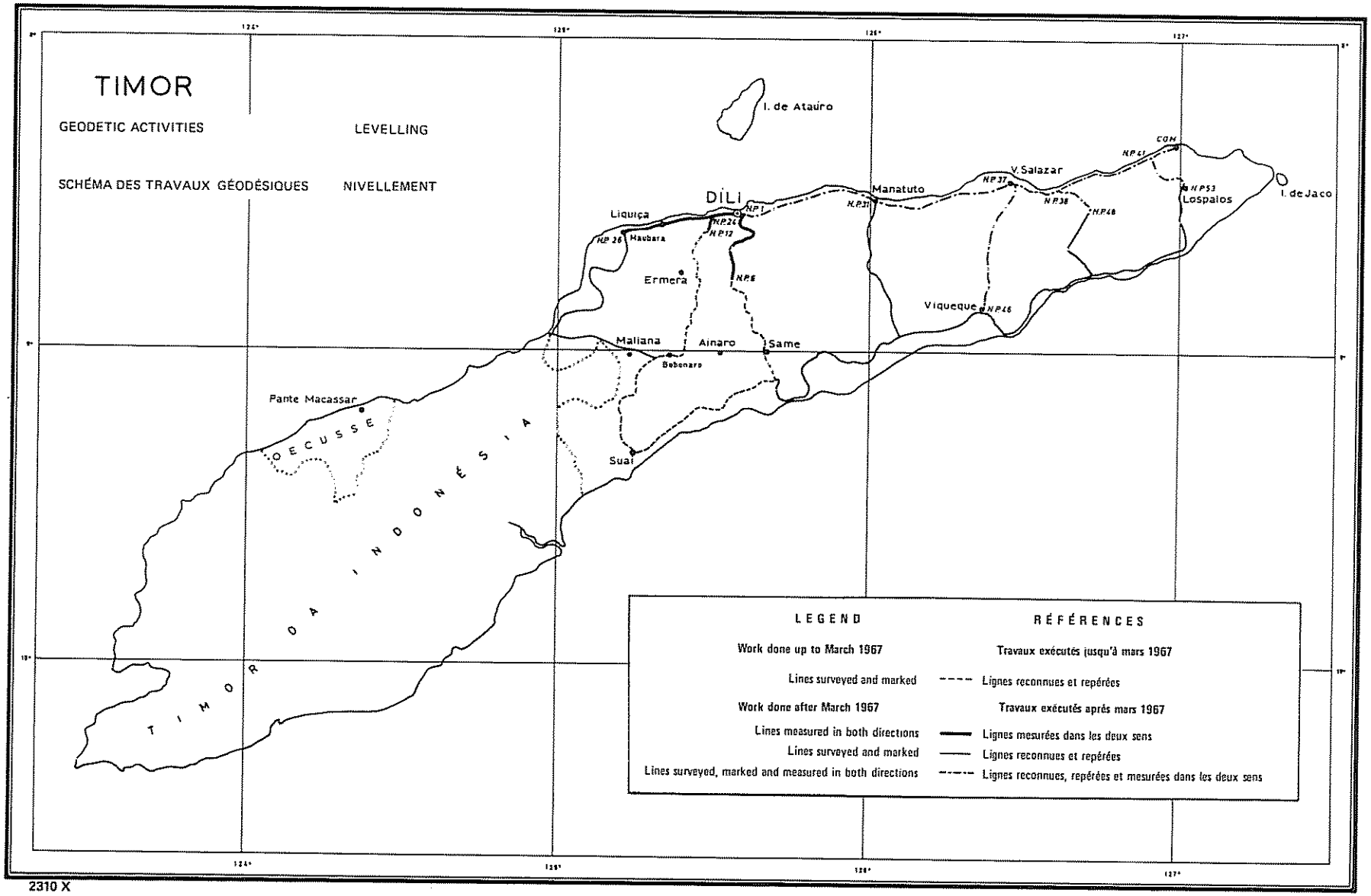


Figure I. Timor: Geodetic activities: Levelling

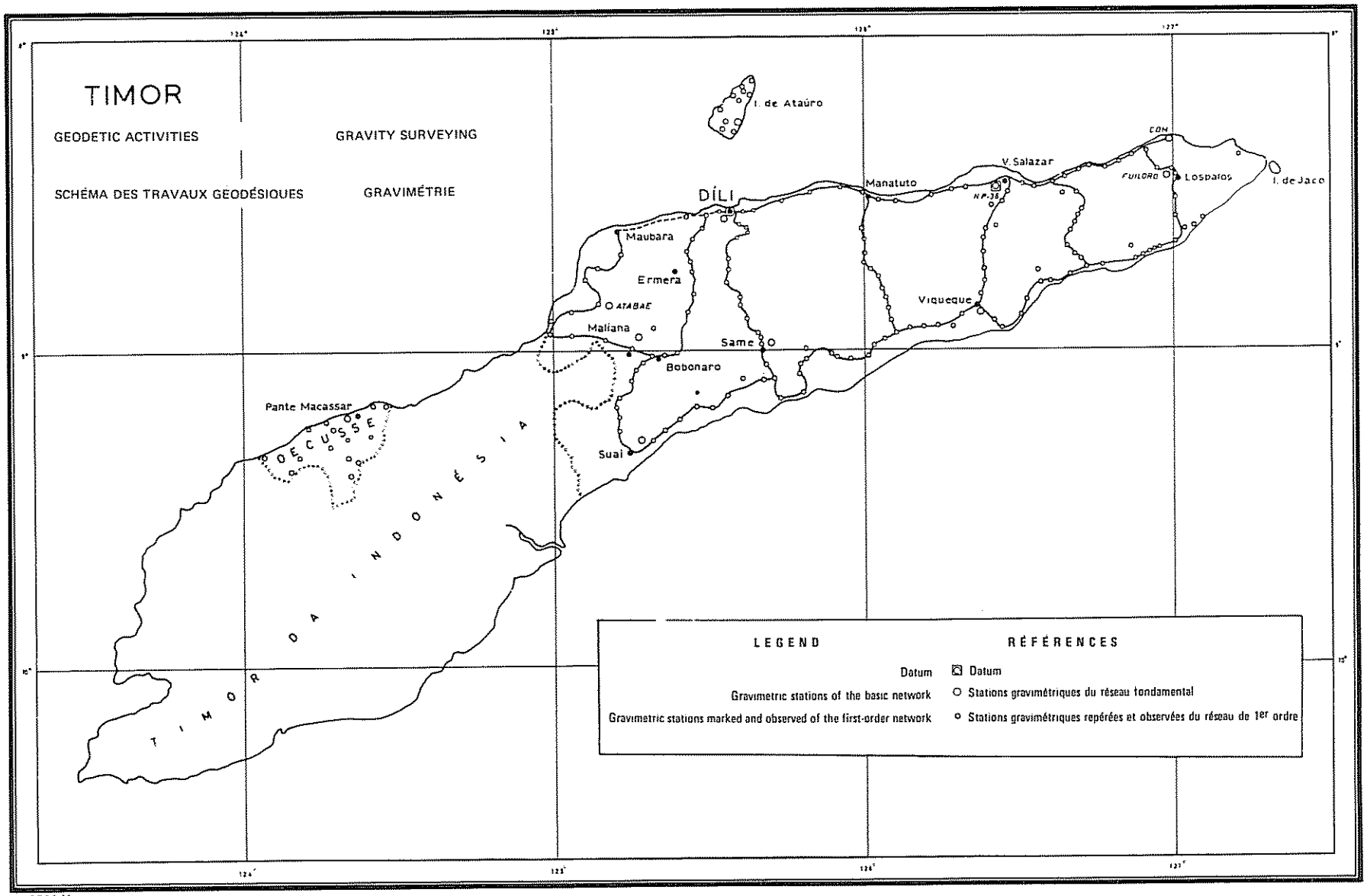


Figure II. Timor: Geodetic activities: Gravity surveying

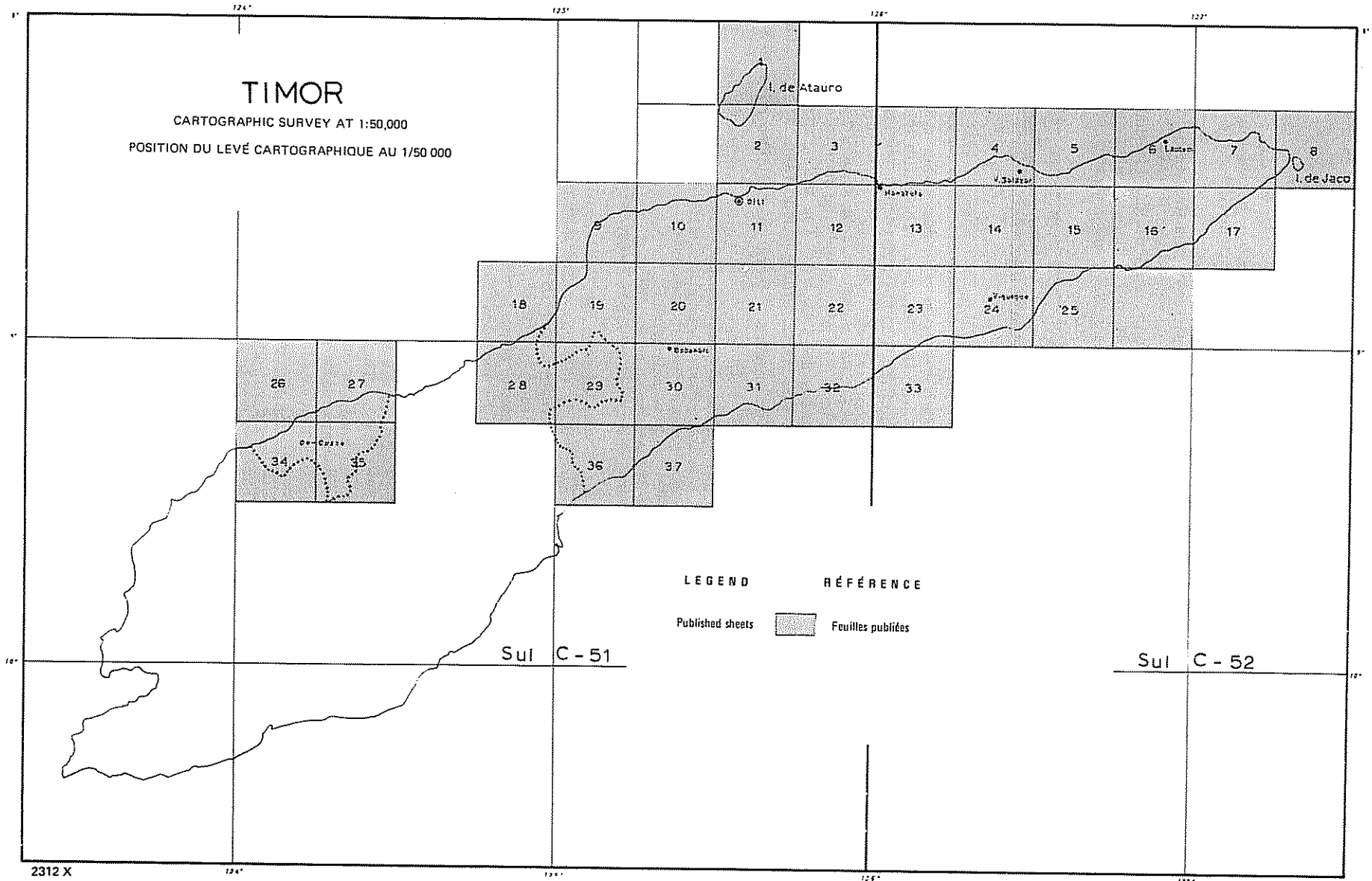


Figure III. Timor: Cartographic survey at 1:50,000

CARTOGRAPHIC ACTIVITIES IN SWITZERLAND

Paper presented by Switzerland[1]

PRIVATE SURVEY COMPANIES

There are approximately 230 private survey companies in Switzerland, thirteen of which are equipped with photogrammetric plotters; one operates an aerial photography service. These companies not only handle private contracts, but they also participate to a great extent in the official surveys under the direction of the appropriate federal or cantonal authorities, against payment according to an established schedule of fixed rates. This applies especially to cadastral surveys, many of which are entrusted to private cadastral surveyors.

SWISS FEDERAL TOPOGRAPHIC SERVICE

To maintain the first- to fourth-order triangulation network in perfect condition, the stones and their auxiliary reference marks are checked periodically. In some areas, especially in connexion with large engineering projects, the checking is carried out by running precision traverses with electro-optical or electronic distance-measuring equipment.

Work is proceeding with the re-measurement of the national levelling network. The north–south lines along the Rhone and Rhine rivers are showing a tendency to rise in the southern areas by 2 to 3 cm per 30 km in forty years.

The Swiss Federal Topographic Service participates, together with the geodetic departments of the two institutes of technology and private companies in the geodetic supervision of dams and other large structures such as bridges.

After a landslide caused a power-dam disaster in another country, the Government directed that regular observations of hill-side shifts should be extended to the area of the reservoirs.

The investigations of water pollution in the Lake Constance area by means of aerial colour photographs proved to be successful. A similar investigation will therefore be carried out in 1971 in the area of the Lake of Geneva.

Remapping at 1:50,000, 1:100,000 and 1:500,000 has been completed. The new national map at 1:25,000 is nearing completion. The entire series, totalling 245 sheets, will be available in 1973. The 1:5,000 general map series covering the midlands (*Mittelland*) and southern regions has been completed. The 1:10,000 general map of the mountainous areas is expected to be ready in three years' time. The first sheet of the new 1:200,000 map has been published.

The revision of the national map series is based on a 1:25,000 to 1:30,000 scale. Revision is done in blocks of three to four map sheets at 1:100,000 every six years. The time required from the survey flight to the publication of the revised map is one to two years. The criterion observed by the Topographic Service is that map quality should not deteriorate through revision; this explains why photogrammetric precision plotters are also being used for this type of work. Tests are being carried out with orthophotographs. The results seem to indicate that conventional photogrammetric mapping is more economical for revision work, at least under the conditions prevailing in Switzerland. One reason is the superior interpretation of detail that is possible with the large photogrammetric plotters.

The fifth instalment of a total of nine of the "Atlas of Switzerland" was published this year. The loose sheets cover such items as hydrology, vegetation, history, ice periods, export and import, climate and the like. The sixth instalment will contain a series of new geological maps.

The 1:300,000 map showing the cultural heritage of Switzerland has been completely revised and will be published in November 1970.

SWISS FEDERAL DIRECTORATE OF CADASTRAL SURVEYS

The Directorate of Cadastral Surveys is a supervisory authority that, in co-operation with the cantonal survey authorities, commissions private licensed surveyors to carry out cadastral surveys. These surveyors are nevertheless given a very free hand in the choice of survey methods. In general, only the map scale and the required accuracy are specified. The scale varies between 1:500 and 1:10,000 according to land values and parcel areas.

The progress of work up to 31 December 1969 was as follows:

Total area of Switzerland	41,288 km²
Surveys completed	19,938 km²
Surveys provisionally approved	2,380 km²
Surveys in progress	3,207 km²
Area not to be surveyed	6,500 km²
Surveys not yet started (mostly in mountainous areas)	9,263 km²

Photogrammetric cadastral surveys are carried out mainly in areas where third-order accuracy is required (instruction zone III). In areas of second-order accuracy (instruction zone II), the tendency is to fly blocks with a side lap of 60 per cent between strips, so that each lot corner can be measured independently in at least two stereo models. The maximum discrepancy tolerated between two such independent measurements of the same point is 15 cm in X and Y. The so-called "erratic points" can thus be determined with a high degree of certainty. All lot corners are marked with white paint prior to the survey flight. The use of movable signals made of cardboard, plastic or other suitable material is no longer tolerated because their correct position at the moment of exposure cannot be ascertained.

All stereomodels are supplied with full ground control, mostly by means of the infra-red Distancer DI10 Distomat. Block adjustment methods may again be taken into consideration at a later date.

The co-ordinates recorded in the autographs are fitted into the network of control points by means of a Helmert spatial transformation.

The photo-cadastre has proved its value as an interim solution where the regular land-registry survey can only be carried out later. It consists of unrectified enlargements of aerial photographs at approximately 1:1,000 or 1:2,000. Lot corners are not marked. Property boundaries, agricultural limits and buildings are identified in the field and

[1] The original text of this paper, prepared by R. Scholl, appeared as document E/CONF.57/L.116.

annotated in the enlargements by qualified specialists in the presence of a committee of landowners. The registers of properties and property owners can be established and, together with the enlargements, they form a valuable basis for legal transactions.

The working group for automatic data processing has now published the first part of the regulations for the application of automatic data processing in cadastral surveys. It covers such items as checking of data, numbering of points, surveying and computation methods, classification of points, co-ordinate lists, mapping of points, computation of property areas, computation of cultivated areas and checking of agricultural statistics. The chapters dealing with revision, photogrammetry and automatic drafting will follow later, and the extent to which automatic data processing is suitable for taxation and settlement of accounts will be investigated.

Swiss Geodetic Commission

The Swiss Geodetic Commission is a branch of the Swiss Society for Nature Research. It concerns itself with fundamental geodetic problems and co-operates closely with the Geodetic Department of the Swiss Federal Institute of Technology, the Swiss Federal Topographic Service, the Satellite Observation Station at Zimmerwald and other organizations.

The location of Switzerland in the centre of the European triangulation network and deep in the high Alps calls for a rigid and solid anchoring of the network. In order to carry out this task and other investigations, the Geodetic Commission and the other organizations are undertaking the following programme.

(*a*) Checking the first-order triangulation through high-precision distance measurements with the Distomat DI50 and the Geodimeter 8;

(*b*) Determination of additional Laplace points;

(*c*) Determination of the geoid. Further measurements and theoretical investigations have confirmed the values found for the geoidal undulations. The geoid warps about 1 m above the reference ellipsoid under the Jura mountain range in the north, sinks about 1 m below it in the *Mittelland*, rises 2 to 3 m above it in the Alps, and falls to about 3 m below the reference ellipsoid in the south;

(*d*) Connexion of the Swiss satellite observation station at Zimmerwald to similar stations through long-range precision distance measurements with electro-optical and electronic distancers, in co-operation with other countries;

(*e*) Determination of a gravimetric net. The gravimetric net of Switzerland forms part of the European network. It is an area net with average distances between gravimetric stations of 20 to 25 km at level land, and 15 km in the mountains. A higher-order control net with a total of eighty stations was measured with three LaCoste–Rhomberg gravimeters in 1968–1969.

Land Consolidation (Reallotment)

The consolidation of scattered holdings into larger lots is carried out by private surveying and photogrammetric firms under the control of the federal and cantonal land-consolidation authorities. As a rule, the old situation is surveyed photogrammetrically after marking the lot corners. In general, land consolidation reduces the number of lots to one-quarter of the previous figure.

Land consolidation in Switzerland (position as at 31 December 1969)

Projects completed (*ha*)	*Projects in hand* (*ha*)	*Total* (*ha*)	*Projects outstanding* (*ha*)
267,275	167,823	435,098	374,148

Swiss Federal Institute of Technology (Zurich)

Photogrammetry

The Institute of Photogrammetry is equipped with all the instruments needed for teaching and solving research problems in all fields of photogrammetry. At the request of the Institute, a number of photogrammetric instruments have been fitted with dual-instruction oculars to facilitate operator and student training. Research projects are under way on strip and block triangulation, economy of observations in photogrammetry, highway planning, digital terrain model and use of orthophotographs for regional and urban planning.

The Institute is involved in a number of consulting and practical projects, such as the supervision of a glacier break near a dam. Photographs are taken every four months. The cross-sections, profiles and all crevasses are plotted. Another interesting project consists of model-scale experiments on stepped barriers for mountain streams. Four hundred stereomodels have already been taken with a stereometric camera having a 40 cm base.

A course on the application of close-range photogrammetry to the protection of cultural heritages (conservation of monuments) was held at the Institute in the spring of 1970. Its aim was to familiarize the administrations involved with modern methods of maintaining records on historical buildings and monuments, as well as on archaeological sites, so as to enable reconstruction after loss in wartime or because of natural catastrophes. A second course is planned for next year, with participants expected from throughout the world.

Department for Urban, Regional and National Planning

Among other things, this Department is involved in offering post-graduate courses and advanced training in environmental planning; processing of Swiss municipal-planning concepts at the request of the Federal Ministry of Economics; laying down of guide-lines for urban, regional and national planning; carrying out feasibility studies in connexion with applications for housing-construction subsidies; and advising local planning authorities.

A national planning data bank—a so-called "information grid"—with an initial capacity of fifty sets of data in the following categories is planned for 1972: use and characteristics of the land, residential and working population, economy, education, recreation, health, public offices, communications, services and state of planning. The information stored in the computer is based on a 100×100 m grid linked to the national co-ordinate system. Moreover, certain sets of data are stored in lines (e.g. communications networks) or communities (e.g. incomes). For all combinations of data the output can be in the form of tables or, graphically, in the form of maps.

Swiss Federal Institute of Technology (Lausanne)

The current research programme of the Department of Geodesy and Photogrammetry covers the following fields: application of statistical methods to traversing; tests with the infra-red distancer Wild DI10 Distomat; application of the Wild C120 stereometric camera to laboratory work, such as deformation measurements on construction elements; application of statistical methods in topography; automation of photogrammetric and cadastral surveys.

Swiss School for Photogrammetric Operators (SSPO) (St. Gallen)

Since it was established in 1966, the SSPO has been gradually expanded to cope with the increasing demand for operator training. The staff now comprised six teachers. Lectures are held in English, French, Spanish and German. Substantial donations made it possible for the number of instruments to be increased so that up to thirty students can now be admitted to the courses. The present instruments include ground-survey equipment, three aerial cameras, one phototheodolite, one Wild E4 rectifier, one Wild VG1 enlarger, two diapositive printers, one Kern PG2, one Santoni 11c stereosimplex, one Nistri photomapper, one Wild A5, one Wild A6, one Wild A7, three Wild A8, two Wild A9, two Wild B8, six Wild B9 and one Wild STK1 stereocomparator.

The courses now last seven months, instead of six. They begin in September and end in March, with an examination before a panel of internationally known experts. Successful candidates are awarded a photogrammetric operator diploma.

United Nations Seminar on Photogrammetric Techniques

A United Nations Seminar on Photogrammetric Techniques will be held from 15 March to 3 April 1971 at the Department of Geodesy and Photogrammetry, Swiss Federal Institute of Technology, Zurich. The seminar is open to department heads from Central and South America, as well as from Africa and Asia. The official languages are English, French and Spanish. The number of participants is limited to thirty.

Fellowships

The Department of the Interior and the Bureau for Technical Co-operation continue to grant fellowships to students from developing countries for the following:

(*a*) A full course of studies up to diploma level at the departments of geodesy and photogrammetry of the Swiss federal institutes of technology in Zurich or Lausanne;

(*b*) Post-graduate courses of at least one year at these institutes;

(*c*) On-the-job training in private surveying offices; and

(*d*) On-the-job training in the instrument industry.

CARTOGRAPHIC ACTIVITIES IN TURKEY

Paper presented by Turkey[1]

Relations between the Mapping Service of the Turkish Ministry of National Defence and International Organizations

The Mapping Service of the Turkish Ministry of National Defence became a member of the International Union of Geodesy and Geophysics (IUGG) in 1947. In accordance with the statute of the International Union of Geodesy and Geophysics, the Turkish National Union of Geodesy and Geophysics was set up in 1968.

The activities of this National Union are carried out by: (*a*) a representing agency; (*b*) the General Assembly; (*c*) the Council of the General Assembly; and (*d*) committees. In accordance with the statute of the Union, the Mapping Service represents Turkey at the International Union. Scientific activities are carried out by seven committees which correspond to the international associations of IUGG.

Turkey also became a member of the International Society for Photogrammetry in 1959 and is represented in this association by the Mapping Service.

Preparations are continuing for the establishment of the Turkish National Association for Photogrammetry, in accordance with the statute of the International Society for Photogrammetry.

[1] The original text of this paper appeared as document E/CONF. 57/L.117.

Triangulation work

Triangulation activities started in Turkey many years ago and were carried out with various data and projection systems. Since 1955 triangulation points have been established in the European system, which has now been applied to the entire country. The first- and second-order triangulation networks were completed in 1952. Triangulation connexions have been established with Iran, Iraq, Bulgaria, Greece and Cyprus. Adjustment of first- and second-order geodetic points for the country has been completed.

Levelling activities

Levelling activities in Turkey started in 1935, and to date a first-order levelling network of 4,000 km, consisting of forty-four polygons, has been established. In between these polygons third-order levelling measurements over some 225,000 km have been made, as required.

The seven mareograph stations from which the initial elevations of the levelling network were derived are located in Iskenderun, Antalya, Izmir, Bodrum, Karadeniz Ereglisi, Samsun and Trabzon.

Preparations are under way for adjustment of the first-order levelling network. Meanwhile, construction and development of the nodal points of the polygons to be adjusted are also under way; seventy-three nodal points are being established.

In addition, with a view to calculating the theoretical errors of the polygons, gravity measurements were taken at specific levelling points.

Photogrammetric work

The Turkish Mapping Service first undertook photogrammetric compilation in 1929 by using ground photographs. This method was continued until 1937; thereafter aerial photographs were used, and to that end a C4 Zeiss planigraph was purchased from Germany. As very good results are obtained with this method, more planigraphs will be purchased in the years to come.

At present we have sixteen German-made Zeiss planigraphs, three Swiss-made Wild planigraphs and one Italian-made Santoni planigraph. In order to meet the requirements of all the ministries and military and civilian organizations, maps and plans are being produced at 1:1,000, 1:2,000, 1:5,000 and 1:25,000. Topographic cadastral mapping in Turkey at 1:5,000 is being carried out by aerial photogrammetry. About 2,000 km^2 per year are being covered at that scale.

Compilation of 1:25,000 mapping of Turkey has been completed and revision activities are now being carried out. In the process of compilation, drawing operations are carried out by both classical and aerotriangulation methods.

Cartographic activities

Before 1956 map printing and other printing work were carried out in limited colours by using filling methods and offset printing techniques. Thereafter greater accuracy and speed were obtained by using the positive colour-separation method with black ink on transparent surfaces and the negative scribing method.

Plastic relief mapping

The Plastic Relief Mapping Section was established on 20 June 1968. Three officers received training in plastic relief map production and relief by shading at the Military Cartographic Organization, in Italy. Initial work in this field included shading of 1:250,000 scale maps, sections of some dams and a relief map for special purposes. The necessary equipment has been obtained.

Magnetic activities

Measurements were taken in 1965 with a view to determining magnetic declination, intensity and inclination, and a secular variation network consisting of eighty-five points has been established at certain intervals. The plan is to repeat these points every five years. The frequency of the intermediary points was increased so as to have one point in each $15 \times 15'$ quadrilateral. To this end the Kandilli Observatory, as well as the observatories of the universities and neighbouring countries are being used. Lacour-type quartz magnetometers (QHM) (BMZ) are being used. Measurements are precise to the nearest gamma, and theodolites are used to determine the geographic azimuths.

INDONESIAN AND AUSTRALIAN ACTIVITIES IN CONNEXION WITH THE SURVEY OF THE BORDER BETWEEN WEST IRIAN AND THE TERRITORIES OF PAPUA AND NEW GUINEA

Paper presented by Indonesia and Australia[1]

At the first meeting of Australian and Indonesian authorities to discuss the survey of the border between West Irian and the Territories of Papua and New Guinea, held at Djakarta in July and August 1964, it was recommended that astronomical positions should be determined and marked at ten positions on the 141° east meridian, from the northern coastline to the Fly River, and at four positions on the meridian passing through the middle of the mouth of the Bensbach River from the mouth of that river to the Fly River. It was agreed at the meeting that these astronomical positions were to be based on mean values derived from independent observations by Australian and Indonesian survey parties.

At the second meeting of the authorities, held at Canberra in May 1966, it was agreed that the demarcation of the border required first the survey of the meridians and secondly the approval of both Governments for the establishment of each permanent border landmark.

At the third meeting of the authorities, held in Djakarta in January and February 1967, it was agreed that the geodetics connecting the meridian markers should be located photogrammetrically and marked as accurately as possible on air photographs, on the express understanding that this was only a preliminary location that would not prejudice subsequent marking on the ground.

At this third meeting it was also agreed that the survey authorities should meet again for the purpose of agreeing on a final report to the Governments concerned setting out the results of the joint survey of the meridians.

After exchanging correspondence and meeting at Canberra on 12 February 1970, the leaders of the Australian and Indonesian survey teams jointly reported to the Governments of Australia and Indonesia that:

(*a*) Joint surveys had been completed and copies of observation records and computations exchanged in respect of, and marks established for, mutually accepted positions of the meridians at the following locations:

Station No	*Latitude (south)*	*Longitude (east)*
1	2° 35′ 39″	141° 0′ 0″
2	2° 40′ 42″	141° 0′ 0″
3	3° 01′ 27″	141° 0′ 0″
4	3° 14′ 02″	141° 0′ 0″
5	3° 55′ 22″	141° 0′ 0″
6	4° 08′ 41″	141° 0′ 0″
7	4° 54′ 54″	141° 0′ 0″
8	5° 38′ 33″	141° 0′ 0″
9	5° 52′ 39″	141° 0′ 0″
10	6° 19′ 32″	141° 0′ 0″
11	6° 53′ 27″	141° 01′ 10″
12	7° 49′ 19″	141° 01′ 10″
13	8° 25′ 45″	141° 01′ 10″
14	9° 07′ 37″	141° 01′ 10″

[1] The original text of this paper appeared as document E/CONF. 57/L.118.

(*b*) The geodetics connecting the meridian markers along the border from the north coast to the first intersection of the Fly River (MM1–MM10), and from the second intersection of the above river to the south coast (MM11–MM14) had been independently determined on air photographs by the Australian and by the Indonesian survey authorities, and that the mean positions between the two determinations had been adopted as the approximate location of the respective meridians and also marked on the air photographs;

(*c*) Two complete sets of copies of these photographs had been signed and each had retained one set;

(*d*) The country through which the meridians pass is described in the annex to this report; it would be seen that for the most part there were few or no inhabitants, but that there were sizable settlements near to or straddling the border in the following sections:

MM4 to MM5: 76 km, from Waris to the Hauser River;

MM7 to MM8: 80 km, from the Star Mountains to Ingembit;

MM8 to MM9: 27 km, from Ingembit to Woran.

It was further reported that at the meetings of the survey authorities and during the field operations the parties cooperated fully. The Governments were to be especially commended for the determination and professional skill shown by the survey parties of both countries in expeditiously carrying out the required astronomical observations and related surveys under extremely difficult conditions of terrain, climate and accessibility.

Annex

DESCRIPTION OF COUNTRY CROSSED BY MERIDIANS

MM1–MM10

141° east meridian from the northern coast to the Fly River

Section	*Description*
MM1–MM2 from the northern coast to the Moso River (9 km)	This section of the meridian begins at the northern coast and crosses the Bougainville Mountains, rising steeply from the sea at Wutung to some 1,000 m and down almost to sea level again at the Moso River. There are no inhabitants in this section.
MM2–MM3 from the Moso River to the Bewani River (39 km)	The meridian crosses the Ijapo Mountains, passing a few hundred m east of Kapou (village); it then crosses the Kohari Hills and runs over 10 km of swamp to the Bewani River. The Kohari Hills consist of very rough limestone with numerous craters. The small village of Kapou and the village of Sekotchiau on the Bewani River, near the meridian post, are the only inhabited zones except for a few houses in the swamp, 6 km north of MM3.
MM3–MM4 from the Bewani River to Waris (23 km)	The meridian crosses the Bewani Mountains, which rise up to 1,500 m from the river and fall abruptly at Waris. The mountains are heavily timbered and difficult of access, although there are some paths in them. This section is uninhabited.
MM4–MM5 from Waris to the Hauser River (77 km)	The meridian passes near many villages, which extend some 12 km south of Waris through an undulating forest with garden areas. It then passes through 30 km of undulating, almost uninhabited forest towards the border mountains. Some paths cross the meridian, which then crosses over 25 km of the border mountains consisting of limestone peaks. There are small settlements along the tributaries and some larger villages on the northern side of the mountains. The meridian then crosses 10 km of flat forests to the Hauser River.
MM5–MM6 from the Hauser River to the Sepik River (25 km)	The meridian passes through flat forested country which becomes swampland as it approaches the Sepik River. This section is uninhabited.
MM6–MM7 from the Sepik River to the Star Mountains (85 km)	The meridian passes through a swampy area of approximately 50 km, crosses the Sepik River and then climbs the Star Mountains. This section is practically uninhabited.
MM7–MM8 from the Star Mountains to Ingembit (81 km)	The meridian crosses the Star Mountains and then passes through broken, sharply ridged foot-hills to Ingembit, where point MM8 is located, in the middle of the village. There are a few small settlements in the Kauwol valley, 30 km south of point MM8, and at Kugo, 10 km further south (1 km west of the meridian). There are many villages near the meridian, in the section extending 30 km north of Ingembit.
MM8–MM9 from Ingembit to Jat (26 km)	The meridian passes through undulating, heavily forested terrain. There are several villages near the meridian, including Opka, a fairly large village located 0.5 km east of the meridian and 6 km south of Ingembit.
MM9–MM10 from Jat to the Fly River (50 km)	The meridian passes through heavily forested terrain and the only inhabited site is Angamarut, on the Fly River, 0.5 km to the east.

MM11–MM14

141° 1′ 10″ east meridian from Fly River to the southern coast

Section	*Description*
MM11–MM12 from the Fly River to the Waiwai River (102 km)	This meridian crosses swamplands in the northern part and then passes through Lake Gab-Gab over 13 km. This section is uninhabited, but there are paths in several places.
MM12–MM13 from the Waiwai River to Sotar (68 km)	The meridian passes through flat, lightly forested terrain. A vehicular road runs south-west from Sotar (just west of the meridian) to Merauke, and south-east to Wereave. Sotar is the only inhabited spot near this section.
MM13–MM14 from Sotar to the south coast (77 km)	The area crossed by the meridian is flat and lightly forested, becoming more swampy near the river, but elsewhere vehicles may travel through it in the dry season. This section of the meridian ends in the middle of the mouth of the Bensbach River. It is uninhabited, but one or two paths cross through it.

CARTOGRAPHIC ACTIVITIES IN THE FEDERAL REPUBLIC OF GERMANY SINCE MARCH 1967

Paper presented by the Federal Republic of Germany[1]

At former United Nations cartographic conferences for Asia and the Far East, it was shown how surveying and mapping in the Federal Republic of Germany had been decentralized especially with respect to the practical aspects of the geodetic work and cadastral surveys. High population density, industrialization and the intensive use of land had made this decentralization necessary. The practical tasks have been delegated to the lower levels of administration. In particular branches of surveying, e.g. reallotment, traffic and water supply, special authorities have been established.

In developing countries, on the other hand, topographic work and cadastral surveys are more centralized. As these countries develop further and strengthen their infrastructures, they will decentralize these operations.

In recent years institutes for education and research have developed considerably, and it is hoped that they will develop further in the future within the framework of the Federal Republic's training programme. Surveyors are trained exclusively in special schools that are no longer governed by the central authorities.

Our usual practice is to start with large-scale surveys that are then reduced to a smaller scale. However, we should start with the detailed surveys which are now frequently used in the Federal Republic. We obviously need many large-scale maps of the entire country for several kinds of work above or under ground (agriculture, water supply, traffic and other public services). To this end the current cadastral maps should be revised and renewed. The topographic base map at scale 1:5,000 is produced mainly by photogrammetry. Automation plays a major role in the accelerated production of maps and registers. Our aim is the creation of a data-processing chain starting with surveying, continuing with the calculation of co-ordinates and areas and ending with the automatic plotting of maps and preparation of registers. The data-processing chain has been used extensively in detailed surveys, especially for producing larger-scale maps and preparing cadastral registers. This result has been achieved essentially by the development of instruments combining theodolites and electronic distance-measuring devices.

However, this cadastral work can also be used for other purposes such as payment of taxes, inventory of property, planning statistics and topography. All countries that have started to prepare large-scale maps are therefore urged to proceed in the same way. The production of orthophoto maps is very important for an integrated cadastral system. It should be noted that the geodetic points of lower order are determined mainly by aerotriangulation, for which analytical methods are now preferred. An essential part of current research work therefore has to do with problems of aerotriangulation, especially those of block triangulation with many models in which computers are involved.

With regard to detailed surveys the Federal Republic operates on the principle that all surveying work should be related to the framework of points that have already been fixed. The Government is therefore very much interested in maintaining and renewing the existing net of triangulation and height.

The Federal Republic has also attempted to show that it is possible to prepare a cadastral register economically. This work is especially important for countries that intend to set up a cadastre.

The Federal Republic's topographic map at scale 1:25,000 is based upon the 1:5,000 scale map. Our other topographic maps at scales 1:50,000, 1:100,000 and 1:200,000, and the International Map of the World on the Millionth Scale are examples of a close scale sequence. Studies of instruments and tests of automatic equipment have been conducted with a view to revising and preparing these maps automatically later. This is a very important problem, which must be solved if the revised maps are to be accurate.

The Federal Republic's first-order triangulation network has been completed and extended by resumption of observations in several stations. Angular instruments and microwave and electro-optical distance measuring devices have been successfully used for these observations. Additional Laplace azimuths have been observed in order to improve the orientation of the first-order triangulation network. Several astrogeodetic plumb-line deflections have been determined to establish a new definition of the geoid within the Federal Republic. By order of the president of the permanent international commission for the readjustment of the European primary triangulation

[1] The original text of this paper appeared as document E/CONF. 57/L.119.

network, the West German part of the European triangulation net has been readjusted and the most recent observations have been taken into account. For this adjustment all observations have been projected exactly from the Bomford geoid to the surface used as a computation basis, namely, the international ellipsoid.

Several gravimetric measurements have made it possible to connect former measurements to the European milligal. The West German gravimetric map has been prepared on that basis.

The tide forecast service has been continued. Greater accuracy of observations has been obtained by recording with two gravimeters equipped with electric springs.

For several years both divisions of the *Deutsches Geodatisches Forschungsinstitut* (German Geodetic Research Institute) and some technical university institutes have contributed to international projects of satellite geodesy. Six stations are participating in the observations of the western European satellite triangulation net. In this connexion, observation groups of the *Deutsches Geodatisches Forschungsinstitut* have also made observations from the Norwegian stations of Tromsö and Spitzbergen. One of the two computing centres in which the adjustment of the western European satellite triangulation net will be made has been established in the Federal Republic.

Moreover, two observation groups of the *Deutsches Geodatisches Forschungsinstitut* are collaborating with the United States Coast and Geodetic Survey. Several German organizations are also participating in other work, for example, the observations of the Geos and Isagex projects.

CARTOGRAPHIC ACTIVITIES IN AUSTRIA

Paper presented by Austria[1]

Introduction

Austria has a population of 7.5 million and an area of 80,000 km^2, one third of which is extremely mountainous. One third of the inhabitants live in and around Vienna, which was once the capital of a much bigger country, the Austro-Hungarian monarchy. The remainder of the inhabitants live in smaller towns and villages, well distributed over the eight provinces (Vienna is the ninth).

Distribution of cartographic activities

Cartographic work in Austria is carried out by approximately 750 engineers with a university diploma in surveying and by an appropriate number of trained technicians divided into three groups of about the same size.

The Federal Office for Standards and Surveying employs 250 engineers. The main office is in Vienna, and there are ninety branch offices throughout the country (ninety surveying districts). The address is Bundesamt Fuer Eich- und Vermessungswesen, Friedrich Schmidtplatz 3, A-1080 Vienna, Austria.

Another 250 engineers work in 200 private cartographic and surveying companies; the largest has about 200 employees and the smallest only one. The addresses of two cartographic institutes are (*a*) Freytag-Berndt und Artaria, Schottenfeldgasse 62, A-1070 Vienna, Austria; and (*b*) Eduard Hölzel Geographical Institute, Rüdengasse 11, A-1030 Vienna, Austria. The addresses of the surveying companies that co-operate for international activities may be obtained from the Federal Office for Standards and Surveying.

The remaining 250 engineers work in the universities or other schools, municipal or provincial surveying offices, agricultural reallotment offices, geology, forestry and last but not least, the civil engineering companies.

Federal Office for Standards and Surveying

The Triangulation Department maintains the geodetic network from the first to the fifth order. The first-order net will be readjusted as a whole as soon as the remaining 20 of 144 points have been reobserved. The first-order net is connected with those of the seven neighbouring countries thus forming a part of the European net. Recently a part of this net was reobserved and adjusted in order to serve as the European base line for the international world-satellite triangulation network. Another department and the ninety district offices are responsible for the sixth-order triangulation points. For the sixth-order points ("EP" standing for *Einschaltpunkt*), the mean-square error is ± 7 cm or smaller. Their distance apart is about 350 m. These points are established only if they are often needed for cadastral and/or engineering activities. In 10 years 35,000 km^2 will be covered by 350,000 of these points. Many of them have been aerotriangulated by using single-model methods and Wild A7 instruments. The photography is carried out with Wild RC8 15/23 survey cameras; the photoscale is 1:16,000 for two sets with 60 per cent sidelap and 1:8,000 for one set. The 1:16,000 photoscale gives well-checked results and mean-square errors of ± 10 cm. Transformations for the 1:8,000 models finally result in the specified ± 7 cm accuracy. The results are highly reliable. When photogrammetry is less economical, the EPs are surveyed by using Wild T2 theodolites and Wild DI10 infra-red distancers or similar equipment. All computations are carried out by electronic data processing; calculating machines are used for network preparation and computers are used for final adjustments.

The levelling departments maintain the level-line networks that cover the entire country. They are also responsible for the gravity measurements. Two networks are combined, the first- and second-order network and that for technical level lines.

The cadastral departments take care of the cadastral survey of the country, which was completed 100 years ago on the scales 1:2,880, 1:5,760, 1:1,440 and 1:720. Approximately 20 per cent of the country has been resurveyed

[1] The original text of this paper, prepared by P. Waldhäusl, University of Technology, Vienna, appeared as document E/CONF.57/L.120.

on the scales 1:2,000, 1:1,000 and 1:500, the scale of the survey depending on the importance and density of detail. Other parts of the old 1:2,880 cadastral maps have been and are going to be revised by photogrammetric methods using mainly Wild A8s and at 1:8,000 to 1:12,000 photoscales. Since the end of the last century, the ninety cadastral offices in their survey districts are responsible for updating the cadastral maps.

The departments for photogrammetry and topographic mapping will finish within the next three years the last of the 213 sheets of the Austrian map at 1:50,000 scale, which replaced the old series at 1:25,000 scale and the provisional map series at 1:50,000 scale, which was just an enlargement of the old 1:75,000 scale series of the former Austro-Hungarian monarchy. The 1:25,000 scale series has been cancelled. Because of today's advanced techniques, the new series at 1:50,000 scale contains more and better information than the old 1:25,000 scale series; besides, the capacity of the Federal Office is too small for updating both series. The 1:50,000 scale series was produced with an original plotting scale of 1:10,000; these 1:10,000 scale originals, drawn only in pencil, are in the archives and are available for any technical planning when needed.

The cartographic and reproduction departments are responsible for the production of the new Austrian maps, of the geological and other thematic maps and of maps derived from the 1:200,000 scale series, as well as for their periodical revision. For some very important areas, such as the surroundings of Innsbruck, where the Olympic games took place in 1964, 1:25,000 scale maps have been issued.

Private Cartographic Institutes and Survey Companies

Freytag-Berndt und Artaria issues well updated tourist maps at 1:100,000 scale, which are based on the Austrian map at 1:50,000 scale. The institute also produces series at 1:200,000 scale (Austria), 1:300,000 scale (Austria and northern Italy), 1:600,000 scale (Switzerland, Austria, Czechoslovakia, Hungary, Romania, Bulgaria, Greece, Albania), 1:2,000,000 scale (Europe, North Africa, the Near East and the Middle East up to western Iran) and atlases. Freytag-Berndt also works all over the world as a contractor for cartography. The Kuwait geological map is one example of its activities in the Middle East. Hölzel produces road maps, town plans and atlases. Both of these cartographic institutes co-operate closely with the surveying companies.

Approximately 250 surveying engineers conduct private enterprises as consulting engineers for surveying and handle detailed cadastral surveys and road and civil engineering surveys; they also work in all fields of photogrammetry. For the latter purpose three joint-venture groups have been formed, each comprising a few companies. These groups co-operate when necessary with the Federal Office, the cartographic institutes and the technical universities to do the photogrammetric work.

Other public offices and large civil engineering companies

The last third of the Austrian surveying experts works partly in municipal surveying offices to help the city administration in the production of large-scale maps, and organizes most of the surveys for the civil engineering projects in their area of competence. Other surveyors work for the big power plants in the Alps and along the rivers. An important group co-operates in the tasks of reallotment with the provincial authorities for land consolidation.

The provinces of the Tyrol, Upper Austria, Vienna and Styria each have a Wild A7 instrument for their regional and special planning and mapping purposes.

The Federal Office for the Conservation of Monuments (Bundesdenkmalamt) runs its own photogrammetric department with two Zeiss plotters (Planimat and Terragraph).

Universities of Technology

The University of Technology, Vienna, comprises four institutes: cadastral survey and triangulation, general surveying, photogrammetry, astronomy and earth surveying. Twenty-five students graduate every year as surveying engineers. The photogrammetric institute co-operated with the United Nations Development Programme (UNDP) to help set up the Saudi Arabian national mapping programme.

Together with the other members of the European Organization for Experimental Photogrammetric Research (OEEPE, commission E), the institute undertook basic research for the topographic interpretation of detail at various scales. The results will be published soon and may also be of interest for developing countries.

The University of Technology, Graz, also comprises four institutes dealing with the same subjects and graduates about ten students per year. The photogrammetric institute now undertakes basic research on radargrammetry and two-media photogrammetry and will issue the photogrammetric volumes of the new Jordan–Eggert–Kneissl manual of surveying.

The technological universities and the universities of Innsbruck and Vienna also train architects, mechanical engineers, civil engineers and geographers in the various fields of surveying and cartography, including photogrammetry and all reproduction methods. Austria trains enough surveying engineers for itself and trains some for other countries. Students from Norway, Germany, Greece, Egypt and Iran are now attending Austrian universities, which are open to students of all nations.

CARTOGRAPHIC ACTIVITIES IN SAUDI ARABIA, 1967–1970

Paper presented by Saudi Arabia[1]

Several organizations are contributing to the surveying and mapping activities of Saudi Arabia. The Aerial Survey Department, Ministry of Petroleum and Mineral Resources, was recently established to act as a central survey and mapping organization for the country. It is mainly responsible for co-ordination, planning and execution of the national geodetic net and national topographic mapping.

Considerable progress has been achieved in some aspects of cartographic work since the Fifth Conference. It can be summed up as follows.

GEODETIC NET

During the period under report, a national geodetic net (NGN) was established. The net consists primarily of precise levelling and traversing. A flare-triangulation net is expected to be completed shortly.

The spirit-levelling net totals about 15,000 km and comprises eighteen loops. The average length of a loop is 600 km. The average distance between two consecutive bench-marks is 6 km. Nearly 2,000 km of the spirit-levelling net are of first-order accuracy, along a line that crosses the country from west to east. The remaining 3,000 km are of second-order accuracy.

The accuracy of the net is as follows:

$$3 \text{ mm } \sqrt{K'} \text{ for the first order}$$
$$8 \text{ mm } \sqrt{K'} \text{ for the second order}$$

where K' is the distance in kilometres.

Gravimetric measurements are carried out along the first-order line. However, orthometric correction for the second-order lines are included as a function of the latitude.

A traverse net of about 14,500 km has been established parallel to the levelling net. Electronic distance measurements are carried out at average distances of 18 km. Each lap is measured eight times; the horizontal angles are measured at each station, together with the vertical angles.

For azimuth orientation, astro-observations are carried out every 80 km, on the average. For azimuth adjustment of the net, junction figures have also been established at each junction point of the net. The accuracy between two points of the net is:

$$1:1{,}000{,}000 = \sqrt{\frac{K}{30}}$$

where K is the distance in km.

Flare triangulation. Although the standard of the traverse net is rather high, it is expected that a flare-triangulation net will be carried out at fifty stations distributed all over the country, at average distances of 250 km. The flare triangulation will be scaled relative to five base lines that are already completed. The total length of the base lines is 1,000 km.

TOPOGRAPHIC MAPPING

In 1968 the Government revised the national topographic mapping programme to meet the growing requirements of the country. About 2,000,000 km² of Saudi Arabia had to be mapped at either 1:50,000 or 1:100,000 depending on the needs of the users. The "Empty Quarter" will be mapped at 1:250,000.

A superwide-angle camera is used (except where inapplicable) at an average photo scale of 1:80,000. An area of about 200,000 km² has already been photographed (in addition to the complete coverage of the country at 1:60,000. It is expected that over 170,000 km² will be completed by the end of the current photographic season.

In order to provide the required ground control for mapping, an APR net covering an area of about 100,000 km² was completed last year. The loops of the NGN are also subdivided into smaller loops suitable for block adjustment.

Orthophotomapping has been adopted (except where impractical). An area of about 17,000 km² has been mapped at 1:50,000. As the NGN and the APR projects are completed, it is expected that an area of some 400,000 km² will be mapped within the next three years.

The Saudi Arabian Government has approved the national topographic mapping programme, which will cost more than $US 25 million.

[1] The original text of this paper appeared as document E/CONF. 57/L.121.

CARTOGRAPHIC ACTIVITIES IN IRAQ

Paper presented by Iraq[1]

Detailed surveys in Iraq began in the 1930s, when the land settlement law was passed and its application required maps at various scales ranging from 1:1,000 for towns, cities and orchards to 1:20,000 or less for farms and uninhabited and sparsely populated areas.

Old surveys were of little use, and new surveys had to be undertaken in order to meet the economic, social and military requirements of the country. These new surveys must be up to date and their quality must be up to internationally recognized standards.

About 66 per cent of Iraq's territory was surveyed by the Survey Department, the main body responsible for preparing and issuing topographic and cadastral maps for all government offices.

AERIAL SURVEY

The taking of photographs for surveying and preparing topographic maps began in late 1952, when an area of

[1] The original text of this paper appeared as document E/CONF. 57/L.123.

32,000 km² in northern Iraq was mapped by a foreign company at 1:20,000 with 20 m contour intervals. This was followed by aerial surveys of limited areas for which irrigation and other projects had been planned.

The last aerial-survey operation was entrusted to a private foreign company which was to make maps for an area of 75,000 km² with 5 m contour intervals.

The aerial coverage comprised superwide-angle photographs at 1:50,000 and rectified mosaics at 1:10,000 covering an area of 10,000 km² in the southern part of the country. Maps were urgently needed for irrigation, drainage and other development projects.

This area was photographed at two scales simultaneously, the first at 1:35,000 with a wide-angle camera for mapping purposes, and the second at 1:60,000 with a superwide-angle camera for aerial-triangulation purposes.

In addition, aerial photographs at 1:50,000 were taken with a superwide-angle camera to cover the rest of the country. It may therefore be said that Iraq now has complete aerial photography coverage.

The main task of the Iraqi Survey Department and of its photogrammetric section at the present time is to fulfil the requirements of the new agrarian reform law, which was passed in June 1970 and which calls mainly for good, up-to-date topographic maps, in addition to the available controlled mosaic, for land distribution to farmers, irrigation and drainage projects, and other agricultural and industrial projects.

The Survey Department has therefore begun the work of plotting the line maps for the controlled mosaic area at the same scale of 1:10,000, and has completed the work for about 40 per cent of the area, or about 40,000 km². These plotted sheets have been sent to the field for final checking and completion.

Fifty per cent of this area has been previously levelled either by the spot-height interpolation method or by the direct field topographic method, with 50 cm or 1 m contour intervals.

For the rest of the area contours, some trials and experiments have been made by using the Wild A8 and A7 autographs to produce a map with 2 m contour intervals from the existing 1:35,000 aerial photographs after running some field level lines between several selected control points. Both the relative and absolute accuracies for the shaping of contour lines will be checked in the field.

In addition to the above-mentioned work, a large-scale mapping project for all cities in the country was started by the Survey Department in co-operation with the photography section of the Air Force command.

Detailed topographic maps at 1:500, 1:1,000 and 1:2,500 were prepared and supplied to the departments concerned.

Moreover, the Survey Department supplies other governmental organizations, such as the National Oil Company, the Soil and Land Reclamation Service and the National Mineral Company, with the data they need to enable them to prepare special maps for geology, soil and land use.

All the aerial surveys for large-scale maps, including aerial photography, are currently carried out entirely by Iraqi technicians.

Triangulation and levelling

A net of triangulation systems of first-, second- and third-order accuracies was established a long time ago throughout Iraq for surveying and other purposes.

Geodetic data were calculated in accordance with the least-square methods and were used to compile various maps on different conformal projections. These systems have been changed and the computed projection data have now been referred to the UTM system.

No major changes were made in the levelling system except for checking the zero level at "FAO" and some of the main levelling lines along the principal roads and rivers of the country.

Map draughting and printing

Modern maps at 1:100,000, 1:250,000 and 1:500,000 are under preparation for desert land having an area of 170,000 km². These maps are based on aerial photographs at the same scales. This work will be started very soon, along with the ground-control work for the same area needed for the ITC Jerie analogue computer method of block adjustment. The analytical aerial triangulation method will also be used. The Survey Department will use the electronic computers now available at Baghdad University and at the Ministry of Planning. The Department is also planning to introduce orthophotogrammetry in order to prepare the new and urgently needed maps.

New geodetic networks

Since the triangulation net and first-order level lines are too old now and many of their signs have been destroyed or their degree of precision varies, the Survey Department has decided to establish new first-order geodetic nets, together with the necessary base lines and Laplace-point determination for longitude and latitude.

Technical reports for these projects have been prepared and general and specific operations will be carried out in accordance with international standards.

Mapping

The Survey Department intends to prepare topographic maps for the entire country at 1:25,000 and 1:50,000 in line with the requirements of the country and the wishes of the United Nations.

CARTOGRAPHIC ACTIVITIES IN FINLAND

Paper presented by Finland[1]

Since Finland did not attend the four previous regional cartographic conferences for Asia and the Far East, it is not submitting a special report to the Conference for the period 1967–1970. It prefers instead to provide the representatives of Asian and Far Eastern countries with a summary of geodetic, photogrammetric and cartographic work in Finland.

In the past three to five years the need for and use of maps have definitely increased as a result of general development, and the maps have therefore had to be revised. To meet these demands, Finland has continued to carry out cartographic research, experiments and practical applications. For example, since automobile traffic has expanded because of longer vacations, Finland has thoroughly revised its road map and is producing more tourist maps.

MAPPING ORGANIZATIONS

Geodetic, photogrammetric and cartographic organizations may be divided as follows: (*a*) State services; (*b*) municipal services; and (*c*) private firms.

State services

Higher education is provided at the University of Helsinki and at the Technical University of Helsinki, which has a surveying department where geodesy, photogrammetry and cartography are taught. The Technical University is also engaged in intensive research in geodesy and photogrammetry. The photogrammetric research is particularly important since Finland does not have a regular photogrammetric research institute. Surveyors are trained in four technical schools, which offer a three-year course in geodesy, photogrammetry and cartography. The Finnish Institute for Technical Research employs in its cadastral research laboratory three research officers, one of whom is a specialist in cadastral mapping. The main scientific organization for geodesy is the Finnish Geodetic Institute. The Institute has conducted several special survey operations abroad, in addition to high-precision scientific and practical work in Finland.

With regard to practical work, the Board of Navigation and the National Board of Public Roads and Waterways have special units that carry out mapping operations within their province. Most of the geodetic, photogrammetric and cartographic work, however, is carried out by special State survey units, the Survey of Finland and the Army Map Service. The Army Map Service concentrates its operations in the northern part of the country and includes a well equipped geodetic, photogrammetric and mapping division. The basic high-precision work is carried out by the Geodetic Institute, whereas most of the practical geodetic, photogrammetric and cartographic work is performed by the Survey of Finland. The Survey is responsible to the National Board of Survey, which comprises the following main divisions: geodesy, photogrammetry, town planning survey, topography, cartography and land distribution. The Survey has also field offices—a Provincial Survey Office in each province and a District Survey Office in each municipality or group of municipalities. The Geodetic Division is responsible for extending the geodetic and levelling nets and for inspecting this work when it is carried out by private or other firms. In addition to aerial photography and photomap compilation the Photogrammetric Division is responsible for aerotriangulation to prepare the basic map and large-scale maps. The Topographic Division undertakes the field work and stereoplotting for the basic map. The Cartographic Division compiles small-scale maps by using the basic map at 1:20,000 and attends to the fair drawing of maps at various scales. The maps are printed and sold by the Map Printing Service of the National Board of Survey. The Town Planning Survey Division extends geodetic and levelling nets for the mapping at scales ranging from 1:500 to 1:4,000 of municipalities and other limited areas. The Cadastral Division and the provincial and district offices are responsible for extending the control nets and for mapping of areas closely related to their operations.

Many other State services need and use various maps and measurements. In most cases they rely on the facilities provided by the Survey of Finland.

Special mention should be made of Professor Yrjö Väisälä of Turku University and member of the Academy of Sciences, who invented the Väisälä light interference method of measuring base lines and the stellar triangulation method for measuring more accurately the national triangulation networks.

Municipal services

Municipalities in Finland comprise two main groups: cities and boroughs and rural communes. The first group numbers seventy-eight municipalities, sixty of which have a surveying department employing one or more "city surveyors". In the remaining eighteen municipalities the survey work is carried out by part-time officials; most of them are employees of the Survey of Finland. The cities and boroughs also employ private companies to do this work. There are 440 rural communes in Finland, and their survey work is done mainly by the Survey of Finland or by private firms. Only ten rural communes have a land surveyor doing geodetic and planning work. The survey work carried out by outside specialists for the communes is supervised and inspected by the Geodetic Division of the National Board of Survey. The municipal maps are usually at scales ranging from 1:500 to 1:2,000.

Private firms

There are several private surveying firms that have a wide variety of instruments at their disposal, including distance-measuring devices, photogrammetric plotters and an orthoprojector. They offer their services to the State authorities, cities, boroughs and rural communes, as well as to industry. The private firms have also exported their know-how to many European, Asian and African countries and have carried out work in aerial photography, plotting, levelling and geodetic measurements.

Equipment

There are in Finland about fifty electronic or electro-optical distance-measuring devices, including Distomats, various kinds of tellurometers and geodimeters. For photogrammetric point measurements there are two stereocomparators, four first-order plotters and about fifty

[1] The original text of this paper appeared as document E/CONF. 57/L.125.

second- or lower-order plotters. Data-processing techniques are applied at every stage of the computations relating to geodesy and photogrammetry.

Some details about surveys are given below, mainly with regard to the work carried out by the Geodetic Institute and the Survey of Finland.

Geodesy, aerial photography, photogrammetry

The high-precision geodetic network established by the Geodetic Institute consists of 291 points, 198 of which are Laplace points and the rest deflection points. The scale has been determined by sixteen base lines. The net consists of single chains, except for the southernmost double chain. The three standard directional errors are as follows: (*a*) $\pm 0.305''$ (from the direction residuals); (*b*) $\pm 0.295''$ (from the astronomical residuals); and (*c*) $\pm 0.289''$ (from the residuals of extended sides). The residuals correspond to a relative standard error of about ± 1.5 ppm.

The high-precision geodetic network is extended by the Survey of Finland and, in Lapland, by the Army Map Service. The lower-order triangulations can be subdivided as follows: (*a*) first-order triangulation; (*b*) second-order triangulation; and (*c*) third-order triangulation. In the first-order triangulation all the angles and distances are measured. In the second-order triangulation net, which consists of ten to thirty stations, most of the angles and distances are measured. The density resulting from these three categories of triangulation is 1 point per 100 km^2. Three more points per 100 km^2 are determined by third-order triangulation. These third-order points do not usually form nets; they are resection points (angular observations on the third-order points only). The three-point distances are usually measured with the tellurometer or geodimeter.

The geodetic network described above forms the basis for local geodetic surveys carried out by the city surveyors, town-planning officials, cadastral surveyors and private firms.

The Geodetic Institute has recently started to measure a triangulation net consisting of fifteen stations (with 200 km sides on the average) by the stellar triangulation method. A special report on this method, prepared by Mr. T. J. Kukkamaki, Director of the Geodetic Institute, has been submitted to the Conference.

The density of the vertical network is such that level lines are from 5 to 10 km apart. The levelling comprises high-precision levelling and basic levelling, which is subdivided into first-order levelling, second-order levelling and third-order levelling. The total length of the level lines amounts to about 61,000 km, 40,000 km of which represents third-order levelling. The standard deviations are as follows:

High-precision levelling:	± 0.33 mm/km (back and forth levelling) ± 0.64 mm/km (after adjustment)
First-order levelling:	Slightly better than ± 1 mm/km
Second-order levelling:	± 1 mm/km (back and forth levelling; slightly higher after adjustment)
Third-order levelling:	± 5 mm/km (after adjustment)

With regard to aerial photography, the entire country is covered by photos at scales ranging from 1:22,000 to 1:60,000. For densely built-up areas the photos are at scales ranging from 1:3,000 to 1:15,000. New photos are taken every summer to meet the requirements of new large-scale mapping projects and to bring the topographic maps up to date.

The control network established by field triangulation is extended by aerial triangulation since the density of the basic map at 1:20,000 must be about 150 points per 100 km^2. Basic mapping had for a long time been the only area of application for aerial triangulation, but in recent years, following the introduction of analytical methods, aerial triangulation is being used more frequently to extend the control networks for town-planning maps, road-planning maps, and the like.

Analytical triangulation with its precise least-squares adjustment has opened up new possibilities for photogrammetric point measuring. The Finnish method, based on Mr. R. A. Hirvonen's formulas, is programmed for Elliot 503 and IBM 360/60 computers, for example. Up to 100 pictures can be adjusted simultaneously. As to accuracy, when only the geodetic points are beaconed and the other points are natural details, a point accuracy of 7 to 10 microns (on the photo scale) can be achieved. If all the points are beaconed, as usually happens with large-scale mapping, the accuracy has been as high as 4 to 6 microns.

In this connexion it should be emphasized that high-quality cameras are essential if the analytical triangulation is to be accurate. They must be checked twice a year, before and after the flight. There are two test fields in Finland for this purpose.

Cartography

General topographic maps

There are three series at various scales—1:20,000, 1:100,000 and 1:400,000—each of which is intended to cover the entire country. The National Board of Survey is the agency responsible for the production of the topographic maps of Finland. Coverage of Finland at scale 1:20,000 requires about 3,700 maps; at the present rate of progress, the series should be completed by 1957. All the field surveys will be finished by 1973. So far 2,250 sheets have been published and work is under way on 1,040 additional sheets.

One important stage in the planning of the basic map at 1:10,000 to 1:20,000 was to determine what information users of maps wished to derive from mapping. In the various fields and professions the requirements vary as to the quality of the necessary information and the quantity and urgency of the regional maps.

The reconnaissance of the terrain and the drawing are carried out at 1:10,000 scale, and the maps are printed at 1:20,000 scale. Since the planimetric details, contour lines and cadastral boundaries are drawn on separate plates composed of dimensionally stable and transparent plastic cartographic sheets (the drawing area measuring 50×50 cm), the method offers a great variety of uses. As the fourth element of the map, in addition to the three drawings, is the negative of the photomosaics, different kinds of reproduction can already be obtained at 1:10,000 scale for different purposes (photoprint, photographic copy, plastic copy and printing) by combining the various elements. In addition, the 1:20,000 scale map makes it possible to use the separate-colour originals for the roads, the arable land and the hydrographic network.

The basic map is printed in six colours. The printed map is available either with or without the cadastral

boundaries, which are kept up to date by the provincial survey offices.

The contour lines of the basic map are drawn at 5 m (sometimes 2.5 m) intervals with Wild stereoplotters A8 and B8. Where extensive mapping is involved, stereoscopic photographs—the so-called triple photos—obtained by gluing together parts of three consecutive aerial photographs, have proved to be an admirable aid in reconnaissance of the terrain. Experience acquired in basic mapping shows that, as far as the forested areas of Finland, especially the horizontal forms of the slopes resulting from photogrammetric contouring, are concerned, control in the field is essential.

The strip-off and masking technique has speeded up the preparation in separate colours of the printing plates of the maps to be edited. This method is particularly effective for representing the hydrographic network of the Finnish archipelagos.

In the field of drawing techniques mention should be made of the progress achieved in map lettering. Use of the Morisawa and Diatype photocomposing machines has improved the quality of the lettering and made the work easier.

Special attention has been paid to collecting geographical names and establishing their correct spelling in order to standardize all names on the basic map and in the other map series. Cartography has an important role to play in the standardization of geographical names. As standardization progresses the new maps inform the public of the correct spelling of names as well as of the location and importance of the geographical elements that they represent, thus establishing them for general use.

The average output per year has ranged from 140 to 180 basic map sheets, each of which covers an area 10 × 10 km.

The topographic map at 1:20,000 substitutes the basic map for the sparsely populated northern parts of Finland. Production of these two series has been synchronized in order to complete them simultaneously. The final drawing is executed on plastic cartographic sheets at 1:20,000. Planimetric details and contour lines are drawn on separate sheets (50 × 50 cm). The drawing is executed according to the specifications set out for the basic map. The contour lines are drawn at 10 m (sometimes 5 m) intervals.

The topographic map at 1:100,000 is a modern map prepared simultaneously with the 1:20,000 maps. Each map sheet generally covers an area corresponding to twelve basic map sheets (30 × 40 km). By the end of September 1970 a total of 206 sheets had been issued. The map will comprise a total of 343 sheets.

The new general map of Finland at 1:400,000, comprising thirty-one sheets (120 × 160 km), was completed in 1966. Several sheets have already been revised since then. In addition, an atlas version of this map is being published containing eighty-four pages of maps and an alphabetical list of 8,000 geographical names (for example, the names of all post offices and railway stations).

Special maps

The road map of Finland, the largest-scale map of the series of road maps published by the National Board of Survey, was completely revised from 1964 to 1968. This map comprises eleven sheets at 1:200,000 and two sheets (northern Finland) at 1:400,000. This series is continuously kept up to date, and new editions of several sheets are published every year.

The road map for motorists, a tourist map at 1:750,000, comprises two sheets, one for southern Finland and one for northern Finland.

The general road map at 1:1,500,000 is primarily intended as a road map for general use. A revised edition of this map is issued every spring, at the beginning of the tourist season.

Maps are becoming more and more of a necessity for campers and outdoor enthusiasts. Excursion maps of various hiking areas are issued as fast as the basic map materials are available. These maps show hiking routes and areas, road signs and bicycle paths.

The Board of Navigation is responsible for hydrographic surveying at sea and for the preparation of sea charts. The main chart system consists of a series of coastal charts at 1:50,000, which form an unbroken girdle along the entire coastline. The corresponding maps of inland waterways are at scale 1:40,000. General charts of the Baltic Sea, the Gulf of Finland and the Gulf of Bothnia at 1:200,000 and 1:350,000 are also available.

The Geological Survey of Finland publishes the results of geological surveys in the form of rock maps and soil maps at 1:100,000 and 1:400,000. Field surveys are carried out with the help of base maps and topographic maps at 1:20,000.

The Agricultural Research Centre has published agro-geological soil maps at 1:20,000, comprising 113 sheets in all.

The aeronautical chart at 1:500,000 (ICAO) covering all of Finland on seven sheets has been completed. The most recent sheets were issued in 1965. The aeronautical chart at 1:1,000,000 was issued in 1964.

International co-operation

Finland is becoming increasingly interested in international development work and has made larger sums available for multilateral and bilateral assistance. On many occasions Finland has expressed its willingness to export its know-how in geodesy, photogrammetry and cartography to assist in the mapping of areas that are still uncharted.

CARTOGRAPHIC ACTIVITIES IN LEBANON

Paper presented by Lebanon[1]

The Directorate of Geographical Affairs in Beirut is the only department responsible for map-making.

GEODESY

Triangulation

The main chain of triangulation in Lebanon has been completed since 1926. Second-order triangulation has also been completed; current operations include fourth- and fifth-order networks and this is influenced by the absence of topographic maps for certain specified projects and areas.

Levelling

The level network for the whole country has already been completed for the first order, 75 per cent completion for the second order and 25 per cent completion for the third order.

We are re-establishing a new tide gauge station 20 km from Beirut.

PHOTOGRAMMETRY

Aerial photography

The whole country is covered by aerial photographs at a scale of 1:25,000, and this coverage has been used to establish our base map at 1:20,000. Large-scale photographs are also abundant and around 12.5 per cent of the country is photographed with scales ranging from 1:12,000 to 1:6,000.

Photogrammetric equipment

In the last three years we have bought two first-order instruments for plotting, a Presa 225 and stereometrograph E. This reflects the increase in demand for photogrammetric mapping.

Photogrammetric control

The necessary control for orienting stereograms is provided mainly by field surveys, and this is due to the mountainous nature of the terrain and to the very dense triangulation network which facilitates the field surveys.

MAP PRODUCTION

General series

The area of Lebanon is about 10,000 km^2, which is small when compared with other countries.

The national base map at 1:20,000 is already 95 per cent complete. It is hoped to complete the whole series within a year. The total number of sheets will be 126.

We are working on a new series at 1:10,000, which is mainly and basically for urban areas; so far only ten sheets have been completed.

The new series at 1:50,000 is now being compiled from the base map at 1:20,000 and is 80 per cent complete. The quality and accuracy of this map are very satisfactory and so the old series at 1:50,000 has been abandoned.

The small-scale map series has been completed and includes: six sheets at 1:100,000; one sheet at 1:200,000.

Special project mapping

A wide variety of different scales and types of mapping has been carried out in accordance with the demands of all developing projects.

During the last three years we have completed around 200 km^2 of mapping at 1:1,000 with 2 m contour interval. These maps were requested by the Urban Development Department.

A special map for the city of Beirut at 1:500 is now being undertaken and is about 70 per cent complete. This map is being produced by a strictly direct topographic method and has been commissioned by the municipality of Beirut.

Cadastral work

Aerial photography is obtained at 1:6,000 and this is enlarged to a scale of 1:1,000. These enlargements are taken to the field, where property boundaries are identified. Exact identification is not always applicable where the regions are mountainous, where there is relief displacement, and in forests and vegetation areas. These boundaries are stereoplotted by means of a first-order photogrammetric instrument at 1:1,000. The map is completed with the cadastral information.

This method was modified last year, and we are now using pre-marking as a basis for the topographic network.

In the last three years we have completed about 300 km^2 of cadastral mapping.

Toponymy

A catalogue of geographical names is now in the press. It lists each geographical name with its co-ordinates in Arabic script and phonetically in Roman letters.

TRAINING

Because of the increasing demand for all kinds and varieties of maps, a new school for topographical studies has been opened. Special programmes and courses are given for different grades of technicians and engineers.

The programme is as follows:

(*a*) Secondary technical course: preparing for the baccalaureate, first part—Technician aide; preparing for the baccalaureate, second part—Technician;

(*b*) Semi-university technical course: preparing for the degree of Senior Technician;

(*c*) Full university technical course: preparing for the degree of Geographical Engineer (five years of study after secondary school).

This programme is accomplished through joint co-operation with the IGN (Institut géographique national) in Paris. Finally, Lebanon would appreciate receiving students from abroad to participate in the programme.

[1] The original text of this paper appeared as document E/CONF. 57/L.126.

UNITED KINGDOM ACTIVITIES

Paper presented by the United Kingdom[1]

INTRODUCTION

This report is an account of the contribution to the surveying, mapping and charting of the countries and seas of Asia and the Far East made by United Kingdom Government agencies between October 1966 and the end of June 1970.

Land survey work has been carried out by the surveyors of the Directorate of Overseas Surveys (DOS) in co-operation with the Survey Departments of the British Solomon Islands Protectorate, the Gilbert and Ellice Islands, Malaysia, the New Hebrides and the Kingdom of Tonga. Military survey parties have worked similarly in Malaysia, Thailand and Singapore, and the Royal Air Force (RAF) has flown photography of East Malaysia and of the Maldive Islands.

Hydrographic surveys have been undertaken in the Malaysian and Persian Gulf areas in order to facilitate the safe passage of new deep-draught oil tankers, and additional surveys have been carried out in the Indian Ocean and in the Arabian Sea.

Further contoured topographical maps at 1:50,000 have been published for the British Solomon Islands, Fiji and Malaysia. A new 1:10,000/1:25,000 contoured series has been nearly completed of Hong Kong, and large-scale contoured maps have been published of Honiara (BSIP) and Kuching (Sarawak). Experimental photomaps have been prepared of Tongatapu and of selected reefs and atolls, and further work is being carried out in this field.

Training in cartography, photogrammetry, field survey, hydrography, and allied subjects has been provided in the United Kingdom under United Kingdom technical assistance schemes, for holders of United Nations and Colombo Plan fellowships, and for other officers nominated by their own Governments. Such trainees have come from Afghanistan, the British Solomon Islands, Brunei, Burma, Ceylon, Hong Kong, India, Jordan, Malaysia, Nepal and Pakistan. In addition, practical training in modern survey techniques has been provided for local surveyors by attachment to the DOS field parties in the Gilbert and Ellice Islands, in Malaysia and in Tonga.

TOPOGRAPHICAL SURVEY, AIR PHOTOGRAPHY AND MAPPING

Arabia

Field surveys by military parties to provide control for mapping took place along the southern coast of Arabia from the Strait of Bab el Mandeb east to 49° E and in the region of Salalah (54° E).

A tellurometer measurement was made across the Strait of Bab el Mandeb in 1966 in the hope that a repeat measurement in later years might provide evidence of continental drift.

Abu Dhabi/Dubai boundary

At the request of the rulers, an RE officer took part in the perambulation of the Abu Dhabi/Dubai boundary and its subsequent marking on air photomosaics.

Australia

In 1968 and 1970 a party of military surveyors from the United Kingdom visited Australia for six months each year to assist in making new control surveys.

British Solomon Islands Protectorate

The establishment of control for current 1:50,000 form-lined mapping of the group was almost completed in April 1967, and the DOS field party was then withdrawn. Their work had included the observation of control traverses and of astro-fixes on Ontong Java, on Vanikoro in the Santa Cruz group and on Rennell and Bellona Islands: the extension of tertiary control on the off-shore islands of San Cristobal and on Santa Isabel, and heighting in Santa Isabel, Kolombangara and New Georgia. The party returned for a short period in mid-1970 to complete additional control in San Cristobal, Santa Cruz and Choiseul. Form-lined maps at 1:50,000 (see Annex I) were completed and published of the Shortlands, Vella Lavella and New Georgia groups and part of Santa Isabel, and at the end of the period work was in hand on the rest of Santa Isabel and on Malaita. A contoured town plan of Honiara at 1:2,500 was plotted and published in twenty-two sheets.

Experimental photomaps were prepared from single air photographs of selected reefs and atolls in order to find out if this type of mapping would be of value in portraying features submerged under shallow water. The results are promising and further experiments are to be carried out.

A number of maps produced by the Lands and Surveys Department at 1:2,500, 1:50,000 and 1:150,000 were printed in the United Kingdom.

Fiji

Work continued on the contoured 1:50,000 series of the main islands: one sheet was published of Koro Island and one of Lomaiviti. A revised edition was produced of the layered 1:250,000 sheet covering Vanua Levu.

Gilbert and Ellice Islands

In 1967 air photography was flown by the Fiji Department of Lands and Surveys, and a DOS survey party arrived in the Gilberts to establish control for large-scale mapping required for cadastral purposes. The surveyors worked in Tarawa, Abaiang, Marakei and Maiana; at the end of the period, the first maps of Betio were in production.

A planimetric map of Christmas Island, based mainly on the RAF photography flown in 1957–1958, was produced and published in five colours. A small map of Tarawa Atoll was prepared to illustrate an official report on the socio-economic survey.

Hong Kong

Work continued on the dual-scale series of contoured maps at 1:10,000 and 1:25,000 during the period. Sixty-one out of sixty-two 1:10,000 sheets were published and eleven out of the twenty 1:25,000 sheets required to cover the whole territory.

[1] The original text of this paper appeared as document E/CONF. 57/L.129.

Malaysia

West Malaysia/Singapore

(See under Singapore below.)

West Malaysia/Thailand

Field work was undertaken in 1968 to make a first-order geodetic connexion across the frontier of Thailand and West Malaysia near the east coast. The work was carried out by surveyors from the two countries assisted by British military surveyors. The results were computed in the Geodetic Office of the Mapping and Charting Establishment (RE) in the United Kingdom and have since been published by the Survey Departments of Thailand and Malaysia.

East Malaysia

Royal Air Force squadrons continued to fly survey photographic coverage of East Malaysia; despite difficult weather conditions, coverage is now almost complete.

Throughout the period British survey parties, both civilian and military, continued to work in Sabah and Sarawak in co-operation with the Director of National Mapping, Malaysia, and the local directors of lands and surveys.

Field work was undertaken primarily to pre-mark survey stations for the new air photography and to establish plan and height control for the 1:50,000 contoured series of maps designed to cover the whole area. DOS parties worked in the east and north of Sabah in the Kudat, Sugut, Dent Peninsula and Lahad Datu mapping blocks, and they assisted local schemes by extending the framework control required for urgent cadastral surveys in certain areas. In central Sarawak they worked in the Pendan–Tubau, Kapit–Belaga and Kanowit–Mukah areas, and they also carried out tellurometer traversing in Sungai Krian to provide control for new settlement schemes.

In 1967 and 1968 military parties made a series of connexions between the DOS primary control near the coasts of Sarawak, Brunei and Sabah, and the military control further inland. Checks for scale and orientation were also observed, notably in Sabah. These surveys led to the adjustment of the primary geodetic control in East Malaysia and Brunei by the Geodetic Office MCE(RE) in consultation with DOS, and the report and results of this work were distributed in 1969.

Production continued of the 1:50,000 contoured maps of East Malaysia, and during 1970 the first sheets were produced to the new Malaysian specification. During the whole period eighty sheets were published by the British Directorate of Military Survey (DMS) and thirty-two sheets by DOS. The contoured 1:1,250 plan of Kuching was also completed by DOS with the publication of the final seventy-three sheets in the series.

Maldive Islands

In 1969 new photography for mapping purposes was flown by the RAF at 1:80,000 and 1:25,000.

New Hebrides

DOS field parties continued to work in the Condominium throughout the period. They ran tellurometer traverses in Espiritu Santo, Ambrym and Pentecost in order to provide framework control to link together earlier isolated surveys. They worked also in Maevo, Aoba and Malekula, but poor visibility due to volcanic activity limited the progress made on the longer inter-island lines.

Singapore

In 1967 the primary triangulation of Singapore and the tie to West Malaysia were re-observed by military surveyors. The results were computed in the Geodetic Office MCE(RE) and supplied to the chief surveyor of Singapore in 1970.

In 1969 a survey took place to establish height datums on off-shore islands in Singapore State. The work was much helped by the use of a British army hovercraft.

Assistance and technical advice were provided by DOS in the placing and execution of two contracts for air photography and large-scale mapping, which were financed from United Kingdom special aid to the Republic.

Thailand

See under West Malaysia/Thailand above.

Tonga

Medium- and large-scale photography was flown by the Fiji Lands and Surveys Department in 1968. After a preliminary reconnaissance a DOS survey party commenced work in the Kingdom in 1969: they are working with the Tonga Lands and Surveys Department to establish control for new contoured mapping that is urgently required.

An experimental photomap at 1:40,000 of Tongatapu was made from the new photography and circulated for user comment: a revised edition is to be published incorporating certain additional cultural information.

SATELLITE GEODESY

During the period 1966 to 1970 British military surveyors took part in two United States projects to establish networks of control points over the whole world.

Stations manned by British teams in the Pacific and the Far East were set up as follows:

SECOR on Gizo, British Solomon Islands; Hong Kong; Manus, Bismark Archipelago; and Maui, Hawaiian Islands;

BC4 on Maui; Thursday Island, north Australia; and Vila, New Hebrides.

Hydrographic surveys

Hydrographic operations by survey ships of the Royal Navy continued in Asian and Far Eastern waters during the past four years as detailed in annex II, and admiralty charts have been published as listed in annex III.

Emphasis has been mainly on surveys in the Malaysian and Persian Gulf areas—and in both cases these have been largely dictated by the requirements of the oil trade, which is being carried in tankers of increasingly deep draught.

H.M.S. *Dampier* was employed in East and West Malaysian waters for the first year of the period and the latter part of her final commission was taken up entirely with surveys in the Malacca Strait and around Singapore. She was withdrawn finally at the end of 1967 and returned to the United Kingdom to be paid off and scrapped after spending an unbroken period of 19 years in the Far East. *Dampier* was replaced by a new ocean survey ship, H.M.S. *Hydra*, but owing to important commitments in the Atlantic it was not possible to deploy her to continue the Malacca Strait survey until the end of 1969. Two years thus elapsed in Far Eastern waters without hydrographic work being done by the Royal Navy. However, *Hydra* is

now making good progress with a new survey which will facilitate safe passage for deep-draught tankers through the Malacca Strait.

Further assistance in this area has been provided by the sale of a survey ship to the Royal Malaysian Navy and the loan of an experienced hydrographic officer to command her and to initiate the establishment of a modern hydrographic organization in Malaysia.

Political developments in the Persian Gulf have provided an impetus to progress on outstanding survey work in the southern part of the Persian Gulf to meet the mounting requirements of the oil-tanker trade in concert with the development of new oil fields, ports and oil terminals in that area.

H.M.S. *Vidal* has worked there during the winter months for the past three years and will complete her final season next summer, before being withdrawn from service after a life of nearly 20 years. Her work during the 1969/1970 season was augmented by the support of two new coastal survey vessels, H.M.S. *Bulldog* and H.M.S. *Beagle*—the first time that this class of ship has been deployed on overseas surveys.

This unprecedented effort in the Persian Gulf has represented an appreciable strain on the United Kingdom's resources, particularly in view of the continued closure of the Suez Canal and the consequent long uneconomical passages round the Cape of Good Hope. Advantage has been taken of such passages, however, to carry out surveys in the Indian Ocean (Diego Garcia and the Maldive Islands) and in the Arabian Sea (Masira). Further work is intended in order to facilitate safe navigation through large areas of poorly charted water on the Seychelles Bank.

Aeronautical charts

Scale 1:1,000,000. Since the last conference production of the Royal Air Force Topographic Navigation Chart (TNC) series has stopped. The series is now being replaced by a modified Operational Navigation Chart (ONC) series, which is produced by the United States.

Scale 1:500,000. Production of the Royal Air Force Topographic Tactical Chart (TTC) series stopped after 1967. A new joint United States/United Kingdom series specification was developed based on a combination of the TTC specification with that of the United States Air Force Pilotage Chart series. Production of the new series, the Tactical Pilotage Chart (TPC) is shared jointly between the United States and the United Kingdom. The United Kingdom has produced twenty-three sheets of Asia and the Far East, covering parts of the eastern Mediterranean, Persian Gulf, West Pakistan, Thailand, Malaysia and Indonesia.

ICAO 1:100,000. Four sheets have been revised by the United Kingdom during the report period. These are East Malaysia (Sarawak) (two sheets), West Malaysia and Ducie Island.

Specialist (topical) maps

DOS continued to produce a variety of specialist maps both for overseas Governments and to illustrate the investigations undertaken by its Land Resources Division. The former are normally prepared from the author's draft material and the latter usually form an integral part of the Division's reports: many are supplied as unpublished working documents to the Governments concerned.

For overseas Governments

Geological maps were published for the British Solomon Islands and for Fiji.

For DOS Land Resources Division's reports

Maps were published to illustrate a report on coconut growing in Christmas Island, Gilbert and Ellice Islands. Resource data were plotted on 1:50,000 maps to support the land capability appraisal of the British Solomon Islands, and the land capability and forestry surveys of Fiji: work continues on maps to support the Solomon Islands and Fiji investigations and is in hand on those required for the recent forest inventory of Erromango carried out for the New Hebrides.

ANNEX I

Summary of maps of Asia and the Far East published by the Directorate of Overseas Surveys between October 1966 and June 1970

Scale	*Region*	*Type*	*Number of sheets*
British Solomon Islands Protectorate			
1:1,000,000		Wall map Revised edition	2
1:50,000	Shortlands	Form-lined	4
	Vella Lavella	Form-lined	2
	New Georgia	Form-lined	11
		Planimetric	1
	Santa Isabel	Form-lined	13
		Planimetric	1
1:2,500	Honiara	Contoured	22
1:1,000,000		Geological Revised edition (drawn in BSIP)	1
		TOTAL	57
Fiji			
1:250,000	Vanua Levu	Contoured/layered Revised edition	1
1:50,000	Lomaiviti group	Contoured	2
1:50,000	Viti Levu	Geological	5
		TOTAL	8

ANNEX I (*continued*)

Summary of maps of Asia and the Far East published by the Directorate of Overseas Surveys between October 1966 and June 1970

Scale	*Region*	*Type*	*Number of sheets*
Gilbert and Ellice Islands			
1:50,000	Christmas Island	Planimetric	1
1:25,000/1:50,000	Christmas Island	Specialist maps	10
	Tarawa Atoll	Small report map	1
			TOTAL 12
Hong Kong			
1:10,000	Whole Territory	Contoured	61
1:25,000	Whole Territory	Contoured	11
			TOTAL 72
Malaysia			
1:50,000	Sabah	Contoured	6
	Sarawak	Contoured	26
1:1,250	Kuching	Contoured	73
			TOTAL 105
Tonga			
1:40,000	Tongatapu	Experimental photomap	1

ANNEX II

Hydrographic surveys by H.M. Survey Ships in Asian and Far Eastern waters since October 1966

Region where survey was carried out	*Scale*	*Ship*	*Year*
Persian Gulf			
El Sharji to Jazirat Das	1:75,000	H.M.S. *Vidal*	1967
S approaches to Bahrein I	1:75,000	H.M.S. *Vidal*	1967
Ras Haujura to Ras Ghanadha	1:25,000	H.M.S. *Vidal*	1968–69
Al Hala to Um Shanab	1:50,000	H.M.S. *Vidal*	1968–69
NE approaches to Jazirat Das	1:50,000	H.M.S. *Vidal*	1968–69
NE approaches to Jazirat Halul	1:50,000	H.M.S. *Vidal*	1969
NE approaches to Zarqua	1:50,000	H.M.S. *Vidal*	1969–70
Outer approaches to Halul	1:50,000	H.M.S. *Vidal*	1970
Vicinity of Jazirat Bu Musa	1:50,000	H.M.S. *Vidal*	1969–70
Approaches to Khor al Ghanadha	1:25,000	H.M.S. *Vidal*	1970
Khor Ghanadha to Ras Ghantut	1:50,000	H.M.S. *Vidal*	1970
Jebajib Bay to Umm al Qaiwan	1:50,000	H.M.S. *Bulldog*	1969–70
Approaches to Umm al Qaiwan	1:25,000	H.M.S. *Bulldog*	1970
Approaches to Dubai	1:12,500	H.M.S. *Beagle*	1969–70
Mina Rashid to Ajman	1:25,000	H.M.S. *Beagle*	1969–70
Arabian Sea			
N approaches to Masira	1:20,000	H.M.S. *Bulldog* & H.M.S. *Beagle*	1970
Indian Ocean			
Diego Garcia	1:25,000	H.M.S. *Vidal*	1967
Addu Atoll-Gan Anchorage	1:10,000	H.M.S. *Vidal*	1967
East Malaysia			
Labuan-Victoria Harbour	1:12,500	H.M.S. *Dampier*	1966
Labuan-Bethune Head to Victoria	1:25,000	H.M.S. *Dampier*	1966
Approaches to Semporna	1:25,000	H.M.S. *Dampier*	1967
West Malaysia			
Malacca Strait:			
One-Fathom Bank Channel	1:75,000	H.M.S. *Dampier*	1967
South Sands to Raleigh Shoal	1:75,000	H.M.S. *Dampier*	1967
Fair Channel Bank	1:75,000	H.M.S. *Dampier*	1967
Parit Jawa to Tanjong Laboh	1:50,000	H.M.S. *Dampier*	1967
Selat Langkawi	1:25,000	H.M.S. *Dampier*	1967
One-Fathom Bank to Tanjong Kling	1:50,000	H.M.S. *Hydra*	1969–70
Singapore Strait:			
Tanjong Ayam to Horsburgh	1:50,000	H.M.S. *Dampier*	1967
Buffalo Rock	1:50,000	H.M.S. *Dampier*	1967

ANNEX III

British Admiralty Charts of Asian and Far Eastern waters published since October 1966

Chart No.	*Title*	*Scale*	*Date*
	Persian Gulf		
3786	Ad Dawhah Harbour and approaches	1:25,000	Nov. 1967
*3960	Approach to Bandar Mish' Ab	1:60,000	Dec. 1969
	Gulf of Oman		
3522	Approaches to Muscat and Mina al Fahl	1:100,000	Dec. 1967
2869	Muscat to Jazirat Fahl	1:25,000	
	Muscat and Matrah	1:10,000	Dec. 1967
	Indian Ocean		
5126 (3)	Routing chart—Indian Ocean (March)	1:13,880,000	Jan. 1970
5126 (4)	Routing chart—Indian Ocean (April)	1:13,880,000	Feb. 1970
	India, West Coast		
1488	Vada Mieya to Khanderi Island	1:300,000	Dec. 1967
1508	Vengurla to Jaigarh	1:300,000	Dec. 1967
1509	Coondapoor to Vengurla	1:300,000	Mar 1969
492	Marmagao and Panjim	1:30,000	Jan. 1967
1564	Tellicherry to Bhatkal	1:300,000	Mar. 1969
1565	Alleppey to Cannanore	1:300,000	Aug. 1969
	West Malaysia		
2152	Approaches to Port Swettenham	1:15,000	Feb. 1968
2153	Port Swettenham	1:7,500	Apr. 1967
	Singapore		
1995	Singapore Harbour—Eastern roads	1:12,000	Aug. 1967
2165	Western approaches to Singapore	1:27,500	Oct. 1969
	Gulf of Thailand		
2414	Singapore to Saigon and the Gulf of Thailand	1:1,500,000	Oct. 1967
	East Malaysia		
1686	Kunak and approaches	1:20,000	Feb. 1968
*947	Approaches to Victoria Harbour	1:25,000	
	Victoria Harbour	1:12,500	Nov. 1969
	Philippines		
*3558	Batangas	1:20,000	Jan. 1970
	Hong Kong		
1917	South-eastern approaches to Hong Kong	1:25,000	Jan 1968
1918	South-western approaches to Hong Kong	1:25,000	Aug 1969
3280	Western approaches to Hong Kong Harbour	1:12,500	Aug 1967
3632	North-western approaches to Hong Kong Harbour	1:12,500	Mar. 1968
1459	Hong Kong Harbour	1:6,000	Dec 1969
3279	Eastern approaches to Hong Kong Harbour	1:12,500	Jul. 1967
	Japan		
*3650	Irako Suido and approaches	1:50,000	Nov. 1968
*356	Yokkaichi ko and approaches	1:25,000	Apr. 1968
*3105	Chiba ko and approaches	1:30,000	Mar. 1968
1938	Oita ko	1:20,000	Nov. 1967
3153	Tokuyama-Kudamatsu ko and approaches	1:35,000	May 1968
3602	Ya Shima to Naka Shima and Hiroshima	1:75,000	Apr. 1967
3603	Ao Shima to Osaki Kami Shima	1:75,000	Apr. 1969
698	Himeji ko	1:20,000	
	Takamatsu ko	1:15,000	Oct. 1966
	USSR		
3041	Zaliv Amerika	1:25,000	Sep. 1967
2161	Port Aleksandrovsk—Sakhalinskiy and approaches	1:50,000	
	Reyd Aleksandrovskiy	1:25,000	Feb. 1968
954	Reyd Uglegorsk	1:25,000	
	Portovyy Punkt Shakhtersk	1:25,000	
	Port Kholmsk	1:25,000	
	Port Nevel'sk	1:25,000	Dec. 1967

* New-style (metric) chart.

CARTOGRAPHIC ACTIVITIES IN THE UNITED ARAB REPUBLIC*

Paper presented by the United Arab Republic[1]

GEODETIC TRIANGULATION

The new geodetic triangulation of the United Arab Republic consists of a system of chains of braced quadrilaterals covering a large area of the country. The average length of the sides is about 50 km, except over flat terrain where the length is about 15 km. The length of the bases ranges from 6 to 12 km, each base being measured with 24 m invar-standardized wires (the last standardization was undertaken in Paris in 1970).

Wild T4 theodolites are being used for astronomical observations, and Wild T3 instruments are used for horizontal and vertical angles; the horizontal angles are observed with eight arcs (except for base extensions, where the number is doubled) following the direction method.

Distances between successive bases measure from 200 to 250 km. Each block between one base and the next is adjusted by the method of least squares; the use of a high-speed electronic computer is being considered.

PRECISION LEVELLING

The new precision levelling, which was begun several years ago, consists of a set of closed circuits covering nearly the entire western desert and some lines in the eastern deserts. New observations are also being undertaken to check the levels of the old bench-marks established more than 30 years ago. The instruments used are mainly of the Ni 004 type levels and invar stabes graduated on both sides.

GRAVITY OBSERVATIONS

When the gravity work was resumed in 1960, ninety-six gravity stations were established in co-operation with the Geodetic Institute of Uppsala, Sweden, by using the Worden 362 gravimeter. These gravity stations were connected with the Helwan basic gravity station, which had been linked to the international datum at Potsdam. Connexions were also made with the first-order gravity net in Italy. A Bouguer anomaly map was completed for the Nile delta at 1:1,000,000. Work is in progress with a view to covering the entire country with gravity stations.

TOPOGRAPHIC MAPPING

The normal series of topographic maps of the United Arab Republic are at 1:25,000 and 1:100,000. An extensive programme of photogrammetric mapping at 1:50,000 is being undertaken to cover regions of special economic significance. This new type of map is of standard size (15′ × 15′), with contour line intervals of 1 m, increasing to 10 m in desert areas. New maps of Lake Nasser at 1:10,000, with 2.5 m contour interval, have been produced from aerial photographs. Traditional methods were used to produce special topographic maps, with spot heights to the nearest centimetre and 50 cm contour intervals, covering the new areas to be reclaimed and cultivated, which extend over about 1 million *feddans*. A tourist colour atlas of the country has been issued.

CADASTRAL MAPPING

The first cadastral survey was begun in 1897 and was carried out in several separate parts. When the main part of the geodetic triangulation was completed in 1914, it became possible to plan the cadastral survey as a single continuous system. A long-term plan was undertaken to revise the cadastral maps (at 1:1,000 and 1:2,500) as well as the town maps (at 1:500 and 1:5,000). Since 1967, engineering plans at 1:1,000 have been drawn up by a photogrammetric process for housing projects.

At present, research is being conducted on photogrammetric applications to cadastral mapping.

EDUCATION AND TRAINING

A centre for training the staff of the Survey Department in technical subjects was recently established. An institute for survey technicians was also set up. Students with a high-school certificate are admitted for a two-year programme that includes theoretical and practical training in geodetic control, photogrammetry, cadastral and topographic mapping and related subjects; graduates are granted a diploma.

* Now Egypt.

[1] The original text of this paper, prepared by I. M. Ganem, General Director, Survey Department, Cairo, appeared as document E/CONF.57/L.130.

SUMMARY OF CARTOGRAPHIC ACTIVITIES IN CYPRUS THROUGH THE AGES

Paper presented by Cyprus[1]

INTRODUCTION

This is the first time that Cyprus is participating in a United Nations Regional Cartographic Conference for Asia and the Far East. It is therefore considered expedient to give a brief account of past cartographic activities and of how they have led to the present situation. The Government of the Republic of Cyprus wishes to seize this opportunity to thank the Secretary-General of the United Nations for having invited them to participate in the present Conference. Because of the limited activity in Cyprus in the field of cartography, they may have little to contribute to it. However, there can be no doubt that the Conference will benefit Cyprus considerably.

Cyprus has been mapped several times by various peoples and on various scales during the last five centuries. An island in the eastern Mediterranean, Cyprus has an area of 3,572 square miles. From the viewpoint of general topography, it comprises two almost parallel mountain

[1] The original text of this paper, prepared by A. Christofi, Senior Land Survey Officer, Department of Lands and Surveys, Nicosia, appeared as document E/CONF.57/L.133.

ranges going from west to east and an almost flat plain extending between them from Morphou to Famagusta through Nicosia, the capital.

Although a number of cartographers attempted to map Cyprus from 1200 to 1878, no one had ever tried to triangulate the island as a prerequisite to mapping. The first known map of Cyprus that gives its latitude fairly correctly is that found in Ptolemy's *Geographia*, several manuscripts of which are available. The first Roman edition of this map was produced in 1478 and reproduced in 1490.

Other maps of Cyprus include those found in the Italian *Isolaria* by Bartolomeo Zamberti dalli Sonetti (1478–1485) and Benedetto Bordone (1528). Matheo Pagano issued a rare woodcut map of Cyprus in 1538, which followed Zamberti's map in shape and orientation. Battista Agnese, a famous portolan draughtsman, and G. F. Camocio, an engraver and map seller, both Venetian, also used Zamberti's map for later engravings on copper plates of the map of Cyprus produced from 1558 to 1575. Gerhard Mercator, the great mathematician and geographer, issued his famous world atlas from 1585 to 1595. Although he was criticized for assigning a wrong position to the island of Cyprus, historians who studied the various editions and specimens of his atlas discovered that the great man never published a map of Cyprus. Such a map appeared in the Latin edition of the atlas published in 1606 by Mercator's son-in-law, Jodocus Hondius, after the former's death in 1594.

During the Turkish occupation of Cyprus, from 1570 to 1878, cartographic work on the island appears to have been suspended except of course for the compilation of coastal charts. The records indicate that the first hydrographic survey work in Cyprus was undertaken in 1849 by Lord Lieutenant John T. Browne of the Royal Navy and by Captain Thomas Graves of H.M.S. *Volage*. The oldest of these charts is that of Limassol, which includes Cape Gata, at a scale of 1:26,960, with soundings in fathoms. It was published by the British Admiralty in London on 22 August 1878, about one month before the British occupation of Cyprus. During the same period the Royal Navy had also established several bench-marks on public buildings in the harbours and related them to the chart datum. Records also show that land transactions were recorded in a cadastre.

Kitchener's map

The first known accurate map of Cyprus, based on a trigonometrical survey and relatively well positioned on the globe, is that of Kitchener (1878–1883). More recent maps of the island differ only slightly from it in area, geographical position and orientation. These differences will be described later in greater detail and it may suffice here to say that the area of the island as computed from Kitchener's survey was 3,584 square miles, whereas more recent surveys set the area at 3,572 square miles.

Soon after the British occupation of Cyprus Lieutenant H. H. Kitchener of the Royal Engineers (later Lord Kitchener of Khartoum), undertook the first triangulation and survey of the island. The survey was ordered by the Secretary of State for the Colonies and the object was the production of a topographical map, at a scale of 1 inch to 1 mile, for administrative purposes.

Kitchener, assisted by another officer and a number of non-commissioned officers of the Royal Engineers, British Army, started the survey in September 1878. In February 1883, nearly four and one half years afterwards, he reported to the Chief Secretary that the triangulation and survey had been completed and that all the original material had been sent to Stanford's Geographical Establishment in London for publication. The map was published in 15 sheets, copies of which are still kept in the Department of Lands and Surveys in Nicosia. Although the map was not contoured, it was beautifully hachured, and the engraving and lithography by Stanford are excellent.

Fiscal and cadastral surveys

While the topographical survey was in progress, a law was passed in July 1880 providing for a fiscal survey. This commenced in 1883, following completion of the topographical survey. Grant, who succeeded Kitchener as Director of Surveys in 1884, was responsible for a resurvey of the island at the scale of four inches to one mile. It was a compass survey based on the triangulation points fixed from 1878 to 1882 and consequently was not sufficiently accurate to form a basis for land registration or even for fiscal purposes.

In 1904 the need was felt for a cadastral chain survey for the settlement of title in the Famagusta district. The survery was commenced in the south-eastern portion of Famagusta and was based on Kitchener's triangulation. The plotting of detail proceeded on the spot and no field notes relating to the plan could be traced. This survey, which was later called the "unsound survey", continued for about seven years over the plans of the Famagusta district. It has formed the basis for a general registration of land titles and is still used at present.

Early in 1909 a law came into force providing for the compulsory registration of title to all property in the island and for a general valuation for levying an immovable property tax. To meet these requirements, an accurate location of each holding and the determination of its shape and size was called for. The survey of the plains of Famagusta met these requirements, but it could not be extended to the uneven and hilly areas. Indeed the system referred to in the preceding paragraph broke down when the survey reached the hills of the northern range, which extends into the Karpas peninsula. Moreover, the scarcity of control in the area meant that a minor triangulation of the peninsula had to be undertaken in September 1911.

It would appear from a memorandum signed by Colonel H. M. Jackson in May 1909 on the nature of the survey required for registration of title and revaluation in Cyprus that he favoured a survey based on a sound triangulation and dense traverse control. He recommended that Captain Lyons, D.Sc., F.R.S., then Director-General of the Survey of Egypt, should be consulted on the question of control. It was on this recommendation that the Secretary of State asked Lyons to come to Cyprus and prepare a report. Lyons visited the island for just over two weeks in November 1911 and issued his report in 1912. His recommendations are still the basis of the cadastral survey to this day. Having decided that the best scale for a cadastral plan in the rural areas was 1:2,500 and in the urban areas 1:1,250 or larger, he proceeded to review the available net. He recommended that a new and more accurate triangulation should be undertaken. This was to replace Kitchener's triangulation (1878–1882), which he

found inadequate (*a*) because it was designed for topographical and not for cadastral mapping, and (*b*) because most of the points had been lost or destroyed between 1882 and 1912.

When Lyons came to Cyprus in 1911, the survey of the Famagusta district based on Kitchener's triangulation and carried out as explained above was still in progress. By that time the plains, which cover about half the area of the district, had been surveyed. There remained the hills to the north and the Karpas peninsula, where the method used could not be applied (*a*) because it was practically impossible to set out the cadastral grid on the ground over the hills and (*b*) because there was only one triangulation point in the whole of the Karpas. It was therefore decided that an independent minor triangulation in the Karpas was indispensable and it was commenced before Lyons came to Cyprus. It is not known what type of survey was then contemplated for the Karpas, but by the time the triangulation had been completed, Lyons' report was published and so his recommendations were implemented there first.

Once the Karpas triangulation was completed, the survey of the details was started, but accuracy was neglected owing to lack of time. The plans were drawn up at scale 1:2,500 for the rural areas and at scale 1:1,250 for the built-up areas and they still form the basis for registration of title to the present day. The survey of Famagusta district as a whole was completed in 1915.

As indicated, Lyons submitted his report in 1912, when the Karpas triangulation and survey were in progress. However, on the strength of his recommendations, a new island-wide primary triangulation was commenced so as to obtain a uniform planimetric control system for the cadastral survey of the rest of the island, in order to meet the requirements of the law mentioned earlier. The triangulation started in 1913 and lasted eighteen months, including the computations. On completion of the primary triangulation, it was broken down into third-order and fourth-order triangulations to facilitate the survey of the details.

After Famagusta and the Karpas, the survey of Kyrenia was undertaken on almost the same principles, i.e. at 1:2,500 scale for the rural areas and at 1:1,250 for the urban areas. However, on the basis of the experience acquired on the rate of progress of the chain survey, it was soon realized that the survey of the island could not be completed within twenty years as the law stipulated. The persons then in charge therefore resorted to a tacheometric plane-table survey at scale 1:5,000 for the rest of the rural areas of the island. By 1929, twenty years after the law first came into force, all properties were surveyed in one way or another and at some scale or other so that Cyprus was again covered by what is today known as a "cadastral survey".

For the purpose of the above-mentioned survey the island was divided into fifty-nine rectangular sheets, each comprising an area of 8×12 square miles. Each of these sheets was divided into sixty-four parts called cadastral maps, each covering an area of 1×1.5 square miles. The area of Cyprus thus computed is the reported area of 3,572 square miles mentioned earlier. The survey of Cyprus is drawn up on a Cassini projection, using Clarke's 1858 spheroid as reference. In 1928, on the recommendation of Brigadier Winterbotham, all cadastral maps were graphically and mechanically reduced in scale, and the 2 inches to 1 mile series of maps as well as the 0.25 inch Cyprus administration map and the 0.5 inch Cyprus motor map were produced. These maps were intended to replace Kitchener's map, which fell into disuse owing to lack of revision and which was clearly less accurate than the new maps.

Geographical position of Cyprus

In 1931, the British Navy survey ship H.M.S. *Ormonde* made astronomical observations at several triangulation stations in Cyprus. When the results obtained by the *Ormonde* were compared with the reported latitude and longitude of the same points, it was noted that Cyprus had been located about 1 minute of arc too far to the east and about 0.5 minute of arc south of its position in latitude, that is, about 6,000 ft too far east and 3,000 ft too far south. After endless arguments between the Director of Surveys and the British Admiralty's Hydrographic Department, it was agreed to adopt the *Ormonde's* values for longitude and leave the latitude unchanged. In order to avoid any shifting of the sheet lines of the cadastral survey, it was decided to subtract 1 minute of arc from the longitude of each triangulation point as well as from the point of origin. The new basic point of origin of the island's triangulation system is located at latitude 35° N and longitude 33° 19′ E. The *Ormonde*'s calculations were proved to be correct in 1944 and in 1954, when the British Army connected Cyprus trigonometrically to Syria and Turkey. The results of these connexions compared very favourably with those of the survey ship. Nevertheless, the triangulation of Cyprus has always raised doubts.

Aerial photography and topographic mapping

During the Second World War the Director of Military Surveys of the British Army undertook the preparation and production of a 1:50,000 scale topographic map of Cyprus in colour, based on the 2 inches to 1 mile series, revised in the field by plane-table methods and verified by aerial photography. The altitudes were obtained from aneroid barometer traverses, which were in turn connected to the trigonometric control already heighted. This provided vertical control for multiplex plotting and produced contours at 100 ft vertical intervals, the accuracy of which left much to be desired. The map was printed in colour to military specifications, and for a number of years its circulation was restricted. The map of the island was divided into sixteen sheets, each comprising an area of 16×24 square miles. In fact, each sheet contained four of the cadastral sheets of the survey of Cyprus as described above. The projection used was that of Cassini, and the reference spheroid was that of Clarke (1880).

In 1957, it was decided that the island should be remapped by means of aerial photographs at scales 1:25,000 and 1:10,000 for some areas. It was therefore necessary to have a homogeneous system of co-ordinated and heighted triangulation throughout the island, requiring a proper mathematical connexion of the 1911 independent triangulation of the Karpas peninsula with the 1913 primary triangulation of Cyprus. This operation was successfully carried out by the Department. However, the remapping was discontinued when Cyprus became independent in 1960, and only about one-eighth of the island had been covered. With the invention of the tellurometer, an electronic distance-measuring device, all the lines of the primary triangulation network were measured by using

such equipment between 1961 and 1962. The triangulation was readjusted by tellurometry and its scale accuracy is now considered to be better than 1:100,000.

Cyprus has been photographed from the air several times in the past twenty years. It was photographed in 1949 by the Royal Air Force at an approximate scale of 1:10,000; in 1957 and 1963, by Fairey Surveys Ltd. (England) at scales 1:25,000 and 1:10,000 respectively; in March and July 1968, again by the Royal Air Force, at scale 1:15,000; and finally in August and September 1970, by the Royal Air Force at scales 1:50,000 and 1:15,000 with the new Williamson F49 MK IV camera. The 1949 photographs had become obsolete and were abandoned. The 1957 photographs were used for the mapping referred to in the preceding paragraph, which was discontinued when Cyprus became independent, but they are still used for aerial triangulation in current mapping. The 1963 photographs supplemented by those of July 1968 photography have been used extensively for mapping since 1964 in connexion with the Government's development projects. The photographs of March and July 1968 have been used to prepare a land-use map of the island for the Cyprus water-planning project at scale 1:25,000. Finally, the 1970 photographs at scales 1:50,000 and 1:15,000 are being used for new town maps at scale 1:25,000 and for the systematic mapping at scale 1:5,000 described below.

In 1964, the Director of Military Surveys of the British Army, in co-operation with the United States Army Map Service, Corps of Engineers (now Topographic Command), and the Cyprus Department of Lands and Surveys undertook the production of a new series of maps at scale 1:50,000. The map was drawn up on the universal transverse Mercator projection based on the European datum zone 36S with 20 m vertical contour intervals. Although the drawing and printing of the map are excellent, its accuracy is doubtful and inconsistent. Twenty-five sheets, each representing an area of 15 minutes longitude by 15 minutes latitude, cover the island. Efforts are being made to revise the map and improve its reliability as much as possible. Cyprus is grateful to the two organizations mentioned above for their contribution to its mapping efforts.

Levelling

Although the island was triangulated by Kitchener in 1878, retriangulated in 1913 on Lyons' recommendations, and trilaterated in 1962, it was never covered by an adequate net. The need for a primary levelling was felt when topographical mapping was started in 1964 for development projects. The primary levelling begun in 1964 and completed in 1966 now provides consistent contouring for the island as a whole. It was carried out by two automatic levels fitted with parallel-plate micrometers and using invar staves to geodetic standard specifications. The four loops constituting the network were adjusted by the method of least squares and the resulting accuracy makes this a first-class network.

Photogrammetry

As the demand for topographic maps by departments working on government development projects increased, the need was felt for the establishment of a Photogrammetric Section in the Department of Lands and Surveys. At present, the Section is equipped with a Zeiss Jena stereometrograph D plotting instrument entrusted to a photogrammetrist trained in England and assisted by four locally trained machine operators. However, one instrument is not sufficient to meet the increasing demand; at least one more will be needed. A system of work shifts has been introduced, and with the acquisition of a second stereoplotting instrument and additional staff working a double shift, it is hoped that the Department will be able to map the island within the next 12 to 15 years. The current output of the stereoplotter working a double shift twelve hours per day is about 3 square miles per five-day week. The present mapping is carried out at scale 1:5,000 with 2 m vertical contour intervals by using the 1963 and 1968 photographs. It is hoped soon to start mapping by using the 1970 photographs taken at 1:15,000 scale with the Williamson F49 MK IV camera. In order to print the maps locally and make photographic reductions or enlargements from them, the Department is about to install an automatic offset press and a cartographic process camera. A graduate of the London School of Printing is employed as a senior photolithographer and is already trained in the use of the above-mentioned equipment.

The Department expects to send more people abroad for training in modern methods of mapping by photogrammetry and in cartography. It is hoped that within the next five years the Department will be one of the best equipped in the Middle East. The Department is grateful to the Ministry of Overseas Development of the United Kingdom for granting scholarships to members of its staff in land surveying, cartography, photogrammetry and valuation of property, and to the Director of Military Surveys of the British Army for arranging for new aerial photography of Cyprus.

WORK OF THE INSTITUT GÉOGRAPHIQUE NATIONAL (IGN) IN ASIA AND THE FAR EAST SINCE 1967

Paper presented by France[1]

Since 1967 the Institut géographique national (IGN) has been active in various fields in the Pacific territories under French sovereignty.

New Caledonia

Detailed triangulation has been carried out within the geodetic network formed between 1951 and 1954. A precision-levelling network has been established.

With regard to cartography, a 1:500,000 scale map of the entire island has been published on a single sheet in eight colours in the same style and on the same Lambert projection as the IMW. Relief is indicated by contours at 100 m intervals and touched up by shading.

Publication of the 1:200,000 scale map has been completed. The island is covered by five sheets at this scale.

[1] The original text of this paper appeared as document E/CONF. 57/L 135.

New Hebrides

The archipelago is now fully covered by a 1:100,000 scale map in fifteen sheets based on photogrammetric surveys without field completion.

Two sheets covering the Banks Islands and four sheets covering Malekula have been issued at 1:50,000 scale.

French Polynesia

The following sheets of the Tuamotu archipelago have been issued at 1:20,000 scale: Anaa (two sheets), Haraiki and Hikueru.

Eleven sheets of the Tuamotu archipelago have been issued at 1:50,000 scale: Zikeau (one sheet), Fakarava (two sheets), Makemo (three sheets) and Rangiroa (five sheets).

In addition, some atolls have been rapidly mapped at a large scale from aerial photomosaics.

General maps relating to the region

International Map of the World on the Millionth Scale (IMW)

The Tahiti and Nouméa sheets have been issued; they conform to IMW specifications.

Aeronautical charts

Three sheets at 1:2,000,000 scale have been issued in a style that conforms to the specifications of annex 4 to the Convention on International Civil Aviation. They cover the Tuamotu Islands, the Marquesas Islands, the Society Islands, the Tubuaï Islands, New Caledonia and New Hebrides.

Two sheets at 1:1,000,000 scale conforming to the specifications of the above-mentioned annex 4 have been issued. They cover Nouméa and Tahiti.

Miscellaneous small-scale maps

A general map of the world has been issued in twelve sheets on the Mercator projection (scale 1:10,000,000 at the equator).

A map of the Middle East has been published on the Transverse Mercator projection (scale 1:2,500,000). It covers an area extending roughly from the latitude of Ankara to that of Jedda and from the central meridian of the Aegean Sea to that of Abadan.

Training in cartographic sciences and techniques

From 1967 to 1970 the IGN admitted to its Ecole nationale des sciences géographiques fifty-seven students and trainees from countries of the region as follows: Iran, twenty-five; Syria, seventeen; Laos, seven; Cambodia, six; Japan, one; and Afghanistan, one.

During the same period the IGN sent thirteen of its engineers to countries in the region as lecturers or instructors: five to Lebanon; one to Iran; one to Syria; one to Viet-Nam; two to Laos; and three to New Caledonia.

Work of the IGN in countries of the region other than those under French sovereignty

Saudi Arabia

The IGN fixed forty-eight astronomical stations as part of the programme for establishing a national geodetic network.

In addition, aerial photographs were taken at 1:50,000 scale over 40,000 km² and at 1:12,500 scale over 1,528 km². Photomosaics at 1:50,000 scale were made over 40,000 km².

Lebanon

A relief map of the Lebanese Republic at 1:200,000 scale was prepared, as well as a photomosaic in colour of the city of Beirut at 1:5,000 scale.

Aerial geophysical surveys were carried out in New Guinea (35,091 km²) and in Indonesia (73,779 km²).

MAPPING IN SINGAPORE

Paper presented by Singapore[1]

The Survey Department in Singapore is responsible for all cadastral and topographical surveys for mapping; however, since its inception, it has been geared primarily to meet the needs of cadastral surveys. Since it was closely linked in varying degrees and at various intervals with the Survey Department in Malaysia in the years prior to independence, it was expedient to have the Singapore maps produced by the Malaysian Survey Department. Occasionally the Assistant Director for Military Surveys of the United Kingdom, who was stationed in Singapore, also helped in the production of the maps. We do not therefore have comprehensive facilities for map production work as yet. We are, however, making an effort to acquire such facilities with the assistance of the United Kingdom Government. It is expected to establish a Mapping Unit by the end of this year (1970).

From the cartographic viewpoint Singapore is small (about 225 square miles in land area), and it therefore comes as no surprise that it is fully and well mapped. Complete coverage for all of Singapore is available at 1:250,000 (1 inch = 1 mile), 1:63,360 and 1:25,000. Coverage for the city area is available only at 1:10,000. A large-scale 1:2,500 map for all of Singapore with 10 ft contour intervals, in two colours (black and brown), and comprising about 400 sheets, is currently being prepared with United Kingdom aid. Work on this map was started in 1969 and it is expected that it will be completed around 1972.

[1] The original text of this paper appeared as document E/CONF. 57/L.137.

AGENDA ITEM 7

Reports on progress in matters forming the basis of resolutions adopted by the previous conference

SUMMARY OF PROGRESS WITH RESPECT TO THE RESOLUTIONS AND RECOMMENDATIONS ADOPTED AT THE FIFTH CONFERENCE, 1967–1969

Paper presented by China [1]*

Regional economic atlas for Asia and the Far East

In order to meet the requirements of economic development, the Ministry of Interior has published a regional economic atlas for China. The atlas consists of eight map sheets: four sheets at 1:500,000 and four sheets at 1:6,500,000. These map sheets provide data concerning terrain, geology, communications, soil, mineral production, agriculture, fishery, animal husbandry, water conservation and electric power. These maps were published in colour, in accordance with the resolution adopted at the Fifth Conference. One set will be sent to the United Nations Mapping Information Centre in Bangkok.

National and world atlas

With a view to meeting the requirements of geographical study, the National Defence Research Institute of China has compiled an atlas of China and an atlas of the world. The atlas of China consists of five volumes. The atlas of the world also comprises five volumes covering the Far East, northern Asia, Europe, Africa, America, Australia, the Pacific and the world. The scales of these volumes of maps range from 1:250,000 to 1:5,000,000. These atlases were printed in gradient tints by the China Topographic Service, which also added latinized geographical names to the maps.

International Map of the World on the Millionth Scale (IMW)

The China series consists of seventy-two sheets. As of now, forty-seven sheets have been published, i.e. about 65 per cent, of the total coverage. The maps were compiled according to the specifications of the international format agreed upon at the 1963 United Nations Conference in Bonn.

Standardization of geographical names

The Government sent representatives to attend the United Nations Conference on the Standardization of Geographical Names at Geneva, in September 1967. We not only concern ourselves with problems of geographical names, we also focus our attention on ways to facilitate co-operative activities with other nations in order to improve the system.

Chinese geographical names sometimes consist of official and alternate names, and the pronunciation of Chinese characters is very complicated. A new organization, under the authority of the Ministry of Interior, called The Committee of Supervision for the Standardization of Chinese Geographical Names, has been established. It has invited specialists to conduct research on the problem. The study was based on opinions submitted by different organizations which use latinized geographical names for their operations.

* See introductory note at beginning of volume.

[1] The original text of this paper appeared as document A/CONF. 57/L.36.

REPORT OF THE CORRESPONDING WORKING GROUP ON THE CO-OPERATIVE OCEANOGRAPHIC SURVEY OF A PORTION OF THE SOUTH CHINA SEA

Paper presented by the Chairman of the Corresponding Working Group[1]

The Corresponding Working Group, established in accordance with resolution 26 of the Fifth Conference, was requested to maintain close liaison with, and provide assistance and information to, the IOC, which had been invited to consider undertaking the co-ordination of the necessary investigations of a portion of the South China Sea. These investigations were required to provide for adequate surveys for safe navigation and for data on the potential for fishing and development of natural resources. The assistance of the United Nations, UNESCO and other interested specialized agencies, as well as the IHB for hydrographic activities, was also to be requested.

The Chairman started the work of the CWG on 7 September 1967, by sending out Circular No. 1, in which

[1] The original text of this paper, prepared by M. Nagatani, Director of the Charts Division, Department of Hydrography, Tokyo, appeared as document E/CONF.57/L.51.

he submitted a proposed procedure to be taken by the CWG, i.e. to collect bathymetric data in the area from all countries concerned and to make further recommendations on the basis of those data.

Since the commencement of the work of the CWG, the Chairman has sent out six circulars in three years to solicit comments and suggestions from the members. Replies have been received from most of the members of the Working Group, IHB and IOC, but other members have failed to reply.

Under the circumstances mentioned above, the Chairman requested that a meeting of the Corresponding Working Group be held in Tokyo from 22 to 24 July 1970. Conclusions were reached at that meeting as to: (*a*) area to be surveyed; (*b*) survey standards; (*c*) data to be collected other than hydrographic data; (*d*) execution of the survey and financial assistance; (*e*) updating of nautical charts and (*f*) information to other organizations. These conclusions are based on the various suggestions and comments received from the corresponding members, examination of the plotting sheets compiled from the existing bathymetric data and the discussions held in Tokyo.

PROGRESS IN MATTERS FORMING THE BASIS OF FIFTH CONFERENCE RESOLUTIONS

Paper presented by Japan[1]

Regional geodetic, gravity and magnetic surveys

The outline of geodetic work is summarized in Japan's national report (E/CONF.57/L.34, agenda item 6) presented to the conference.

Integrated large-scale surveys

In connexion with its national land survey plan, Japan adopted the new plane co-ordinate system with thirteen zones. A conversion table was set up to convert longitude and latitude to plane co-ordinates and vice versa, between 30° and 46° north latitude, which covers Honshu, Kyushu, Shikoku and Hokkaido.

When the Ogasawara (Bonin) Islands were restored to Japanese control in 1968, the conversion table had to be extended so that it could be applied to the area between 20° and 30° north latitude; in the near future Okinawa might also have to be included.

The plane co-ordinate system adopted by the GSI is Gauss and Kruger's conformal projection, and its scale factor is 0.9999 at the origin of each zone.

Satellite geodesy

In order to take advantage of the improved observation instruments, Japan established three fixed observation stations, and has been determining the position of Oki Island by the optical tracking method since 1966. Since 1968 the distance between the Kanozan and Sapporo stations has been measured as the base line for satellite observations. The base-line measurement from the Kanozan and Kanoya stations will be undertaken from 1971 to 1974 by traverse survey with the following instruments: the model 8 laser geodimeter to measure distances; the GSI (Geographic Survey Institute) type astrolabe to measure astronomical longitudes and latitudes; the T3 to measure horizontal and vertical angles; and the T4 to measure azimuths.

Crustal movements

Observation of crustal movements for earthquake-prediction research

Recent research on earthquake prediction in Japan has been carried out in the framework of the five-year programme on earthquake-prediction research, which the Government initiated in 1965; a second five-year programme started in 1969. In April 1969 the Co-ordinating Committee for Earthquake Prediction was organized among six universities and five institutes which engage in research in order to exchange information concerning earthquake prediction, determine scientifically whether observed anomalies are related to earthquakes and indicate when these anomalies become critical. The committee has three centres: the Earthquake-Prediction Observation Centre, Earthquake Research Institute, University of Tokyo; the Seismicity Monitoring Centre, Japan Meteorological Agency; and the Crustal Activity Monitoring Centre, Geographical Survey Institute. The latter acts as secretariat for the committee and collects and analyses crustal activity data, especially the results of observations made by geodetic methods. The committee has held eight meetings so far; it has designated the southern Kanto district as an intensive observation area because the vertical crustal movement in the Boso and Miura peninsulas, located in the southern part of the district, recently changed from subsidence after the great Kanto earthquake (1923) to upheaval, and some contractions were observed among several lines connecting triangulation points.

Application of mapping techniques

The medium-scale plotter exhibited at the Canberra Conference has been much improved and is now called the Nikkon plotter. The Nikkon plotters are now being used for topographic plotting at the Geographical Survey Institute.

The direct-scribing method of contouring has been adopted at all scales by many organizations. In large-scale mapping, terrain details are plotted on a coated sheet with coloured ball-point pens; the draughtsman then scribes in the details.

Colour and infra-red photography

The Geological Service of Japan uses infra-red images for mapping geothermal distributions.[2]

The Geographical Survey Institute takes colour photographs of the same area at different seasons of the year so

[1] The original text of this paper appeared as document E/CONF.57/L.58.

[2] See K. Matsuno, H. Hase and K. Nishimura, "On I-R images and their application to mapping geothermal distributions", *Photogrammetria*, vol. 25, Nos. 2 and 3, pp. 61–94 (1969–1970).

as to study the influence of the seasons on colour images. The Institute compares these photographs and uses them to interpret the colour photographs taken at different seasons.

Regional economic atlas for Asia and the Far East

In accordance with a request from the Royal Thai Survey Department, the Institute submitted to it, in December 1966, the official documents on Japan consisting of twenty-three kinds of maps (in fifty-nine sheets) and thirteen books.

Topical maps and national atlases

Japan's national report to the Conference indicates the work carried out on the topical maps. With regard to the national atlas of Japan, the GSI envisages a new plan: the atlas would comprise about 300 pages of B3-type format and about 120 thematic maps having from three to twelve colours. The base-map scale of the thematic maps will range from 1:3,000,000 to 1:6,000,000; that of regional maps will be 1:1,000,000; and the scale of principal city maps will vary from 1:50,000 to 1:100,000.

Geographical names will be given in Latin and Japanese characters. The legends and explanatory notes will be in English and Japanese.

The selection of items for the new national atlas complies with the recommendations of the National Atlas Committee of the International Geographical Union (IGU). However, owing to the particular nature of Japan's regions the questions of economic development and conservation had to be dealt with in greater detail. The atlas is expected to be issued in the period 1971–1975. The first printing attempt was made in 1970; the land-use map was issued at 1:3,000,000.

Standardization of forest maps

In 1967 the Forest Agency established a new survey and mapping regulation to the privately owned forest, and this replaces the one which was established five years ago.

The regulation on the national forest has not been revised since 1962.

On the base of these regulations the forest basic map of scale 1:5,000 has been prepared, and the long-term plan is expected to cover the whole area of the national forests by 1973, and the whole of private forests by 1978.

Geographical names

With regard to the standardization of geographical names, the GSI and the Hydrographic Office jointly decided to standardize the geographical names on the International Map of the World on the Millionth Scale.

At present the work bears mainly on the geographical names appearing on the 1:500,000 district maps and the 1:200,000 coastal charts.

International Map of the World

As Japan indicated in 1967 at the previous conference, the international edition of the IMW was prepared by the GSI. After the conference in 1967 this edition was revised so as to incorporate new information and the domestic edition was prepared on the basis of the new international edition.

Bathymetric charts and development of oceanographic cartography

The Hydrographic Office undertook in 1967 to prepare a detailed "basic map of the sea" series covering Japan's adjacent waters, in accordance with Fifth Conference resolutions 24 and 25. The regular map series consists of the bathymetric chart, the geological structure chart, the total magnetic intensity chart and the gravity anomaly chart. The technical paper submitted by the Japanese Government (E/CONF.57/L.54) describes this programme in detail.

METHODS USED AT THE GEOGRAPHICAL SURVEY INSTITUTE (GSI) TO MAKE THE BEST USE OF AERIAL PHOTOGRAPHS

Paper presented by Japan[1]

The GSI takes about 10,000 aerial photographs every year. In order to make the best use of them for the economic development of the country, the photographs must be arranged so that they will provide useful information quickly. Photographs must therefore be properly filed and the photo library catalogue must be distributed to all possible users.

Labelling of photographs

Photographs are labelled according to scale, area photographed, year, and so on.

(*a*) The country is divided into eight regions corresponding to the main geographical areas and each region is designated by two letters;

(*b*) The year is shown as follows: "70" means that the photograph was taken in 1970;

(*c*) Projects carried out the same year in the same region are numbered consecutively; moreover, each project is given its own reference, such as "KK-65-5X".

In order to identify each photograph, the following items are added: film reel number, strip number, photo number, date of shooting, organization in charge of the project and flying height. For example, "KK-65-5X 1 C25-16 5:22:70 PA 3,400" means that the photograph was taken under project "KK-65-5X", that it is in film reel No. 1, strip number C-25, photo number 16, that it was taken on 22 May 1970 by the PA company and that the flying height was 3,400 m.

[1] The original text of this paper appeared as document E/CONF.57/L.59.

Orientation maps

At first the 1:50,000 topographic maps are stuck together to cover the entire photographed area and the principal point of each photograph is plotted on the base map. If the overlap exceeds 80 per cent, prints are selected so that the overlap is reduced to about 60 per cent, and these photographs are numbered consecutively, starting from the east, in the order which they occupy in each strip.

The main points of these photographs are numbered, then connected by lines traced in groups of five photographs and transferred on the corresponding maps at 1:50,000.

Positive copies of these orientation maps are made on 23 × 35 cm plastic sheets so that they can easily be made available when needed.

In order that all possible users may know what photographs are available, a 1:1,200,000 map was prepared on which the various projects are shown, and this map has been widely distributed.

Maintenance of film and photographs

All films are kept by the Institute. When an area has been photographed several times, old photographs are no longer used for quantitative measurement. A special study was undertaken to determine whether it was possible to microfilm aerial photographs without loss of quality.

Contact prints are also kept by the Institute, and they are available to all possible users for examination.

Use of photographs

Users can easily find on the 1:1,200,000 map the photographs covering the area which they are going to study. They can then request the corresponding orientation map to find the numbers of the photographs they need. Users can purchase any aerial photograph of the country either as a transparency or as a paper print. They may examine contact prints at the Institute before they place an order. The Institute is also planning to establish a film library where users can examine the photographs taken by the Institute as well as by other organizations.

PROGRESS IN MATTERS FORMING THE BASIS OF FIFTH CONFERENCE RESOLUTIONS

Paper presented by Thailand[1]

Thailand has followed various recommendations contained in the resolutions of the Fifth Conference. The extent of the achievements has depended on the availability of manpower and the financial support of priority projects. The following work has been done:

Regional geodetic, gravity and magnetic surveys

During the period under consideration, the Royal Thai Survey Department did all it could to extend the national networks, and the results are as follows:

Geodetic survey

First-order triangulation nets were established and linked with the existing network, as follows:

Geodetic connexion between Thailand and Malaysia

This operation started in October 1967 and ended in July 1968. The result was a triangulation net connecting the Nakhon Si Thammarat base line in Thailand to the Kota Baharu base line in Malaysia, between 6° 37′ and 5° 40′ north latitude and 101° 18′ and 102° 10′ east longitude; the net comprises four stations.

Nakhon Sawan–Udon Thani connexion

This is the connexion between the north and north-eastern networks, from 15° 19′ to 16° 52′ north latitude and from 100° 24′ to 102° 26′ east longitude. This net comprises ten stations.

Buriram–Ubon Ratchathani connexion

A first-order traverse between two triangulation networks already existed in this area. The first-order triangulation net was introduced in the area in order to strengthen the existing network. This was done with the aid of Bilby steel towers since the terrain was generally flat. Twenty-seven stations were established in this network, from 14° 30′ to 15° 50′ north latitude and from 102° 57′ to 105° 17′ east longitude.

First-order astronomical observations

Five first-order astronomical observations (Laplace points) were made, as follows:

(*a*) Stations 171–173. These stations are located in the southern part of the country; both are first-order triangular stations. The probable error of mean observations ranged from ±0.015″ to ±0.045″ in longitude, and from ±0.035″ to ±0.093″ in azimuth; in latitude, it was ±0.050″.

(*b*) Base ends of Lampang base line (station 146–147). This base is located in the northern part of the country. The probable error varies from ±0.024″ to ±0.048″ in longitude, from ±0.066″ to ±0.068″ in latitude and from ±0.092″ to ±0.125″ in azimuth.

(*c*) Earth-satellite triangulation station. This station is located at Chiang Mai airport, and forms part of the United States Earth-satellite triangulation network. A new target station was erected at Doi Lek. The probable error is ±0.028″ in longitude, ±0.061″ in latitude and ±0.088″ in azimuth.

Levelling

The longest first-order levelling line established during the period under consideration is in the southern part of the country. It consists of four sections totalling 551 km. The remaining lines measure 453.5 km for three sections in the north, 564 km for two sections in the east and 156 km for one section in the north-east.

Gravity survey

During the period under consideration, 141 base stations were reobserved, 995 substations were newly occupied and fifty new substations were set up. Complete data were obtained for each season in fifty-three stations in 1967,

[1] The original text of this paper appeared as document E/CONF. 57/L.66.

forty-four stations in 1968, 163 stations in 1969 and 262 stations in 1970.

Geomagnetic survey

The observation area covering the entire country had been divided into five sections. Each station was observed periodically by means of rotation. At present 124 single and double stations are set up in Thailand. Nineteen out of sixty-one stations observed during the period under consideration were new.

PARTICIPATION IN THE SATELLITE GEODETIC PROGRAMME

Thailand has participated in this programme by establishing a Laplace station in the framework of the United States Earth-satellite project described earlier.

PARTICIPATION IN INTERNATIONAL BODIES

Since the Fifth Conference Thailand has participated in the work of the following international bodies:

1. The International Society for Photogrammetry. Thailand has been a member since 1968; it attended the Congress for Photogrammetry in 1968.

2. The International Geographical Union. Thailand has been a member since 1968; it attended the Twenty-first International Geographical Congress in 1968.

3. The International Cartographic Association. Thailand has been a member since 1969; it attended the Fifth International Conference on Cartography in 1970.

INFRA-RED PHOTOGRAPHY

Infra-red photography was used for the classification of forest types in the eastern part of the country. Aerial photography was furnished to the Royal Forestry Department by the Royal Thai Survey Department. The area covered measures about 18,600 km^2 and comprises mainly broad-leaved trees. The results have so far been acceptable for forestry purposes.

NATIONAL ATLASES

In 1968 the Royal Thai Survey Department published volume II of the *National Resources Atlas*, which comprises six topical colour maps at 1:2,500,000. The explanatory notes are in English, and the headings are as follows: reconnaissance geology; general soil conditions; fisheries in Thailand; inland waterways; telecommunications; and highway route numbering system.

Volume III of the *National Resources Atlas* was published in 1969. It comprises seventeen topical maps, including previous editions and new compilations. The maps in this volume are in colour at 1:2,500,000. The explanatory notes are bilingual. The main topics are as follows: administrative divisions; types of climate; climatic charts; reconnaissance geology; general soil conditions; mineral resources; types of forest, national parks and wildlife reserve areas; percentage of land with titles; water resources development; density of population; education; industrial establishment by *changwat* (province); fisheries; electric generation and transmission system; highways, railways and domestic airlines; inland waterways; and telecommunications.

The distribution of these two volumes was limited to the countries of the region. The Department's budget precluded wider distribution.

GEOGRAPHICAL NAMES

Thailand participated in the United Nations Conference on Standardization of Geographical Names in 1967. The modified system of the Royal Institute for romanization of Thai geographical names, submitted to the Conference, was adopted as the international system. Thailand then officially adopted romanization of names for its first two administrative divisions, namely, *changwat*, *amphoe* and/or *king amphoe* in 1967. This romanization system has had other consequences, such as the change of name of railway stations throughout the country and of streets in Bangkok.

The directory of standardized names of subdivisions lower than *amphoe* has been compiled with the co-operation of the various governmental agencies concerned. The Royal Thai Survey Department undertook the study and compilation of names in the field and the preparation of check-lists for the new directory, based on the L7017 map series at 1:50,000, which is the base map for the country.

TRAINING FACILITIES

In recent years, many Thai institutions of higher learning have organized training programmes in surveying and mapping. The only institution which provides complete training in mapping and surveying is the Survey School, under the supervision of the Royal Thai Survey Department; some universities and technical colleges train surveying engineers, and the courses lead to various degrees.

A committee has been set up to review and standardize the existing curricula. It was decided to adopt a single programme and, at the beginning, to offer courses at three different levels, leading to the degree, associate degree and diploma, respectively.

STATUS OF THE MAP INFORMATION OFFICE

Paper presented by Thailand[1]

This report is concerned with the progress made in the establishment of the Thai Map Information Office in accordance with resolution 5 of the Third United Nations Regional Cartographic Conference for Asia and the Far East and resolution 1 of the Fourth Conference. The National Centre was organized in 1966 as a framework for the future regional Map Information Office, which will occupy the building intended for it by the Royal Thai Government.

The documents thus far collected include mainly maps, charts and national atlases from countries within and outside the region. The Centre now has 1,879 map sheets and

[1] The original text of this paper appeared as document E/CONF. 57/L.68.

848 technical reports concerning mapping and related fields.

The Royal Thai Survey Department has concentrated its efforts to ensure that the Centre will function smoothly. All maps have been filed and catalogued in accordance with the system used by the United States Army Topographic Command Map Library. Map catalogues have been set up with four different reference systems, namely, by area, scale, map subject and order number, with sheet name. An example selected from each reference system is on display at the present Conference.

Any inquiries concerning mapping and related materials may not always be adequately handled owing to the Centre's limited facilities and personnel. However, the Centre is willing to offer its services and co-operate with all countries to the fullest.

In view of the expanding services to countries of the region and others, Thailand hopes that the United Nations and all countries with common interests should give assistance to the Centre under the United Nations technical co-operation programme, as provided for in resolution 3 of the Fourth Conference.

In order to accelerate the growth of the Thai Map Information Office (the future regional office), Thailand requests that all interested countries should provide more information in the form of maps and related documents, as recommended in resolutions 3, 9 and 11 of the Fourth Conference and resolutions 7, 8, 12 and 14 of the Fifth Conference. (All correspondence should be addressed to the Thai Map Information Centre, c/o The Royal Thai Survey Department, Bangkok 2, Thailand.)

AGENDA ITEM 8

Geodesy and ground control

ISOGONIC CHARTS OF THE UNITED STATES AND OF CENTRAL AND SOUTH AMERICA

Paper presented by the United States of America[1]

INTRODUCTION

The isogonic chart of the United States, containing lines of equal magnetic declination, is published at five-year intervals, the newest published chart being for epoch 1970. This chart is the official basis of magnetic directional information required for the many uses of the compass, e.g. land surveying and navigation of ships and aircraft. The isogonic charts prior to 1970 were compiled by methods involving varying degrees of manual cartographic procedures. In 1965, 0.5° quad means were plotted on a base map and the isogonic lines were drawn manually. For the 1970 chart, a least-squares analysis has been used to draw the isogonic lines mechanically, using an automatic plotter. This paper outlines the procedure used for data selection and reduction, describes the techniques of the analysis and gives an evaluation of the new isogonic chart.

DATA SELECTION AND REDUCTION

For the main part of the chart covering the forty-eight conterminous States and some bordering regions, all declination measurements (30,000 points) made in the pertinent region since 1900 were taken from the world magnetic survey file.

A large enough area was encompassed to ensure that there would be adequate control of the entire forty-eight States. Two thirds of the magnetic declination values are surface measurements; the rest are aeromagnetic measurements derived from the surveys of Project Magnet, conducted by the United States Naval Oceanographic Office.

The secular-change rates for the time interval 1900–1960 that had been developed in the compilation of the 1965 chart were used to reduce the raw data file to epoch 1960. This data file, together with the new data collected since the compilation of the 1965 chart, was then reduced to epoch 1970 using the spherical harmonic coefficients of secular change derived for the 1970 edition of the world magnetic charts (Hurwitz and Fabiano, 1970). The data were next sorted by position and mean values of declination for each 0.5° quad were obtained. Individual values differing by more than two degrees from the 0.5° quad mean were rejected during the process of deriving the final means.

The next step was to form a complete data set consisting of one declination value for every 0.5° quad for the entire region of the analysis. Within the forty-eight States, no measured declination values were available for approximately 20 per cent of the 0.5° quads. To form a complete data set, a preliminary mathematical model was derived by conducting a least-squares polynominal analysis of degree seven (thirty-six coefficients) using as the basic data the available one degree quad means (approximately 2,100 values) of declination for the forty-eight States, reduced to epoch 1970. The 0.5° grid values required to fill in those areas lacking actual data were computed from this preliminary model. At this point we had on magnetic tape the complete data set needed for the final analysis.

ANALYSIS OF THE MAIN FIELD

The primary objectives of the analysis were to enable the chart to be drawn mechanically by an automatic plotter, while at the same time achieving an accuracy at least comparable with that of a hand-drawn chart such as the one compiled for 1965. The general plan was to subdivide the entire region of the chart into sections and to conduct a separate polynomial analysis of each section. Judgements with respect to two points were required before proceeding with the analysis, namely the size of each section and the degree of the polynomial.

It was decided, somewhat empirically, to limit the section size to $8° \times 8°$ in latitude and longitude. It was anticipated that a larger size might result in an overly smoothed chart. On the other hand, too small a size, such as $4° \times 4°$, would result in many (i.e. 144) sections, each with a set of coefficients. This appeared to be an unwieldy set of models to work with conveniently and, in addition, might have required excessive manual smoothing to reconcile all the discontinuities at the borders. The region of the United States (forty-eight conterminous States) was thus divided into thirty-six sections comprising four bands of latitude and nine of longitude. Each section, spanning 8° of latitude and 8° of longitude, has an area of about 700,000 km^2.

It was considered that a polynomial of degree no less than four (fifteen coefficients for each section) would meet the specifications for this chart but the resolution finally chosen for the analysis was to degree seven—that is, thirty-six coefficients for each section. The general equation of condition was of the type:

$$D = A + Bx + Cy + Dx^2 + \cdots + Sy^7$$

[1] The original text of this paper, prepared by E. B. Fabiano, Chief, Magnetic Charts Branch, Office of Seismology and Geomagnetism, Coast and Geodetic Survey, Environmental Science Services Administration, Rockville, Maryland, and submitted under agenda items 8, 9, 12(*a*) and 13, appeared as document E/CONF.57/L.12.

where D denotes declination, x is a parameter representing latitude, and y another for longitude, the desired coefficients being A, B, C, D, . . ., S. Tests indicated that the root-mean-square differences obtained from a degree-four model did not differ significantly from those of a degree-seven model. However, it was decided that for the preselected size the higher resolution would contribute to minimizing the discontinuities at the common section boundaries.

The objective of minimizing isoline discontinuities was served by the judicious fixing of section size and resolution and by the fill-in procedure explained above. Coupled with these elements, another feature of the analysis almost guarantees continuity. Although each set of derived coefficients was intended to be applicable for a certain $8° \times 8°$ section, data for the corresponding $12° \times 12°$ section were included in its derivation. By this procedure, there was a marginal coverage of two degrees around the entire perimeter of each $8° \times 8°$ section.

The analysis was executed on a CDC-6600 computer. Sets of degree-seven coefficients for all thirty-six areas were obtained in ten minutes of computer time. The chart for the forty-eight-state area was plotted directly from the coefficients in one pass, using a 30-inch, flat-bed Calcomp plotter. The time required to plot the chart was approximately three minutes.

Analysis of Annual Change (Isoporic Lines)

The isoporic lines (lines of equal annual change) shown on the 1970 isogonic chart of the United States were drawn from a single fifteen-coefficient (degree four) polynomial model. The model was derived as follows. The current (1970) rate of annual change was determined for the magnetic observatories and at each of the 100 repeat stations in the United States and at additional nearby stations and observatories in Mexico and Canada. For additional control, the 1970 rate of annual change from the magnetic declination chart of the world was used in the ocean areas. This complete set of data was subjected to a least-squares analysis to produce one set of coefficients for the forty-eight States.

Charts of Central and South America

The analyses needed for producing the declination charts of Central and South America were somewhat similar to that used for the forty-eight States. The section size here, however, was $10° \times 10°$. Because of difficulties in deriving an adequate plotter programme (for a bipolar oblique conic conformal projection) to contour the isogonic lines, a different procedure was used. From the coefficients, one degree grid values were computed and hand-plotted. The isolines were then drawn manually, as had been done for the 1965 series of these charts. To derive the isoporic lines, the analytic techniques were similar to those used for the United States charts.

Alaska and Hawaii

In view of the sparsity of data in the State of Alaska, one degree quad means of declination were used to create a single seventh-degree model for the entire state. For Hawaii, it was decided that lines from the world magnetic chart would be suitable, considering the size of this area and the scale of the chart. For both areas, isoporic lines were derived from the world magnetic chart for epoch 1970.

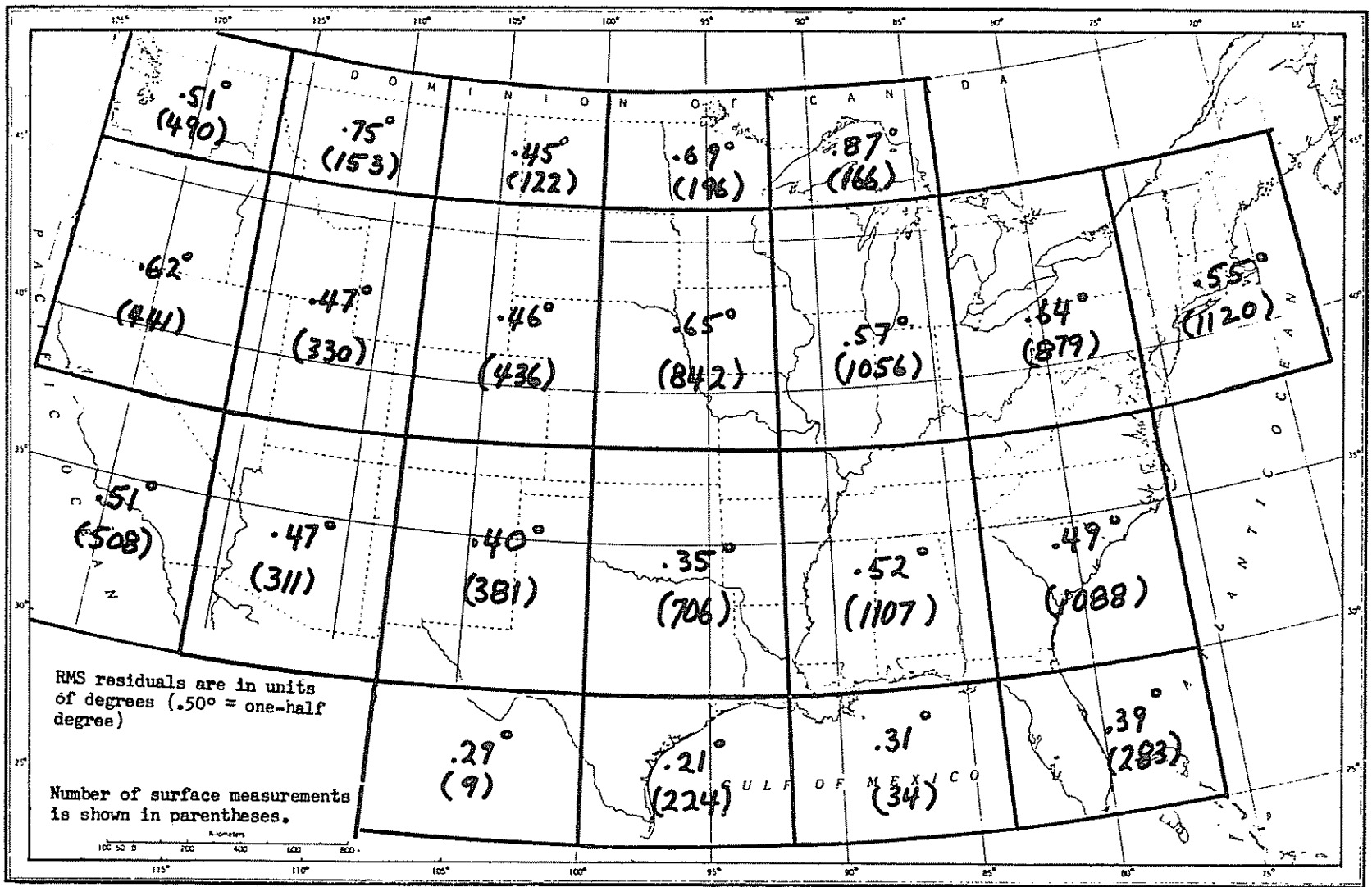
On all of the regional magnetic charts produced by the Coast and Geodetic Survey, the lines of magnetic declination are reconciled at most of the borders with isogonic lines from the world magnetic chart, in order to effect a smooth transition from one chart to the other. Additionally, available lines from the 1970 Canadian declination chart were used to reconcile the patterns at the common boundaries between the United States and Canada. This phase of the chart compilation, as well as smoothing the few minor discontinuities at the section boundaries, was done manually.

Evaluation

The figure illustrates an evaluation of the various polynomial models. Only those areas are shown which include substantial parts of the land area within the charted region. The root-mean-square residuals are shown (station value minus model) together with the number of station values, in each $8° \times 8°$ section. The table itemizes both the RMS residuals of the station values and those of the 0.5° means. The over-all RMS residual of the total set of surface land measurements is 0.52°, a value that seems consistent with past estimates of the accuracy of United States isogonic charts. The RMS residuals of the repeat-station rates of change versus the lines of annual change for the forty-eight States was 0.7 minute of arc per year.

Root-mean-square deviations of the magnetic declination chart of the United States for 1970

Latitude band (north)	*Longitude band (west)*	*No. of points*	*RMS*	
			All points	*0.5° quad means*
(*Degrees*)			(*Degrees*)	
54–46	124–116	490	0.51	0.45
54–46	116–108	153	0.75	0.45
54–46	108–100	122	0.45	0.53
54–46	100–92	196	0.69	0.68
54–46	92–84	166	0.87	0.75
46–38	124–116	441	0.62	0.46
46–38	116–108	330	0.47	0.35
46–38	108–100	436	0.46	0.34
46–38	100–92	842	0.65	0.54
46–38	92–84	1,056	0.57	0.60
46–38	84–76	879	0.64	0.57
46–38	76–68	1,120	0.55	0.47
38–30	124–116	508	0.51	0.33
38–30	116–108	311	0.47	0.32
38–30	108–100	381	0.41	0.29
38–30	100–92	706	0.35	0.29
38–30	92–84	1,107	0.52	0.35
38–30	84–76	1,088	0.49	0.41
30–22	108–100	9	0.29	0.19
30–22	100–92	224	0.21	0.20
30–22	92–84	34	0.31	0.22
30–22	84–76	283	0.39	0.41



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RMS residuals for the isogonic chart of the United States, 1970

Conclusion

The method of least-squares has proved to be a useful tool in the compilation of regional magnetic charts. It has the advantage that the models from such an analysis can be used readily in the automatic plotting of the charts. In the construction of regional charts, consideration must be given to the density and distribution of data, data selection, size of area to be plotted and the optimum degree of the polynomial to be obtained. Further studies will continue in the Coast and Geodetic Survey to evaluate this and other techniques in order to produce more accurate and useful regional charts.

Reference

Hurwitz, L. and E. B. Fabiano. *Geomagnetic Secular Variation, 1937.5–1967.5* (in preparation).

HORIZONTAL MOVEMENT ALONG THE SAN ANDREAS FAULT SYSTEM

Paper presented by the United States of America[1]

Abstract

During the past two years repeat surveys for the study of horizontal movements have been carried out in several different areas along the San Andreas fault system of California. These surveys, accomplished by the Coast and Geodetic Survey, are in the areas of Fort Ross, San Francisco and vicinity, Hollister, Stone Canyon and the Borrego Desert area west of the Salton Sea in southern California. Also, repeat surveys were accomplished at various fault-crossing figures established on a co-operative basis with the California Department of Water Resources in 1964–1965.

In areas where deformation along the fault had been determined from previous surveys, the annual rate disclosed by surveys accomplished during the past two years is in very close agreement with that determined previously.

Horizontal movement along the San Andreas fault system

Resurveys for the purpose of monitoring crustal movements along the San Andreas fault system of California have been carried out periodically by the United States Coast and Geodetic Survey for about 65 years. During the past 10 years the use of high-precision distance measuring instruments in these surveys has provided additional data for the study of crustal movements.

The results of resurveys, accomplished through 1967, have been summarized in previous reports (Meade 1963, 1965, 1968). This report gives a summary of results obtained from surveys accomplished during the two year period 1968–1969. The recent surveys include re-observations of two nets which were established and observed before the San Francisco earthquake of 1906. Results obtained from surveys carried out during the past two years are discussed under the name of the locality identifying the network.

Vicinity of Fort Ross

The net in this area consisting of six stations, figure I, is near the California coast about 95 km north-west of San Francisco. Horizontal angles were observed by the Coast and Geodetic Survey at some of these stations in 1860. However, the results given here are based on surveys of 1876, 1906 and 1969.

After the severe earthquake of 1906, this net was re-observed to determine the magnitude of relative displacement between stations on opposite sides of the San Andreas fault. Results of the 1906 survey, when compared with results of 1876, disclosed right-lateral displacement of 3.9 m in this area.

In the 1969 survey, first-order horizontal directions were observed at all stations and each line in the net was

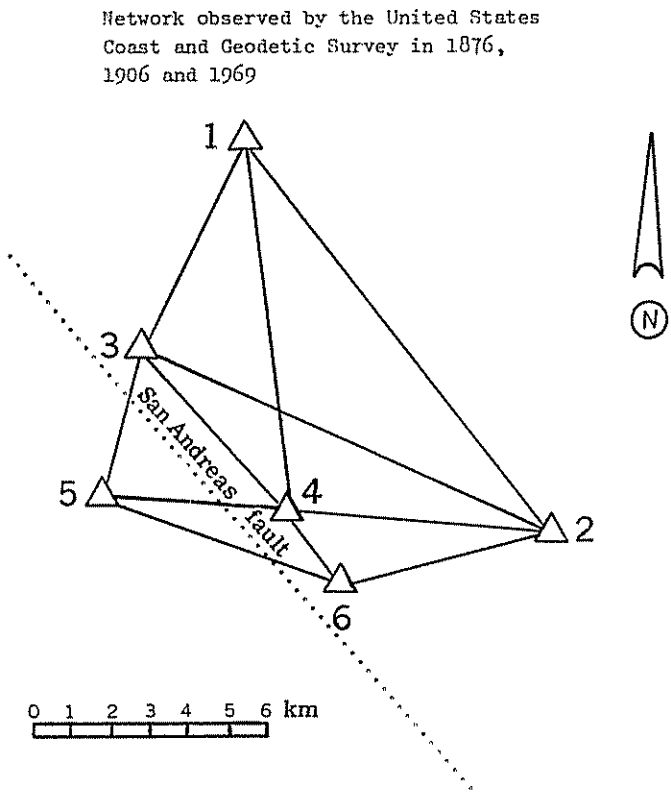


Figure I. Vicinity of Fort Ross, California

measured with a model 4 geodimeter equipped with a laser light source. A simultaneous least-squares adjustment of the triangulation–trilateration net gave a maximum correction of 0.55 second to an observed direction and 2.6 cm was the maximum correction to a measured distance.

At the time of the field survey in this area, October 1969, a research geologist reported that station 6 (figure I) was located on a massive landslide which extended southeasterly to the coast. It was also reported that the block beneath the station, approximately 0.7 km^2, had moved down and in a south to south-westerly direction in recent

[1] The original text of this paper, prepared by B. K. Meade, Chief, Triangulation Branch, Geodesy Division, Coast and Geodetic Survey, Environmental Science Services Administration, Rockville, Maryland, appeared as document E/CONF.57/L.15.

geologic time. Supporting geological evidence was given for this reported movement. However, results obtained from the 1969 survey did not disclose any movement between stations 6, 3 and 4 over the 63-year interval, 1906 to 1969.

Although changes in some of the observed angles, 1906 to 1969, were significant, the results do not indicate slippage between points on opposite sides of the fault. Changes in the adjusted results of these surveys were used to compute strain data for each of the seven triangles in the net. These data are given in the following table:

Parameters of strain—1906 to 1969

(*Units* 10^{-6})

Triangle	E_1	E_2	θ	γ	ρ	ω
1–2–3	+23	−49	167°	72	−13	+16
1–2–4	+30	−37	175	67	− 3	+14
1–4–3	+15	−45	160	60	−15	+26
2–4–3	+31	−16	184	47	+ 7	+23
2–6–4	+31	−46	182	77	− 8	+23
3–4–5	+38	−25	181	63	+ 6	+31
4–6–5	+38	−56	179	94	− 9	+33

Definitions (see Jaeger, 1956):

E_1, E_2 = Principal axes of strain

θ = Direction of E_1 principal axis of strain measured positive counter-clockwise from east

γ = Total shear = $E_1 - E_2$

ρ = Dilation, positive for expansion, negative for contraction

ω = Rotation, positive clockwise

The average value for total shear is 69 parts per million or about one ppm annually during the 63-year interval. The direction of maximum positive shear is 45° less than the direction of the principal axis of strain. The average value of this direction is 130°, which is approximately the same as the direction of the fault.

Bodega Bay

A triangulation–trilateration network of three quadrilaterals straddling the San Andreas fault, with sides ranging in length from 1 to 2.5 km, was established in this area by the California Department of Water Resources in February 1968. A resurvey of the net was accomplished by the Coast and Geodetic Survey in November 1969. In each of the two surveys all sides were measured with model 6 geodimeters. The average and maximum differences in the distance measurements were 5.7 and 12.0 mm respectively. Small changes in the observed angles were well within the expected observational errors of the surveys. There is no indication of slippage along the fault during this 20-month interval. These results will provide valuable information on strain and shear along the fault when periodic resurveys are accomplished.

The 1907 annual report of the Coast and Geodetic Survey states that displacement along the fault in this area, as determined from surveys following the 1906 earthquake, was about 2 m. This locality is about 27 km south-east of the Fort Ross area described above.

San Francisco Bay

Results of an extensive net in this area, involving surveys of 1951, 1957 and 1963, were reported by Pope, Stearn and Whitten (1966). Part of the net was re-observed in the latter part of 1969 and at the present time, June 1970, the results have not been fully evaluated. One of the lines in the net, connecting stations Mocho and Mount Diablo established in 1875, has been used as a reference line for many of the crustal movement investigations in this area. The 1969 values for azimuth and length over the line are in very close agreement with results obtained from previous surveys. Observational data from the recent survey verify the fact that the selection of this line as a reference was an excellent choice.

The six fault-crossing sites, *A* through *F* (figure II), were established in 1964–1966 to monitor creep along the Hayward and Calaveras faults. Resurveys at four of these sites, *B* through *E*, were accomplished during the latter part of 1969 and resurveys at *A* and *F* were completed in February 1970. The localities identifying the six sites are as follows.

A—Mira Vista
B—Berkeley Memorial Stadium
C—Union
D—Irvington
E—Camp Parks
F—Veras

At each of the sites where surveys have disclosed movement, the direction of movement is right-lateral. The annual rate of movement is given below:

Site	*Survey interval*	*Annual rate (mm)* (1)	(2)	(3)[a]
A	October 1966–February 1970	0.0		
B	November 1966–December 1967	5.1		
	December 1967–November 1969	5.1		
C	May 1965–July 1967	5.2		
	July 1967–July 1969	4.5		
D	October 1966–February 1968	6.7		
	February 1968–July 1969	6.6		
E	April 1964–June 1965		0.0	0.0
	June 1965–August 1969		2.0	0.0
F	May 1965–February 1970			2.4

[a] (1) Hayward fault; (2) Pleasanton fault; (3) Calaveras fault.

The surveys at site *A*, 8.6 km north-west of the Berkeley site, have not disclosed positive evidence of movement. There is a possibility that all stations in the net were established on the same side of the fault.

The net at site *B* (see figure III) was established on the rim of the Berkeley Memorial Stadium, University of California. Direct measurements of offsets under the stadium are in close agreement with movements obtained from the surveys.

Site *C*, in Hayward, California, is 37 km south-east of the Stadium site. Engineers in the areas of Hayward and Oakland have reported annual fault creep, determined from direct measurements of curb offsets, of 5 to 6 mm. Site *D* is 10 km south-east of this site in Hayward.

Three nets were established at site *E*. Two of these are on the Pleasanton fault, a branch of the Calaveras, and the other site is 4 km to the west on the Calaveras fault.

At site *F*, the annual rate of movement was not uniform during the two intervals May 1965 to July 1966 and July 1966 to February 1970. The annual rate of 2.4 mm is for the total five-year interval and is based on changes in the directions of lines approximately perpendicular to the fault. This site is on the Calaveras fault about 13 km south of Camp Parks.

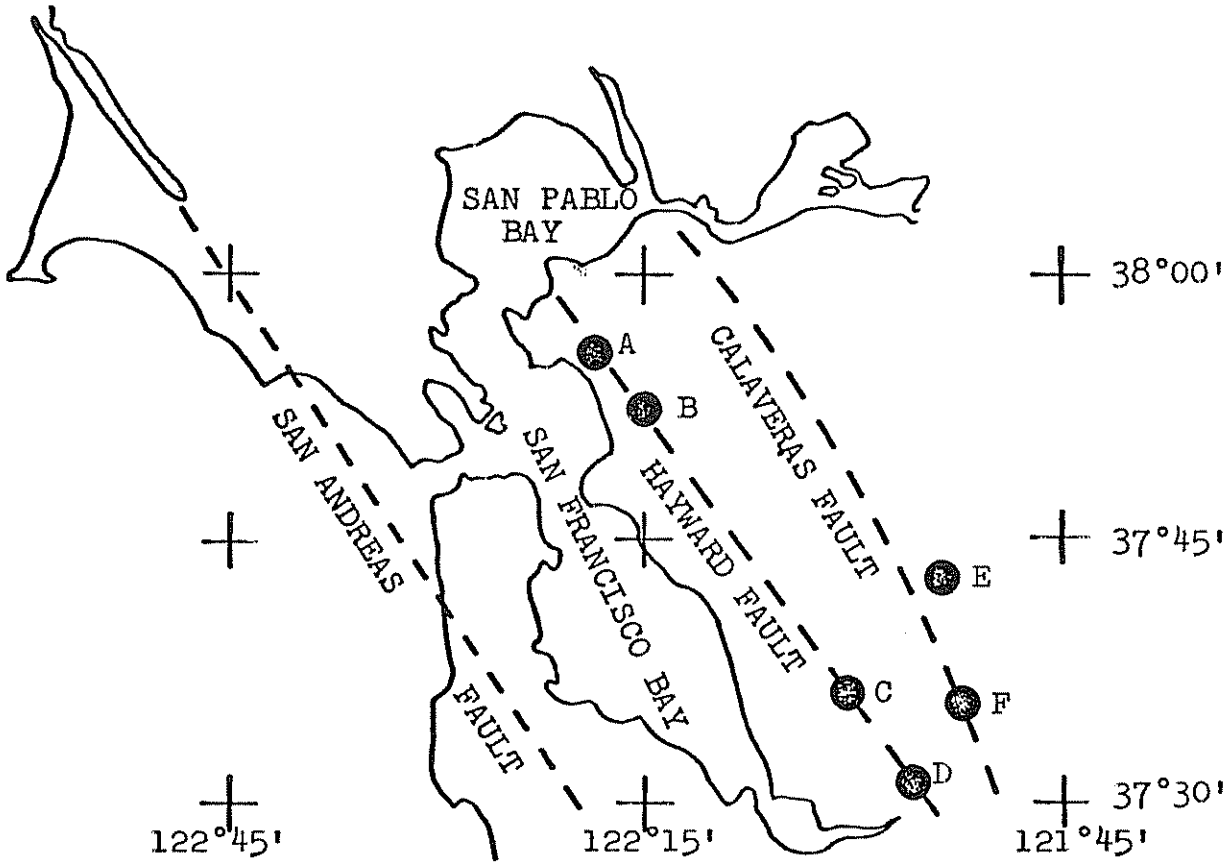


Figure II. Six fault-crossing sites, San Francisco Bay area

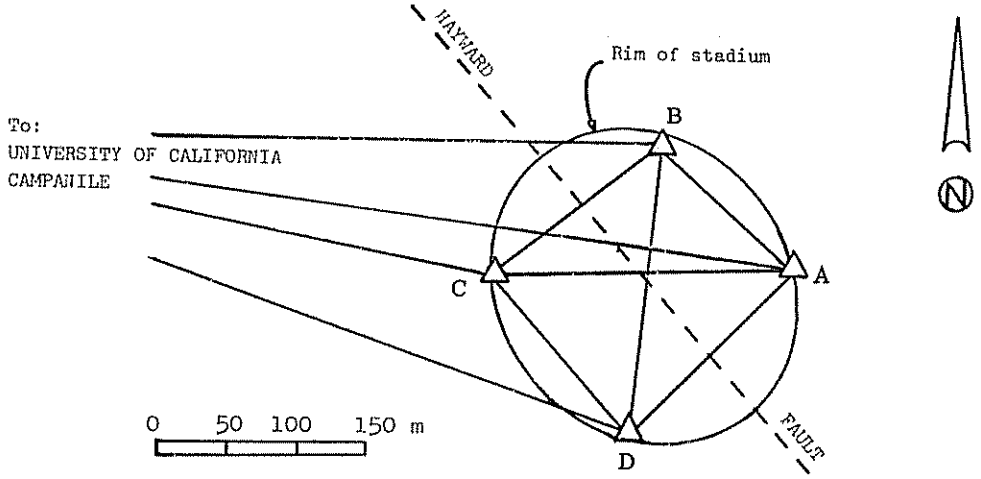


Figure III. Fault-crossing site, Berkeley Memorial Stadium

Vicinity of Hollister and Stone Canyon

The results obtained from surveys at three sites in this area show a uniform pattern of creep over a distance of 25 km along the San Andreas fault. The nets established at each of the three sites are shown in figure IV. Stations at the Harris and Stone Canyon sites were established in 1967 and those at the Winery site in 1957. Annual rates of movement at each site are as follows:

Site	*Survey interval*	*Annual rate (mm)*
Harris	October 1967–March 1969	12.5
Winery	August 1957–October 1968	13.1
	November 1967–October 1968	11.0
Stone Canyon	August 1967–October 1968	14.0

The junction of the San Andreas and Calaveras faults is just south of the Stone Canyon site. Geologists have reported the possibility of strain accumulation extending several km from the fault in this area. In order to obtain additional information on crustal movements, or strain accumulation, the network shown in figure VI was established in the latter part of 1969. Instructions for the survey specified that angles would be measured to first-order accuracy and all distances measured with a model 4 laser geodimeter. Resurveys at intervals of about five years will provide valuable information in this area where fault creep is occurring at a fairly uniform rate.

Junction of San Andreas and Garlock Faults

The Garlock fault extends to the north-east from its junction with the San Andreas at approximate latitude 34° 48′ and longitude 118° 52′. A small net, identified as

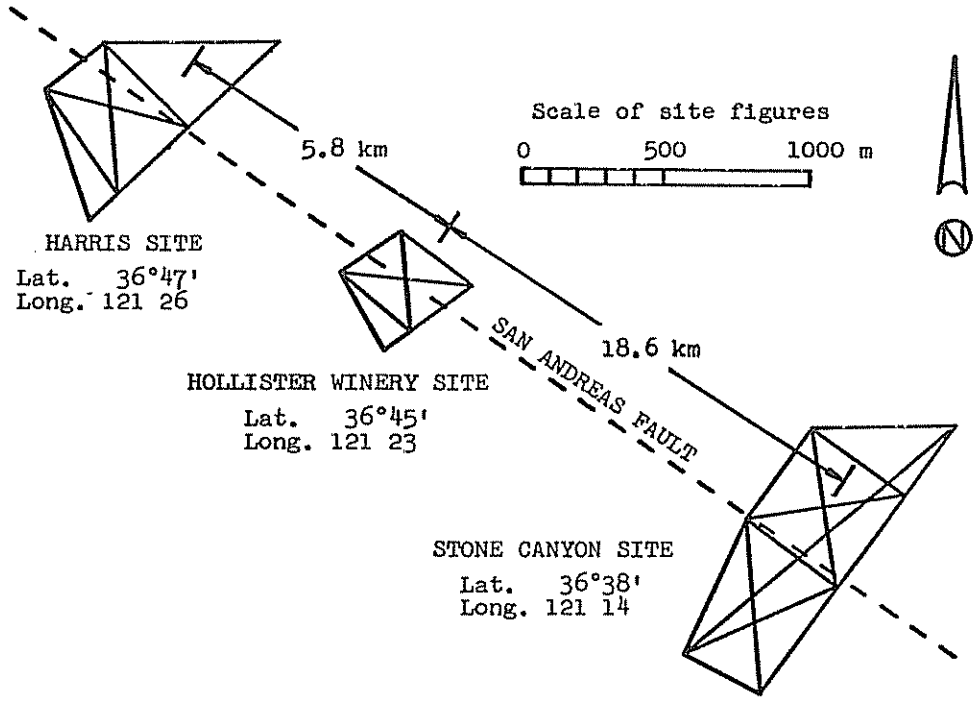


Figure IV. Three fault-crossing sites (about 150 km south-east of San Francisco)

The graph in figure V shows the accumulated slippage at the Winery site from 1957 to 1968. This graph is from Whitten (1969) and he reports,

"About 12 years ago, Tocher (1960) and Steinbrugge (1960) found evidence of slippage along the San Andreas fault at Cienega Winery south of Hollister. This slippage, even though it occurs in episodes of fractions of millimeters, accumulates quite uniformly with respect to time. Special geodetic surveys at the Winery have been repeated almost annually. Tocher has maintained a continuous recording instrument within the Winery. He reports that at the time of earthquakes there is an increased number of episodes with greater slippage. The displacement computed from recent geodetic surveys confirms this increased slippage associated with earthquakes and shows a remarkable uniformity during the long periods of time when there are no earthquakes of appreciable magnitude."

Ranch site, with sides 200 to 700 m in length, was established on the Garlock fault in May 1964. This site is about 14 km north-east of the junction mentioned above. A resurvey was completed in May 1969 and four previous surveys were accomplished at intervals of approximately one year. Significant changes in the observed angles, up to 15 seconds, have occurred during some of these intervals. The accumulated changes over the five-year interval do not form a uniform pattern of movement. However, the direction was left-lateral and in some cases the magnitude was 20 to 30 mm. Also, in connexion with alignment surveys for the construction of a tunnel near this site, engineers have reported left-lateral movement of a few millimetres.

Results of an extensive triangulation network, spanning the junction of the San Andreas, Garlock and White Wolf faults, have been reported in Coast and Geodetic Survey Operational Data Report DR-5 and its supplement DR-6 (Miller *et al.*, 1969). These reports may be

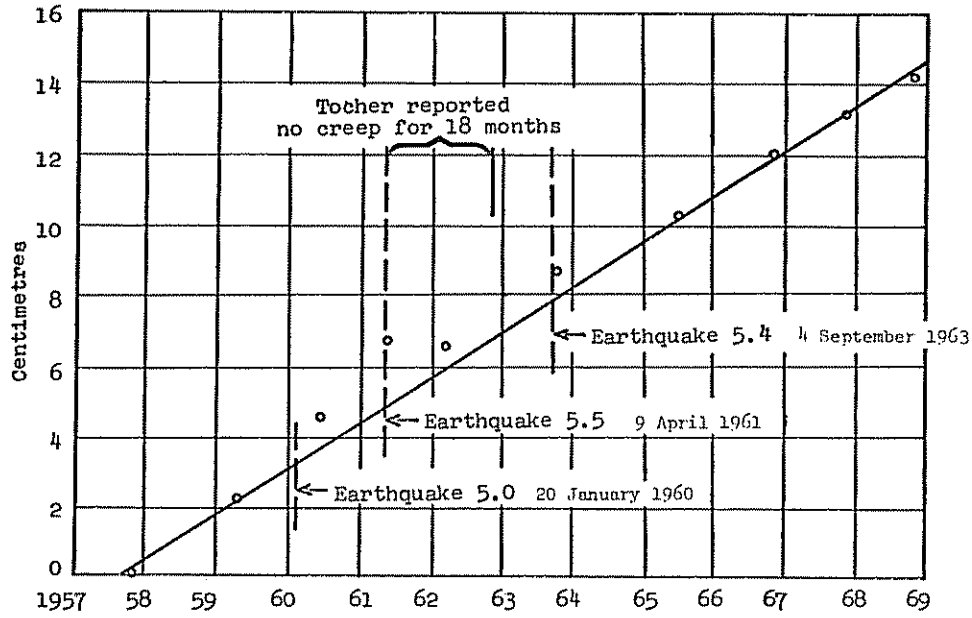


Figure V. Accumulated slippage at Hollister Winery

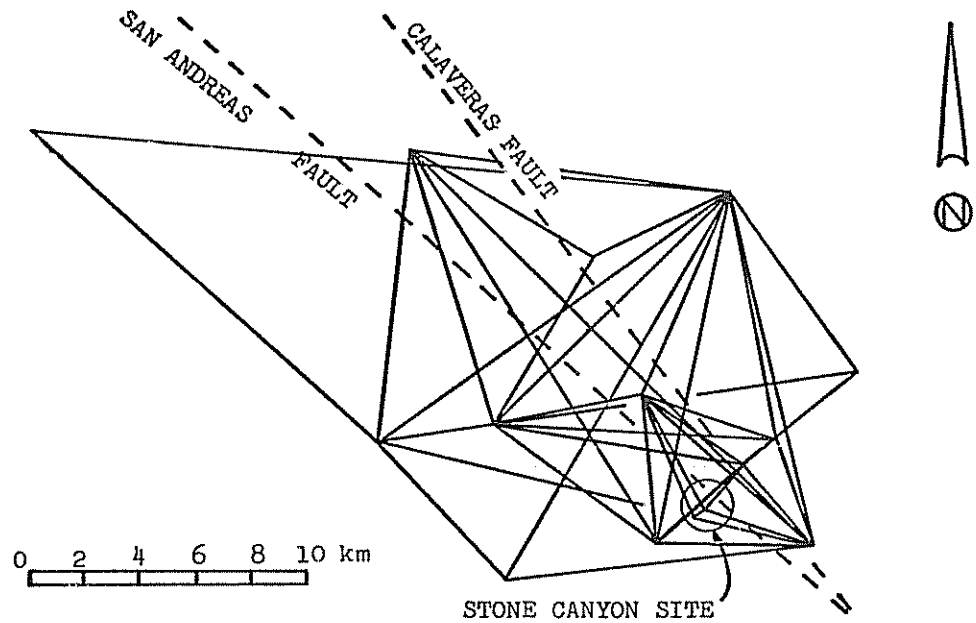


Figure VI. Triangulation and trilateration network, vicinity of Stone Canyon

obtained from the Geodesy Division, Coast and Geodetic Survey.

South-east from the San Andreas–Garlock fault junction, seven fault-crossing sites were established in 1964–1965 on a co-operative basis with the California Department of Water Resources. These nets, similar to those in the San Francisco Bay area, are spaced at fairly uniform intervals along the San Andreas fault over a distance of approximately 160 km. Resurveys at each of these sites have not disclosed any significant fault creep.

Imperial Valley

An extensive triangulation net in the Imperial Valley, adjacent to the Mexican border, was established in 1934, and resurveys were made in 1941, 1954 and 1967. A complete analysis of the results will be published by the Coast and Geodetic Survey later this year as an operational data report.

The epicentre of the large earthquake, magnitude 6.5, which occurred in southern California on 9 April 1968, was near the western edge of the Imperial Valley net. This

epicentre, reported to be at latitude 33° 08.8′ and longitude 116° 07.5′, was 2.3 km north-west of triangulation station Ocotillo, which was established in 1939. This station, along with three other stations established in 1939, was used in a resurvey carried out in March 1969.

At station Bluff, 16 km north-west of Ocotillo, a large change in the direction to the azimuth mark disclosed right lateral movement of 8 cm. The azimuth mark for station Ocotillo is 1 km from the station and the azimuth determined from the 1969 survey was 65 seconds greater than the 1939 value. This change represents right-lateral movement of 32 cm. In this particular case the fault line is perpendicular to the line between the station and its azimuth mark. Immediately following the earthquake in 1968, Allen *et al.* (1968, p. 1184) reported displacement of 30 cm near station Ocotillo.

When the 1969 survey was being carried out, local residents called our attention to large cracks on the surface in the desert area 7 km south-east of station Ocotillo. Some of these were 2 to 3 m in length and they ranged from 0.1 to 0.8 m in width. The narrow cracks, 0.1 to 0.2 m wide, were 2 to 3 m deep. From this area, over a distance of about 2 km to the north-west, fault breaks along the surface were visible. In the opposite direction there was no evidence of cracks in the surface. The visible surface breaks follow the direction of the fault trace indicated by Allen *et al.* (1968, p. 1184).

Summary

Surveys in the area from San Francisco to Fort Ross have not disclosed movement along the fault. However, because of the large accumulation of strain in the Fort Ross area, indicated by the 1969 survey, it seems logical that a severe earthquake can be expected in this region before the end of this century.

The annual rate of movement along the Hayward fault in the San Francisco Bay area is occurring at a fairly uniform annual rate of 4 to 6 mm and the rate increases along the fault to the south. In the vicinity of Hollister, near the junction of the Hayward, Calaveras, and San Andreas faults, the annual rate is about 13 mm. Continuing to the south-east along the San Andreas, previous surveys have shown an increasing rate of movement. This reaches a maximum of about 35 mm annually at approximate latitude 36° 12′ and longitude 120° 47′. From this area along the San Andreas to the Garlock fault junction, the annual rate decreases to zero. Surveys along the Garlock fault have disclosed left-lateral movement of a few mm.

A programme for measuring geodimeter distances criss-crossing the California fault zones, started by the California Department of Water Resources about 10 years ago, has added significantly to the study of crustal movements. During the past year this programme was continued by the State Division of Mines and Geology and about forty lines were remeasured along the fault from the Stone Canyon area to San Francisco. These measurements were completed in the latter part of 1969 and the final results have not been made available.

Several fault crossing sites have been established by the United States Geological Survey in various areas between San Francisco and the vicinity of Hollister. Periodic resurveys of these sites will provide additional information on crustal movements in this seismic area. Also, geologists and seismologists associated with this federal agency are monitoring seismic activity in several other areas of California.

Research geologists associated with the Earthquake Mechanism Laboratory of the Environmental Science Services Administration in San Francisco have installed creepmeters and seismometers in several seismic areas of the State. Data from some of these instruments are transmitted by telephone to San Francisco and recorded on magnetic tape for analysis.

Data obtained from crustal movement studies during the past 50 years, along with the co-ordinated efforts of geologists, geophysists and geodesists in future programmes for monitoring earth movements, will provide valuable information for an earthquake warning system.

References

Allen, C. R. and others. "The Borrego Mountain, California, Earthquake of 9 April 1968", *Bull. Seism. Soc. Am.*, 58, No. 3, 1183–1186, 1968.

Jaeger, J. C. *Elasticity, Fracture and Flow*, John Wiley, New York (208 pages), 1956.

Meade, Burford K. "Horizontal Crustal Movements in the United States", Report to the Commission on Recent Crustal Movements, IUGG General Assembly, Berkeley, California, August. *Bull. géodesique*, No. 77, 215–236, 1963.

———. "Report of the Sub-Commission on Recent Crustal Movements in North America", Proceedings of the Second International Symposium on Recent Crustal Movements, Aulanko, Finland, August. *Ann. Acad. Sci. Fennicae*, A, III, 90, 247–266, 1965.

———. "Report of the Sub-Commission on Recent Crustal Movements in North America", Problems of Recent Crustal Movements, Third International Symposium, Leningrad, USSR, May. USSR Academy of Sciences, 62–70, 1968.

Miller, Robert W. and others. "Crustal Movement Investigations—Triangulation, Taft-Mojave Area, California", Operational Data Report C & GS DR-5 (106 pp.) and DR-6 (85 pp.), 1969.

Pope, A. J., J. L. Stearn and C. A. Whitten. "Surveys for Crustal Movement along the Hayward Fault", *Bull. Seism. Soc. Am.*, 56, No. 2, 317–323, 1966.

Steinbrugge, Karl V. and Edwin G. Zacher. "Creep on the San Andreas Fault: Fault Creep and Property Damage", *Bull. Seism. Soc. Am.*, 50, No. 3, 389–396, 1960.

Tocher, Don. "Creep on the San Andreas Fault: Creep Rate and Related Measurements at Vineyard, California", *Bull. Seism. Soc. Am.*, 50, No. 3, 396–404, 1960.

Whitten, Charles A. "Crustal Movement from Geodetic Measurements", Proceedings of NATO Advanced Study Institute; Earthquake Displacement Fields and the Rotation of the Earth. London, Ontario, Canada, June. In publication, 1969.

A WORLD SURVEY CONTROL SYSTEM AND ITS IMPLICATIONS FOR NATIONAL CONTROL NETWORKS

Paper presented by the United States of America[1]

The establishment of a modern geodetic control network is shown to be affected by two developments: the coming of age of the method of satellite geodesy and the technical progress made in the general field of precise metrology. A general description is given of the method and potential of dynamic satellite geodesy and geometric satellite triangulation for the creation of a geodetic world-wide reference system as well as for the establishment of densification control on continental land masses. The three-dimensional densification nets are shown to provide the zeroth-order nets, the frame to which the results of the conventional geodetic surface operations can be tied, thus leading to a homogeneous and unambiguously defined presentation of both the geometric and the physical parameters determined by geodetic operations. The conceptual approach is paralleled with the description of programmes now in progress, including some quantitative statements about the contemplated schedule and the expected accuracies.

The mechanical revolution of the past created measuring techniques which under laboratory conditions enable us to measure linear dimensions to parts in 10^8 and relative directions to parts in 10^7, while the current electronic revolution provides the means to generate and measure time sequences to parts in 10^{14}. Applied geodesy, which depends decisively on precision metrology, has profited accordingly in the development of its measuring instruments. In addition, the electro-optical length measuring capability has filled a gap in the arsenal of geometric measuring concepts which was formerly restricted to observing directions, aside from the cumbersome methods for measuring occasional, relatively short base-line distances. Fully as important as the means for executing relative gravity measurements with increased precision and speed is the recent development of instrumental capability to measure absolute gravity readily and with high accuracy.

Hand in hand with increased precision of the instruments, progress has been made in simplifying the corresponding operational procedures, thus providing to the geodesist and surveyor economical methods of decisively increased accuracy.

In the data reduction phase the electronic computer has made possible and practical the adherence to rigorous statistical treatment with large amounts of information in the reduction of hybrid measuring systems. With the more recent desk-size version, an economical tool for the rigorous adjustment of lower order surveying operations has become available.

In conceptual as well as practical sense, these developments not only provide new capabilities for the establishment of national control networks, but also create a need for the improvement in accuracy of such existing networks, in order to make them responsive to the traditional requirement that fundamental control nets can be used as constraints in the reduction of lower order survey operations.

Collectively speaking, this modernization of the techniques of applied geodesy can be considered to be a reformatory trend in classic geodetic measuring concepts. The increase in geometrical strength from the added capability of measuring directly the distance between stations, as well as the increase in the performance of the measuring instruments, unquestionably result in higher precision of the end-products of the geodetic operations, aside from the improved economy of the associated field procedures. However, these developments still leave the geodetic discipline in its traditional status and with its limitations. The corresponding measurements lead only to a local geodetic datum and the results, in terms of horizontal positions and elevations, are determined only relative to such a specific datum to which are referred the system of astro-geodetic plumb-line deflections and resulting relative geoid undulations as well. Thus, the reformatory trends present themselves as improvements of the traditional geodetic concepts. However, in addition an essentially different and almost revolutionary change has taken place in the geodetic discipline with the advent of the close-to-earth man-made satellite (1). Satellite geodesy has provided theoretical geodesy with new conceptual means to reconceive the approach to its fundamental mission. Moreover, satellite geodesy has introduced into the field of applied geodesy still more new measuring concepts and techniques. Nevertheless, it should be understood that satellite geodesy has not altered the basic goals of the geodetic discipline. Rather, it has provided the tools to accomplish such a mission with methods requiring a minimum of *a priori* hypotheses. In other words, satellite geodesy has overcome the limitations of classic geodetic measuring concepts, thus enabling the geodetic discipline, for the first time, to solve its fundamental problem. This problem is the determination of the geometry of the physical surface of the Earth including the surface of the oceans, and the description of the gravitational field associated with the Earth's mass and bounded by that surface, in a common unambiguously defined co-ordinate system, with a minimum number of *a priori* hypotheses. Obviously such a development must influence almost all of the principal phases of the geodetic mission, including, in a significant way, the establishment of national control networks.

It therefore appears that critical analysis of the process of originating or updating a national control network must, if only for very practical reasons, take into account two fundamentally quite different developments. On one side, the coming of age of the methods of satellite geodesy must be recognized by accepting their geometric and gravimetric results. On the other side, the increased accuracy of classic geodetic operations, an answer to the growing engineering and scientific requirements, places a demand for higher accuracy on the fundamental geodetic reference frame as manifested in a national control network.

POTENTIAL OF SATELLITE GEODESY

Dynamic satellite geodesy

From a strictly conceptual standpoint dynamic satellite geodesy has the capability of solving the fundamental geo-

[1] The original text of this paper, prepared by H. H. Schmid, Director, Geodetic Research and Development Laboratory, Coast and Geodetic Survey, Environmental Science Services Administration, Rockville, Maryland, and submitted under items 8 and 10, appeared as document E/CONF.57/L.16

detic problem by providing a system of geodetic control covering the entire Earth, i.e. by establishing on all continents and islands the three-dimensional positions for selected points, in a single mass-centred co-ordinate system. Simultaneously with the determination of the satellite tracking station geometry the lower order terms of the gravitational field are determined. Thus, results are obtained which constitute the fundamental parameters necessary for solving the two principal tasks of geodesy: the determination of the spatial variations of the topography of the physical surface of the Earth, and the determination of a mathematical model for the gravity field associated with the Earth's mass and dependent on its distribution. The physical surface of the Earth is the outer boundary layer of this mass. The idealized ocean surface, that is to say that surface which would be formed if only gravity acted upon the water bodies, constitutes by definition an equipotential surface (the geoid) and represents for applied geodesy the most useful materialized exhibition of the gravity field over two-thirds of the surface of the Earth (mean sea level). It is therefore quite logical to demand the compatibility between the geometric and gravitational results in geodesy, in terms of an unambiguously defined reference system. The ability of the dynamic method to provide such an answer is the reason for the early attention given to this approach and is reflected in the programme conducted by the SAO, applying optical satellite tracking referenced to the right ascension-declination system, and in the probably most extensive and still progressing programme of this nature by the United States Naval Weapons Laboratory using the Doppler method.

For dynamic satellite geodesy the significance of the artificial satellite is the fact that its orbit is created by the gravitational field of the Earth and the geometry of this orbit is therefore a function of the gravitational force field, related intimately to the general distribution of the Earth's mass and particularly to the centre of mass.

The measuring concept of dynamic satellite geodesy is to observe certain geometrical parameters functionally related to the satellite and specific stations of the Earth. These measurements are mainly time related directions to the satellite referenced to the surrounding stars, that is to say directions observed by photogrammetric methods with respect to the right ascension-declination system, and time related distances by laser or electronic ranging. In other words the distances between the observing station and the satellite, referenced to UT1, are measured, or the time related rate of change of these distances is observed using the Doppler effect, thus essentially determining the relative velocity vector of the satellite with respect to the observation station.

The data reduction process begins with the utilization of the quantitative values of the gravitational field in the form available from the body of conventional geodetic knowledge. With the so-called initial orbital conditions, that is to say by assuming certain orbital elements for a specific epoch, the spatial positions of the satellite can be computed for any number of selected instants of time, by making allowance for forces acting on the satellite in accordance with the assumed gravitational field. Thus, by applying our basic knowledge of celestial mechanics and potential theory, a model of the orbit is computed. In other words, if the gravitational field were identical with the one assumed and if the initial orbital conditions were correct, such a satellite would, in the absence of further perturbing forces, follow an orbit in accordance with the above outlined computations.

Secondly, one accepts the positions of the tracking stations as computed from conventional geodetic surveys. It is only necessary to transform the corresponding ellipsoid-centred, Earth-fixed Cartesian co-ordinates with the help of the known values for precession, nutation, polar motion and UT1 into inertial co-ordinates, an operation which can be executed with the required accuracy. Thus a model is obtained for the geometry of the tracking station locations and the satellite positions, both as functions of UT1. It is now possible to compute the values at a selected time of geometric quantities existing between the corresponding satellite position and any one of the tracking stations, such as, for instance, directions, ranges or relative velocity vectors. These, as one may recall, are the quantities which can be measured by the various optical or electronic tracking systems.

Assuming for the moment flawless measurements, one would expect the measured values to agree with the computed values to the extent that all the assumptions made in obtaining the computed quantities are correct. In other words, if, and only if, the assumed initial orbital elements, describing as a possible choice the satellite's position and its velocity vector at a certain epoch, the forces acting on it derived from the assumed gravitational field and the assumed locations of the tracking stations in terms of mass-centred positions were all flawless, then the difference between the observed and the corresponding computed quantities would constitute a zero vector. Conversely, one can obviously state that the actually obtained difference vector, which will, in general, not be a zero vector, is a quantitative measure of the flaws in the originally made assumptions. Carrying this conceptual approach to its logical conclusion, it is only necessary to measure as many such quantities as there are assumed parameters and to solve the corresponding system of observation equations. The corresponding roots are corrections which transform the originally assumed parameters into their final values. Because second order terms are neglected in the resulting system of linearized equations, it is necessary to provide for an iteration cycle in the computations.

There are however practical difficulties. First, it is necessary to realize that each specific difference between a computed and measured quantity is the sum of as many individual discrepancies as there are imperfectly assumed parameters involved in its determination. To the extent that small changes in the various assumed parameters produce similar changes in the "computed observations", the numerical solution is impaired in its ability to correctly resolve the individual difference vectors into specific error contributions, and consequently a significant numerical solution for the parameter corrections is correspondingly impaired. Statistically expressed, the parameters are correlated, weakening the significance of the inversion of the corresponding equation system and hence the determination of the parameters corrections. The situation is aggravated by the fact that not only forces produced by the gravitational field, but also such factors as time-variable solar radiation pressure, drag, magnetic field forces, etc. influence the shape of the satellite's orbit and must be mathematically modelled, thus increasing not only the number of parameters to be determined, but increasing as well the likelihood of undesirable cross correlation.

Secondly, the physical process of executing the necessary

observations is affected not only by random errors, but by systematic error sources, which must be considered, demanding the introduction of further unknowns for the purpose of simulating such biases.

The principal remedy for this dilemma is sought by incorporating extremely large amounts of information into a least-squares solution, solving simultaneously for all of the necessary parameter corrections. This approach is dictated not only by statistical reasoning, but because the gravitational potential is mathematically given as a triple integral extending over the entire Earth, leading to a corresponding infinite number of spherical harmonic coefficients, thus asking ideally for an infinitely large number of satellite observations distributed evenly over the entire Earth. In practice, one must compromise with a small number of satellites distributed as well as possible over a wide band of inclinations, each tracked from as many tracking stations as economically feasible. In turn the infinite series of spherical harmonic coefficients must be truncated, a procedural step whose influence on the significance of the final result cannot be readily estimated. There exists, however, little doubt that the uneven distribution of tracking data (there are still large areas in the world over which no satellite data have ever been obtained) causes larger deficiencies in the results than the theoretical shortcomings.

A more recent development which replaces the extension of the geopotential in the spherical harmonics with the potential of a simple layer of unknown density (2), promises to overcome some of the deficiencies of the former approach. Not only is the new approach more suited to combine surface gravity measurements with satellite data but the approach based on the boundary value problem of physical geodesy leads to a surface integral whose integrand can be shown to be primarily affected by the density distribution below the satellite and in the close neighbourhood of the sub-satellite point. Thus, by suitably choosing the dimensions of the selected surface elements, the method can be made to be more responsive to the actual distribution of both satellite and surface data. However, the need to replace the surface (double) integral by a corresponding double summation of the influences of a finite number of average densities as associated with a corresponding number of surface elements constitutes again a procedural compromise whose influence on the determination of the exceedingly large number of individual unknown parameters cannot be readily judged.

Other models for the gravity field, using either Stokes' function or applying buried masses (3), (4), differ in subtle details from the former but are confronted in principle with the same difficulties when it comes to problems concerned with the quantity, quality and distribution of data.

These analysing remarks are in no way intended to detract from the remarkable results obtained by the method of dynamic satellite geodesy. Probably close to a hundred tracking station locations around the globe have to date been determined in a mass-centred co-ordinate system using predominantly the Doppler method (5), with a relative accuracy approaching ± 15 m in all three co-ordinates. A model for the gravitational field composed of harmonic coefficients up to the 12th degree and order has been computed leading to gravity with an accuracy of at least ± 15 mgal. Intercontinental distances, which before the satellite age were assumed to be known geodetically to within about ± 100 m were proved to be wrong, sometimes by as much as almost 10 times that amount. Geoid undulations, formerly assumed to be as large as 400 m, are now known from satellite data not to exceed significantly the ± 100 m limit. The international reference ellipsoid adopted in 1924 by the IAG turned out to have an equatorial radius about 250 m too large. Its flattening of 1/297 must, as satellite data indicate, be replaced with a value close to 1/298.25. Thus dynamic satellite geodesy by itself has brought the geodetic discipline a considerable step closer to the goal of determining an accurate world-wide reference system (6).

On the other hand, the aforementioned theoretical as well as practical limitations of the method indicate the need for further investigations, predominantly to assure that the individual geometric and gravitational parameters, which in dynamic satellite geodesy are obtained jointly, are not affected by systematic errors to such a degree as to contradict the statistically obtained estimates of their precision. The primary and most desirable goal in this respect is to free the dynamic solution of as many parameters as possible. Such an approach will not only reduce the hard to satisfy "hunger for information" characteristic of multiparametric solutions, but will also effectively counteract the unfavourable influence of correlation between adjusted parameters, a source of undisclosed systematic errors.

Geometric satellite triangulation

One of the possible ways to attain this goal is to determine the station locations, that is to say the geometric parameters, by a strictly geometric method, as distinguished from the physically conceived approach of dynamic satellite geodesy. The relevant method has become known as geometric satellite triangulation. The significance of the method is based on the fact that it allows the determination of the three-dimensional geometry between any number of selected points on the solid surface of the Earth with a minimum of *a priori* hypotheses, specifically without reference to either the direction or magnitude of the force of gravity.

The satellite is used strictly as a high-elevation target and no recourse is made to its orbital characteristics aside from predicting approximate observing conditions. Conceptually speaking, the satellite is photographed against the background of the fixed star field simultaneously from at least two stations, thus determining its directions in terms of right ascension–declination and UT1, as seen from the observing stations. When such observations are made with respect to at least two satellite crossings, which should differ in their aspects as much as is practical, simple geometric principles allow us to compute the spatial direction between the observing stations. By establishing a pattern of station triangles over the Earth, the three-dimensional positions of the corresponding stations can be computed. Detailed description of the method can be found in (7), (8) and (9). Aside from the already mentioned independence of the method from geophysical hypotheses, the practical significance of geometric satellite triangulation is based mainly on the following factors.

The method does not depend on the execution of absolute measurements but obtains its results by interpolating the observed directions into the strictly geometric reference information as given with the right ascension–declination values from a chosen star catalogue for a certain epoch. It is significant that this interpolation process also eliminates the first-order effect of refraction,

thus rendering the method essentially free of problems of atmospheric propagation (10), which affect adversely most absolute measuring systems. In the data reduction process, it is obviously necessary to consider influences such as non-linearity of scales and lack of perpendicularity of comparator axes, radial and de-centring distortions of camera lenses, astronomical and parallactic refraction (the latter due to the finite distance of the satellite), scintillation, satellite phase angle (a function of the satellite's size, reflectance characteristics and the relative geometry between the sun, the satellite and the tracking station), diurnal aberration, light travel time, proper motion, magnitude and spectral characteristics of the reference stars, pole wandering etc. All these perturbations can either be measured independently with sufficient accuracy, be determined from the recorded star field or be computed during the triangulation process. Most of them produce only small effects in the process of geometric satellite triangulation, requiring in the mathematical formulation of the data reduction procedure either differential rotations or translations. The demand for clock synchronization to better than 100 μs for the widely separated stations is actually accomplished to better than ± 10 μs by either carrying clocks having long term high stability from station to station or by using satellite signals as emitted for instance by the Navy Transit satellites or by transmitting, where geographically possible, clock synchronization signals via a geo-stationary satellite.

While the precision of the method can be statistically improved by increasing the number of stars and satellite images used for the interpolation process and by the number of observed satellite crossings, its accuracy is limited to the accuracy inherent in the reference system of metric astronomy. Using photogrammetric cameras with moderately wide angles of view, as a compromise with somewhat restricted focal length, the method can be based on the most accurate star catalogue, the FK-4 system, which is labelled with an accuracy claim of one part in 4 million. Theoretical error studies show that the present instrumental and observing techniques should produce the triangulation result with an accuracy of better than one part in 2 million in terms of the station-to-satellite distance. Because of some unavoidable degradation, the results so far obtained indicate an optimal accuracy approaching one part in 1.5 million. Preliminary yet extensive reductions, using data obtained from the presently executed world net observations, lead to the fair assumption that the final three-dimensional positions of the forty-four stations, which are spread rather evenly around the globe, will be determined with an RMS error of less than ± 7 m in all three co-ordinates. The scale will be determined from high precision traverses, a combination of astronomically observed directions with optic–electronic length measurements. The accuracy of the resulting chord distance between pairs of satellite stations, limited mainly by atmospheric propagation effects, should be about one part in a million.

Introducing the final result of the world-wide geometric triangulation with its associated covariance, into the reduction of the aforementioned method of dynamic satellite triangulation, three necessary translations are computed in order to relate the origin of the strictly geometric triangulation system to the centre of mass. Simultaneously the general features of the gravitational field (long-wave geoid undulations) are obtained, compatible with the geometry of the tracking stations, independently determined by the method of satellite triangulation. In addition to the opportunity of obtaining a comparison between the dynamic scale, which is derived as a function of the product of the gravitational constant and the Earth's mass, and the geometric scale, as obtained from the directly measured distances, the combined result will provide the essential information necessary to compute the dimensions of a world reference ellipsoid, the fundamental figuration for a geodetic world datum.

Present-day experience and preliminary results indicate this result to be accurate in its geometric parameters to at least one part in a million in terms of Earth dimensions and to about ± 10 mgal with respect to the gross features of the gravitational field.

Further reduction of the number of parameters in the dynamic solution would be possible with the launching of a strictly gravitational satellite, that is a satellite consisting of a shell surrounding a free-floating mass. The latter, being affected only by the gravitational field, will follow a pure gravitational orbit, while the outer shell, exposed in addition to a host of non-gravitational perturbing forces, must be kept from touching the inner satellite by suitable thrusting. The model for the reduction of the corresponding tracking data could then be unburdened from all parameters now necessary to simulate mathematically the non-gravitational perturbing forces, thus providing a result of improved significance insofar as the investigation of the gravitational field is concerned.

Based on today's technology, satellite geodesy can make further contributions by filling in the detail into the frame provided by the geometry of the world net and by the general shape of the gravitational field as obtained from the application of the principles of dynamic satellite geodesy.

Hence, the establishment of additional three-dimensional control points on the continental landmasses is the logical continuation of the world-wide geometric satellite triangulation programme. The techniques of observation and data reduction are identical to those used for the establishment of the world net. In order, however, to obtain increased relative accuracy of ± 1.5 to ± 2 m for the three-dimensional positions, a target satellite (balloon) with approximately 1,500 km elevation is necessary, allowing the establishment of a densification net with stations separated by about 1,000 km. Such stations would, in all unsurveyed areas of the world, serve as geodetic control for mapping projects based on satellite photogrammetry and would provide for all further developed land areas the frame to which conventional geodetic measurements can be tied.

Such an approach highlights the economic significance of geometric satellite geodesy, because the first order triangulation system need not, as before, be established as a net covering a large area in order to determine the parameters of a specific geodetic datum. Consequently the first-order net can be executed sequentially in response to engineering and other social needs. In other words, the geometric satellite densification triangulation constitutes the net of "zeroth order" into which all other survey operations are interpolated. Similarly, off-shore or more distant islands can be tied into a consistent geodetic reference frame, providing the necessary accuracy for, particularly, precision navigational requirements.

With respect to the perfection of our knowledge of the short-term undulations of the geoid, the method of satel-

lite altimetry to the ocean surface presents a theoretically attractive and practical approach (1), (11), (12). In the earlier discussion about dynamic satellite triangulation it was mentioned that the tracking of satellites allows the determination of the long-period features of the geoid. Applying such knowledge, it is then possible to determine the geometry of an orbit from tracking data, even in areas where such observational data are incomplete. If such a satellite frequently measures the distance between its orbit and the sea surface, either by radar or laser pulse techniques, it is possible to obtain the geometry of instantaneous ocean profiles. From repeated observations it should be possible to filter out such effects as solar and lunar tides, as well as sea states, leaving as a close approximation the geometry of an equipotential surface, the geoid. Theoretically speaking, such data can be used to improve the originally determined orbit and in turn provide improved absolute positioning of the obtained geoid profile with respect to a mass-centred reference system. Today's technology should provide ranges and therefore short-term ocean surface variations to at least ± 2 m and absolute geoid undulations to better than ± 10 m. This technique would replace the slow, relatively inaccurate and costly methods of sea surface gravity measurements. While such knowledge in its entirety would provide additional information for determining the best-fitting world ellipsoid, local results along the continental shelves, although more difficult to reduce on account of the effects of coastal topography, would provide the much demanded information for geophysical exploration in such areas.

Present potential of geodetic surface operations

Before making an attempt to develop a coherent concept for the establishment of a geodetic world datum and of national control networks in terms of modern geodesy, it is still necessary to investigate the present potential of the geodetic surface operations which provide the detailed information in a geodetic control system of continental dimensions.

Specifically it is necessary to make some statements concerning the accuracy of the determination of astronomical latitude and longitude and of the measurement of relative and absolute gravity. In addition, some quantitative estimates must be made of the internal accuracy of the classic first-order triangulation, reinforced by high-precision traverses, and of the accuracy of ellipsoidal height as derived from first-order levelling in conjunction with detailed geoid determinations.

From the reduction of large numbers of actual field observations, estimates for accuracies obtainable in the various classic geodetic operations can be deduced. Such estimates are:

(*a*) For astronomical latitude and longitude observations, $\pm 0.2''$ (arc) equivalent to ± 6 m positional uncertainty on the surface of the earth;

(*b*) For absolute surface gravity measurements, ± 2 mgal (probably even better in the near future) equating to about ± 7 m in elevation;

(*c*) For extended and traverse supported first-order triangulation systems an expression for the obtainable accuracy of one part in 200,000 $\sqrt[3]{S/50}$ (S in km) appears realistic, resulting for:

800 km 1:500,000 = ± 1.6 m
1,000 km 1:540,000 = ± 1.9 m
1,500 km 1:620,000 = ± 2.4 m
3,000 km 1:780,000 = ± 3.8 m

(*d*) For detailed geoid differences ± 4 m and for first-order levelling over continental distances ± 0.2 m to ± 0.3 m (relative accuracy) where the possibility of an undetectable systematic error in the amount of ± 1 m can not be entirely ruled out. Consequently, the accuracy of ellipsoid heights over large distances can be assumed to be about ± 5 m.

Rationale for a modern world-wide geodetic control system

The conceptual approach

Based on the qualified and quantified information given in the preceding paragraphs a rationale can now be developed for establishing by satellite geodesy a world-wide geodetic control system, the modern superstructure for both the geometrical as well as the geophysical tasks of geodesy.

The sequential steps necessary for such an approach would be initiated with the determination of the three-dimensional positions of stations forming a pattern girding the globe by geometric satellite triangulation.

Since these station positions result from direct interpolation into the reference system of metric astronomy the Cartesian co-ordinate system describing the positions will have one axis parallel to the Earth's rotation axis, the direction to the pole of metric astronomy. The origin of the co-ordinate system however is arbitrary. Tracking, as a second step, satellites from the geometrically positioned stations permits, by the methods of dynamic geodesy, the determination of the co-ordinates of the Earth's centre of mass and the long-term undulations of the geoid from the geometry of the observed orbits. The origin of the Cartesian co-ordinate system can then be translated accordingly to coincide with the mass centre. The resulting co-ordinate system will then be compatible for both geometrical and geophysical investigations. Satellite altimetry increases the spatial resolutions of the dynamic method by tracking out ocean profiles, thus determining the short-term undulations of the geoid. Thus, both the positions of the satellite tracking stations and a large number of points of the geoid in the ocean areas become known in their three-dimensional positions relative to the centre of mass in a co-ordinate system, one of whose axes is the rotational axis of the Earth for a certain epoch, while the other two axes lie in the corresponding equatorial plane. Furthermore the corresponding data reduction process will lead to a geodetic world datum by fixing a specific equatorial radius and a specific value for the flattening of the world reference ellipsoid.

Satellite densification networks covering continental land masses and established as integral parts of the geometrically conceived world net will then serve as zero-order nets for the interpolation of all geodetic surface operations. Primarily the zeroth-order net serves as a frame for the adjustment of the classic first-order systems which establish the substructure of national geodetic control network and provides anchor points for the determination of detailed geoid information under the continents.

Such additional stations are determined either from

strictly geometric observations or by applying the principles of dynamic satellite geodesy to short-arc reductions or by a hybrid solution employing both methods together. Thus in applied geodesy, both geometric as well as gravimetric surface observations can be reduced worldwide to a homogeneous and unambiguously defined reference system which is characterized by a minimum of hypothetical assumptions, providing at the same time reliably defined estimates for both the internal precision and the absolute accuracy of the geodetic end products.

In order to use the results obtained by satellite geodesy as constraints in the reduction of the conventional geodetic surface operations one must however acknowledge an unavoidable consequence concerning the requisite accuracy of the superstructure. Classic geodetic measuring concepts are based on the sound demand that any lower-order survey be tied to a more accurate higher-order reference frame. From a statistical standpoint this request can be translated into the demand that the variance-covariance matrix of the higher-order system must, as a lower limit for accuracy, be at least compatible with the internal precision of the lower-order measurements. For all practical reasons the accuracy of the higher-order system should be substantially better (by a factor of two to three) than the subordinated survey system, in order to provide a rigorous constraint in the reduction of the lower-order system.

Present status

Establishment of a world-wide geodetic reference system

With the world-wide geometric satellite triangulation programme, at present in progress as a co-operative venture between the Department of Commerce (ESSA–C&GS) and the Department of Defense (DIA), a network of forty-four stations as shown in figure I will be fixed. The observational phase of the programme will be concluded by the end of June 1970 and the final result is scheduled for the end of June 1972.

The large amount of reductions so far executed have, although the corresponding results are only preliminary, enabled us to develop a new generation of reduction programmes reaching a level of sophistication to be consistent with an ultimate accuracy potential of one part in 2 million. In addition, this data-reduction system yields stepwise statistical information with respect to all error contributions, enabling us to shed light on the validity of the *a priori* assumed precision of the individual error sources. Based on a limited amount of reductions performed with the new programmes there can be no doubt that the final result in the world net for all stations for which no deficiency in observational data exists, will have an accuracy of at least one part in 1.2 million, that is to say, a positional RMS error of somewhat better than ± 6 m, specifically ± 5.0 m for the horizontal components and at least ± 8.5 m in direction of height.

These results are therefore expected to be compatible with the accuracies obtainable for astronomic latitude and longitude observations and absolute gravity measurements, given in the previous section under (*a*) and (*b*). The expected result will correspond to the first step, mentioned before, necessary in establishing a modern geodetic world datum. The compromises covering the choice of station locations, necessary mainly because of political considerations, will not impair the significance of the world net for practical application. However, the second step, the determination of the gravitational parameters can at present only be performed as an integral part of the geometric triangulation, to the extent that long arc satellite tracking (for periods of several days) has been executed either from stations of the world net or nearby stations, which can be tied to such stations reliably by conventional survey methods. The fact that the positions of almost all stations of the world net are being determined by the Naval Weapons Laboratory using Doppler tracking could lead to an alternate approach of tying together the results of geometric satellite triangulation and dynamic satellite geodesy. However, such a solution cannot at present be anticipated because of the security policy of the Department of Defense. The use of tracking data available from SAO stations is rather restricted because of the limited distribution of the SAO stations and especially because only a few of these stations coincide with stations of the world net or are close enough to be of value. However, there are two other sources of useful data available.

In quite a number of cases, Pageos and Echo II have been photographed in the world net programme by adjacent stations in two successive simultaneous events. The time differences between the successive events varies between 20 and 50 minutes, so that orbits of corresponding duration can be fitted through the observations, and the co-ordinates of the centre of mass of the Earth can be determined.

An error study devoted to this problem (13), including the extent to which errors in the gravity field introduce distortions, has shown that this information has sufficient strength to support significantly a solution for the determination of the gravitational potential of the Earth by combining, in addition, satellite-tracking data and surface gravity measurements in terms of the potential of a simple layer of unknown density (3), (14), (15). The contemplated solution will be based on $5° \times 5°$ surface gravity data in the form made available by the United States Air Force Cambridge Research Laboratory and Doppler measurements, obtained from the United States Naval Weapons Laboratory, Dahlgren, Virginia, via the NASA Geodetic Data Center (NASA–Goddard Space Flight Center, Greenbelt, Maryland). These tracking data refer to arcs for Geos 1, the BE-B and the BE-C satellites. The data are obtained from stations, most of which are close to world net stations or can be reliably tied by conventional survey to such stations. Thus by introducing the geometrically determined positions of the world net with their covariances into the solution, a presentation of the gravity field, including the position for the centre of mass, should be obtained, with an accuracy compatible with that of the station positions and of the surface gravity data. A final result of such a world datum can be expected by the end of 1972.

Establishment of a densification net in North America

Finally, a few remarks seem to be in order concerning the establishment of a satellite densification net on the North American continent, the area covered at present by the North American Datum 1927 (NAD).

Before the initiation of the observational programme for the world net, a satellite densification net made up of sixteen stations was established as shown in figure II. This system can be anchored in the three world net stations, Thule, Moses Lake and Beltsville.

In awareness of the significance of such a net, when considering a new adjustment of the basic geodetic information in that area, it is now contemplated to supplement the

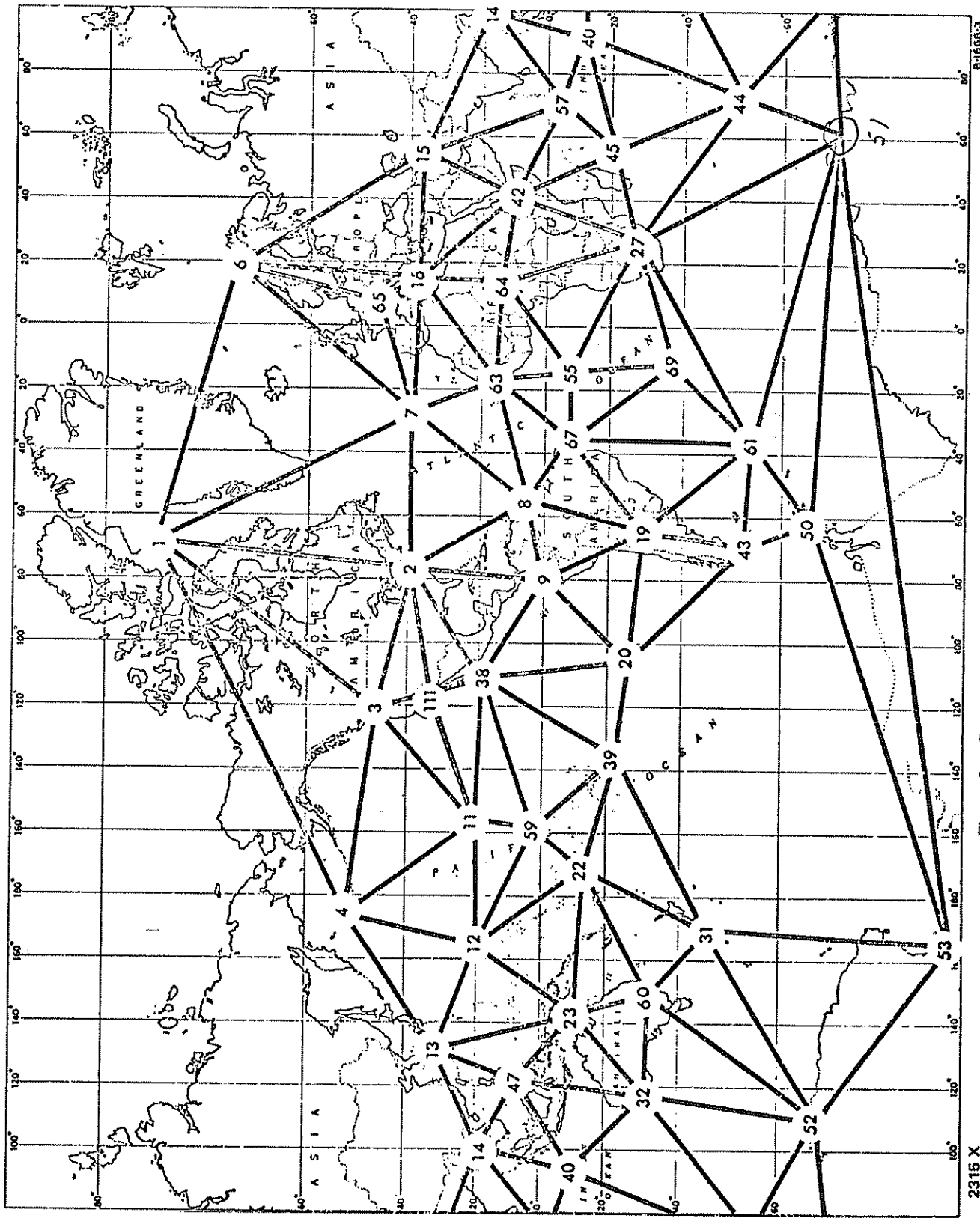


Figure 1. Geometric satellite triangulation world net

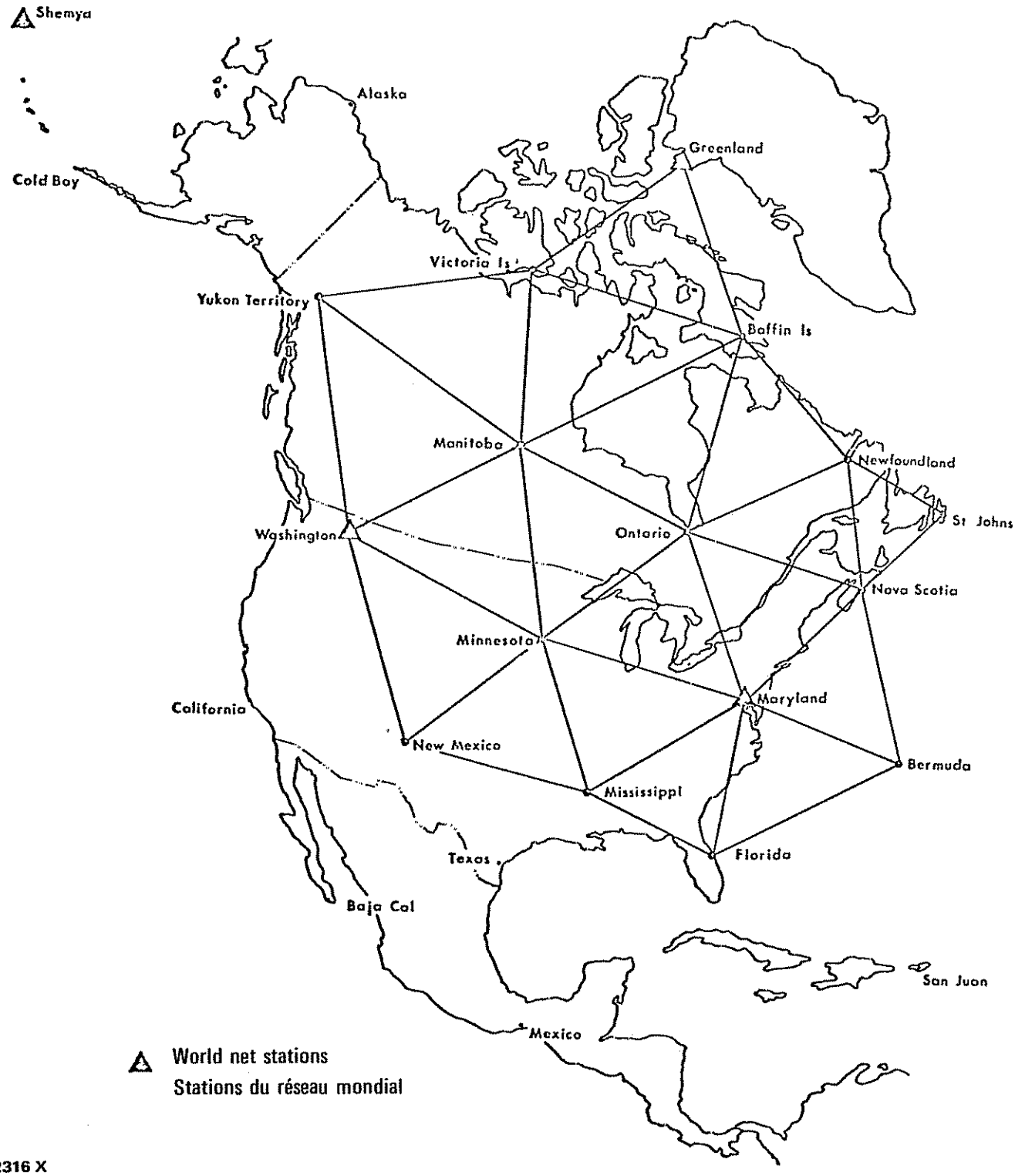


Figure II. Geometric satellite densification net in North America

earlier work by some additional stations. The final satellite densification net will, if these plans materialize, have the figuration shown in figure III, adding four more stations and strengthening the previous work, particularly in the area of eastern Canada. Furthermore, a tie to a fourth world net station, Shemya will be accomplished. Corresponding observations, hopefully as a co-operative effort with the Government of Canada, are scheduled for the period from July 1970 to June 1972.

The corresponding data reduction will, after the completion of the world net, be effected from July 1972 to June 1975. Thus by the middle of the 1970s the basic information will be available, enabling the establishment of a new geodetic reference system in North America during the latter half of this decade.

Unfortunately this densification net will fall short of an optimum solution with respect to both its coverage and its accuracy. From the standpoint of coverage it would have been most desirable to extend the densification net southward tying into the world net stations Revilla (Mexico), Quito and Surinam (northern edge of South America). Such a net would cover the entire area of the old NAD, and, what is more inportant, would avoid the unconstrained southern termination that now exists along a line formed by the stations Wrightwood (California)–Las Cruces (New Mexico)–Brownsville (Texas)–Valkaria (Florida)–Puerto Rico.

Considering the anticipated accuracy in the densification net, one must realize that the earlier observations were made with the 300 mm lens, a slight disadvantage when compared to the 450 mm lens now available. Much more serious, some observations in the earlier phase are slightly impaired, because at the time it was not known that minute orientation changes of the BC-4 system occur occasionally between the period separating pre- and post-star calibrations. An accordingly revised observational technique, which records FK-4 stars during the event, thus eliminating the above-mentioned error source, was not in use during the earlier phase of the densification observations. However there are a considerable number of events available in excess of the number needed. Provided sufficient data reduction funds are available it should be possible to replace undesirably affected missions, thus reducing the impact of any existing systematic error on the final triangulation result. Based on the preliminary reduction of a limited number of missions it appears reasonable to expect that the three-dimensional positions of the densification stations can be determined to at least ± 3 m in all components. The quality of observations in the future phase will be optimal, if only for the simple reason that the field crews enter this phase with the experience of the world net behind them. However, the accuracy of the triangulation result of this programme phase will be impaired, because of the failure to make available an optimal target. After the demise of the Echo I and II satellites only the Pageos satellite is available, which, with an average slant distance of 6 million m yields results degraded by a factor of three, compared with results obtainable with a balloon satellite at the optimum height of 1,500 km above the Earth. Thus, despite the improved methods of field observations and data reduction, the additional positions will probably have an RMS error no better than ± 4 m.

Consequently the over-all accuracy expected in the densification net in the area of North America will fail somewhat in supporting, as a zero-order net, the internal accuracy of the conventional first-order triangulation system in the conterminous United States, whose accuracies are expected to conform with the statement made in (c) above. However, since the portion of the NAD covered by the Canadian survey consists in large part of more or less isolated arcs the ± 3 m accuracy anticipated for the geometric satellite triangulation control stations within that area should provide a particularly meaningful and useful reference frame for the Canadian first-order triangulation system.

Summary and outlook

Geometric satellite triangulation provides the means for determining the three-dimensional positions of any number of points on the solid surface of the Earth. From practical error propagation considerations it can be shown that the present accuracy of the method is better than one part in 1 million of the station-to-satellite distance. In a global net, because of the large distances between islands, such stations are about 4,500 km apart, thus requiring station-to-satellite distances on the order of 6 million m, resulting in a positional accuracy of about ± 6 m. On continental land masses the practical application is limited by the minimal satellite height of about 1,500 km, a requirement for an acceptable satellite lifetime. Thus the relative accuracy of stations established in such areas is about ± 1.5 to ± 2 m in all three positional components.

The corresponding co-ordinate system is characterized in that one of its axes is parallel to the rotation axis of the Earth for a certain epoch, while its origin co-incides in principle with one of the stations, which can be arbitrarily selected.

From the evaluation of long-arc orbits tracked from these stations and selected in their distribution to cover essentially the whole Earth, both the long-term undulations of the geoid and the position of the Earth's mass centre can be deduced by applying the principles of celestial mechanics and potential theory, preferably in combination with surface gravity measurements. The accuracy of these results can be expected to be compatible with the above-mentioned estimates for the accuracy of the geometric parameters.

Thus, an Earth-centred reference system is established for both the geometric as well as gravitational information, leading to a unified world geodetic datum or, if so desired, to best-fitting ellipsoids for particular areas. Geometric satellite triangulation, with three-dimensional densification nets, provides on continental land masses the frame to which conventional geodetic surface operation can be adjusted. Satellite altimetry has the potential to determine, in compatibility with the just-outlined reference system, the short-term geoid undulations over the ocean areas which an accuracy of about ± 2 m, thus complementing, particularly in the areas of the continental shelves the information established with national geodetic control systems.

A look into the future opens spectacular vistas of increased precision in measuring systems and higher accuracies of the derived results. These potentialities will necessitate a reformation of the basic goals of geodesy by replacing the concept of a static Earth with that of a dynamic Earth. In other words, the concept of a model Earth as a reference system to which the measuring results of applied geodesy can be related must be broadened by the rationale of a more nearly absolute reference system in

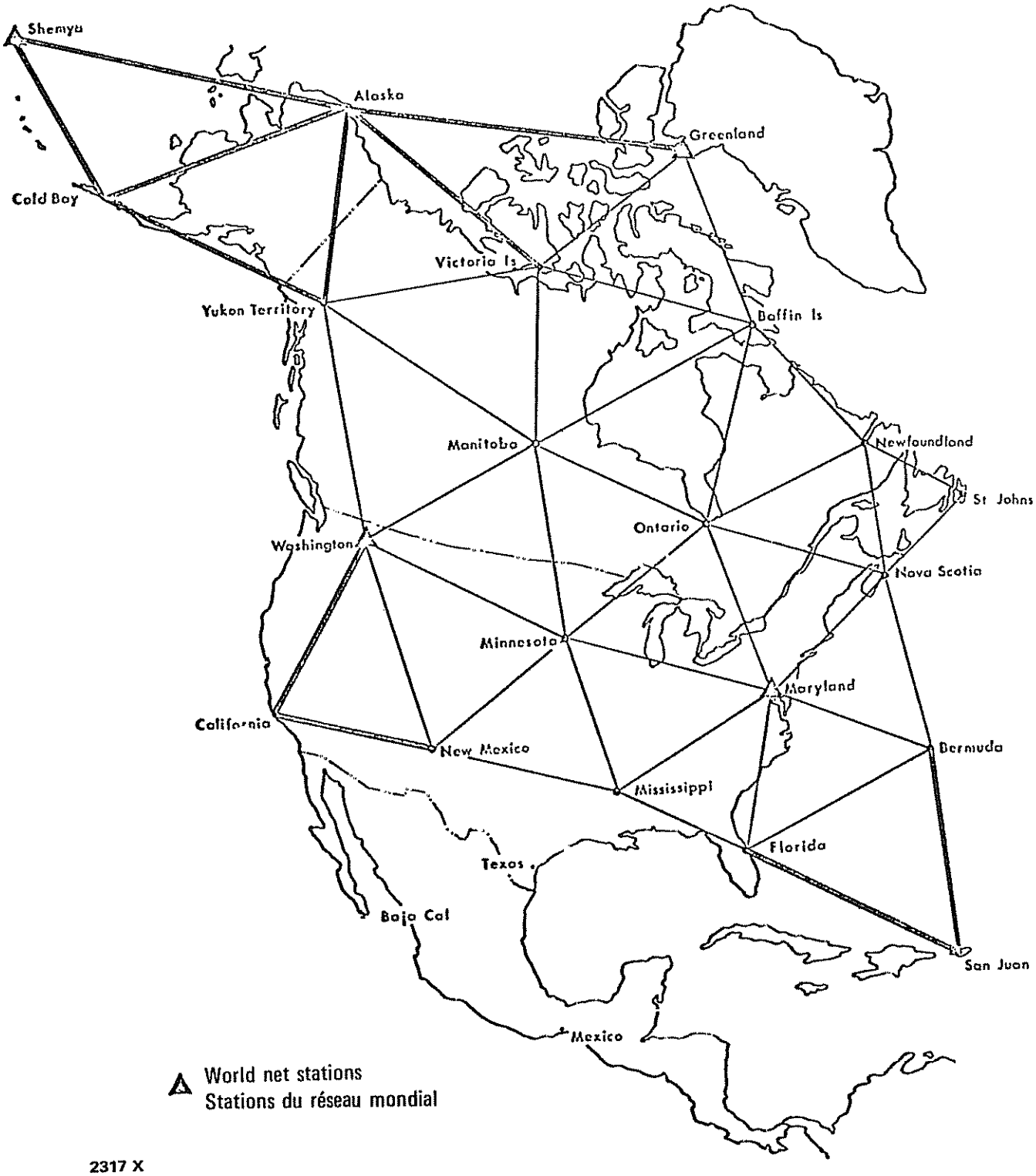


Figure III. Geometric satellite densification net in North America

terms of inertial space, relative to which the time-variable parameters of a dynamic Earth can be monitored. From a conceptual standpoint geodesy will then become increasingly interdisciplinary. On one side it will be linked to metric astronomy, particularly with respect to a fundamental reference system and to celestial mechanics principles. Its other connexions will be to various domains of geophysics which are concerned with short and long period time-variable changes of geometric and gravitational parameters of the physical Earth, covering the entire spectrum from local to global effects, thus opening possibilities for more sophisticated interpretations of geophysical phenomena.

The present methods of satellite geodesy have error limits which do not allow a monitoring of the dynamic behaviour of the solid Earth. In order to satisfy the corresponding requirements, an improvement in absolute accuracy by a factor of 100 appears necessary. Conceptually speaking such accuracies are meaningful only if a strictly geometrically defined reference system can be physically established outside of the Earth from which the dynamic Earth can be monitored.

Present developments in radio-astronomy promise, by use of interferometric techniques, the possibility for establishing an improved system of metric astronomy by determining the right ascension–declination of a sufficient number of star-like objects (quasars) with an accuracy approaching 0.001 second of arc. By reversing the method both the spatial directions and distance between widely separated tracking stations can be determined to perhaps decimetre accuracy (16), (17). If such an approach could be applied to a system of remote satellites, let us say to a system of at least three geo-stationary satellites, the geometry of the resulting triangle could be continuously determined relative to the improved fundamental astronomic system. These geo-stationary satellites would in turn be the tracking stations from which close-to-Earth satellites are observed. The extended view from the geo-stationary satellites would provide the means for considerably extended tracking coverage and at the same time increase the tracking accuracy at least to the decimetre range, partly by eliminating the tropospheric refraction problem. When, in turn, such close-to-Earth satellites are tracked from the hyper-precisely positioned Earth stations, the motions of the Earth, as expressed for instance by polar wandering and Earth rotation, could be continuously monitored with accuracies far better than those obtained from presently applied techniques. Small changes in the geometry between the tracking stations could be resolved, providing information required to study such phenomena as continental drift, sea-floor spreading and other geological movements within a continental mass. Furthermore, greatly improved satellite altimetry would open an approach for determining the deviation of the sea surface from an equipotential surface, thus supporting the increasing demand for the study of the dynamics of the oceans.

Aside from the unquestionably existing formidable problems in precision metrology and the considerable economical expenditures necessary for the implementation of such systems, there appears from a conceptual standpoint, the possibility of developing logically the methods of satellite geodesy into an approach to study the dynamic phenomena of the solid Earth and ocean physics (18).

REFERENCES

(1) Schmid, H. "Reformatory and revolutionary aspects in geodesy", *Bulletin géodésique*, No. 80, June 1966.

(2) Arnold, K. "Skizzierung einer Methode zur Bestimmung des Schwerefeldes der Erde aus Satellitenbeobachtungen", *Gerlands Beiträge zur Geophysik*, Bd. 72, S. 277, 1963.

(3) Koch, K. R. and F. Morrison. "A simple layer model of the geopotential from a combination of satellite and gravity data", *Journal of Geophysical Research*, vol. 75, No. 8 (in print), 1970.

(4) Wong, L., G. Buchler, W. Downs, R. Prislin and W. Sjogren. "Dynamical determinations of mascons on the moon", 50th American Geophysical Union Meeting, Washington, D.C., 1969.

(5) Anderle, R. "Geodetic parameter set NWL-5E-6 based on Doppler satellite observations", *Proceedings of the Conference on the Use of Artificial Satellites for Geodesy*, vol. II, edited by G. Veis, Athens, 1967.

(6) Lundquist, C. A. and G. Veis. "Geodetic parameters for a 1966 Smithsonian Institution standard Earth", *SAO Special Report No. 200*, Smithsonian Institution Astrophysical Observatory, Cambridge, Massachusetts, 1966.

(7) Schmid, H. "Photogrammetry applied to three-dimensional geodesy", *Société Francaise de Photogrammétrie Bulletin No. 14*, July 1964.

(8) ———. "Application of photogrammetry to three-dimensional geodesy", *American Geophysical Union EOS*, vol. 50, No. 1, January 1969.

(9) ———. "A new generation of data reduction and analysis methods for the worldwide geometric satellite triangulation program", presented to the Annual DOD Geodetic, Cartographic and Target Materials Conference, Cameron Station, Virginia, October 1969.

(10) ———. "The influence of atmospheric refraction on directions measured to and from a satellite", *U.S. Army Engineering Research Note 10*, Corps of Engineers, Ft. Belvoir, Va., February 1963.

(11) ———. "A concept for an up-dated three-dimensional worldwide geodetic reference system", presented at the Fifth United Nations Regional Cartographic Conference for Asia and the Far East, Canberra, March 1967.

(12) Koch, K. R. "Gravity anomalies for the oceans from satellite altimetry", *Proceedings of the 2nd Marine Geodesy Symposium*, New Orleans, La. (in print), 1970.

(13) ——— and H. Schmid. "Error study of the determination of the center of mass of the Earth from Pageos observations", *Bulletin géodésique* (in print), 1970.

(14) ———. "Darstellung des Erdschwerefeldes in der Satellitengeodäsie durch das Potential einer einfachen Schicht", *Zeitschrift für Vermessungswesen* (in print), 1970.

(15) ———. "Eine Bestimmung des Schwerefeldes der Erde aus Satellitenbeobachtungen und Schweremessungen" (in print), 1970.

(16) Burke, B. "Long baseline interferometry", *Physics Today*, July 1969.

(17) Jones, H. "Geodetic ties between continents by means of radio telescopes", *The Canadian Surveyor*, vol. XXIII, No. 4, September 1969.

(18) National Aeronautics and Space Administration. "The terrestrial environment solid-Earth and ocean physics application of space and astronomic techniques", *Report of a Study at Williamstown, Mass.*, August 1969.

IMPACT OF A NEW WORLD-WIDE GEODETIC SYSTEM

Paper presented by the United States of America[1]

Geodesists have many goals, but there is one that is outstanding: it is the establishment of a unified world-wide geodetic system. In recent years, the geodetic community has been stretching, has been growing, has been co-operating in the largest international geodetic programme ever undertaken, and is now on the threshold of achieving that goal of a world-wide system. A few decades ago, this was just a concept. The generation immediately before us emphasized the unification of national into continental networks. Some of us who are approaching "the age of senior citizenship" can recall the enthusiasm shown by Bowie, Ross, Hough, Gigas and a host of others as they and their colleagues joined national networks into continental networks. Even though Bowie endeavoured to persuade others that the North American Datum of 1927 would be good for all time, he knew full well that geodetic networks are developed step by step through a series of approximations and refinements. Now that we are approaching the completion of another step in this long geodetic history, I am not so naïve as to suggest that it is the final step. It is, however, a major step and, perhaps, the most significant one so far.

Perhaps you have known of the plans and programmes for world-wide geodetic satellite networks. Many of you have followed the progress that has been made during the past few years. Within a few months, the observing programme on the world-wide geometric network will be completed. Plans have been made for establishing supplemental points on some of the continents. In Europe, a comprehensive programme has been under way for some time with supplemental points established in western Europe, the USSR, and northern Africa. Serious consideration has been directed towards similar efforts in Australia and South America. A co-operative programme is being planned in North America to provide the spacing of additional points required for the maximum utilization of existing classical triangulation.

Also, perhaps you have known of the progress being made on the measurement of a precise geodimeter traverse network for the purpose of scaling the satellite network and strengthening the existing horizontal control. These two major endeavours will be completed within the next few years, and it is time that we begin to consider the impact on the various aspects of surveying and mapping of this more accurate fundamental control.

One can determine three-dimensional, Earth-centred coordinates from the geometric satellite observations when combined with Doppler data from other geodetic satellite systems. The geometric network will be scaled by the precise traverse networks measured on at least four continents. The points in these networks, then, become super control for the existing triangulation. There is merit in describing this sequence of operations as a new adjustment rather than a readjustment. Adjusting primary triangulation to a framework of super-control points is quite different from the old continental-type adjustment. In the earlier method, even though the networks might be adjusted simultaneously, there was always a certain amount of distortion due to the accumulation of error through the extension of the net from its central datum point to the outer limits of the network. Through the use of these more precisely determined control points, the error accumulation will be constrained. There will be no mathematical distortion of the outer fringe due to the accumulated effect of errors from within. The completed new adjustment will be far more homogeneous with respect to internal accuracy.

In order that you may more fully appreciate the problems that have developed during the past 20 years and have led toward the necessity for planning this new adjustment, I wish to review rather quickly the development of the North American Datum as we know it today.

The earliest geodetic surveys were made along the coasts for the control of nautical charts. First, along the eastern seaboard, then the Gulf coast and then along the Pacific coast. The first official geodetic datum in the United States was adopted in 1879. It included surveys in the eastern and north-eastern states, selecting for the origin triangulation station Principio in Maryland. It was named the "New England Datum". The Clarke Spheroid of 1866 was used as the reference ellipsoid. By 1899 the transcontinental arc of triangulation had been completed. It followed roughly along the 39th parallel and connected the surveys of the west to the east. Also, by that time, other primary surveys had been extended to the Gulf of Mexico, connecting the earlier surveys along that coast. The New England Datum was thus extended to the south and west without any major readjustment of the New England Datum. In 1901 the expanded, or perhaps more explicitly described as extended, network was officially named the "United States Standard Datum". Triangulation station Meades Ranch in Kansas was designated as the origin. In a geodetic sense, Principio was still the origin. There had been no change in its position. The latitude and longitude of Meades Ranch, used in the definition of the United States Standard Datum, were merely the results of computations based on the westward extension of triangulation. In 1913, after the geodetic organizations of Canada and Mexico had agreed to reference their networks to the United States System, the datum was renamed the "North American Datum".

Let me interject a comment at this point that may be of interest to some of you. The topographic and hydrographic surveys which had been made along the coasts in the earlier years were referred to the old United States Standard or North American Datum. The courts still recognize the validity of that datum when considering problems related to seaward boundaries.

Now back to the history. By the mid-1920s, the difficulties associated with adjusting new surveys into the existing network had become so acute that plans were made for a total readjustment. Therefore, during the period from 1927 to 1932, all available primary data were adjusted into the system that we know as the North American 1927 Datum. Preliminary investigations of all astronomical data indicated that the geodetic position of Meades Ranch need not be changed. This was a matter of convenience, but you should remember that it was the

[1] The original text of this paper, prepared by C. A. Whitten, Chief Geodesist, Office of Geodesy and Photogrammetry, Coast and Geodetic Survey, Environmental Science Services Administration, Rockville, Maryland, and submitted under items 8 and 10, appeared as document E/CONF.57/L.18.

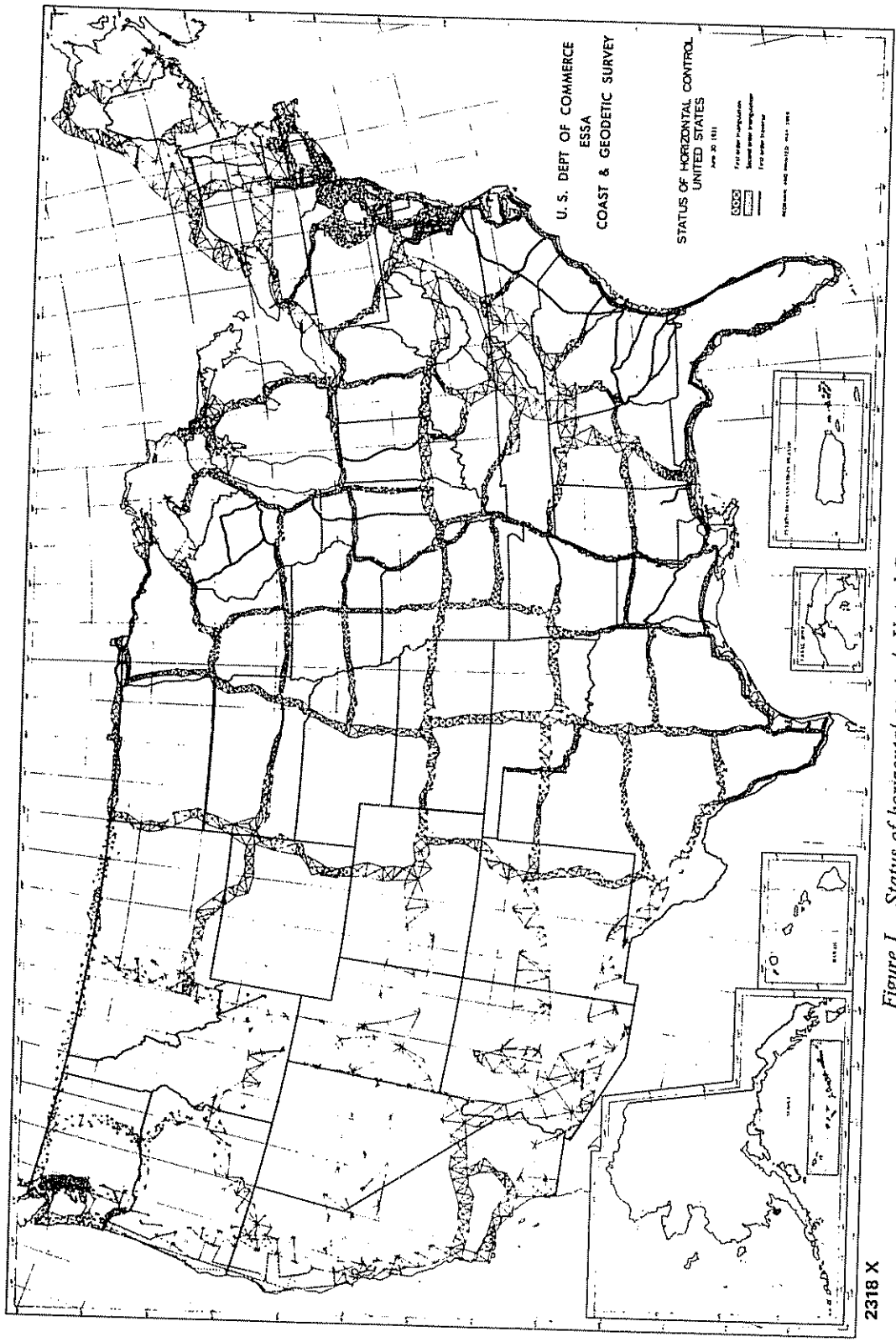
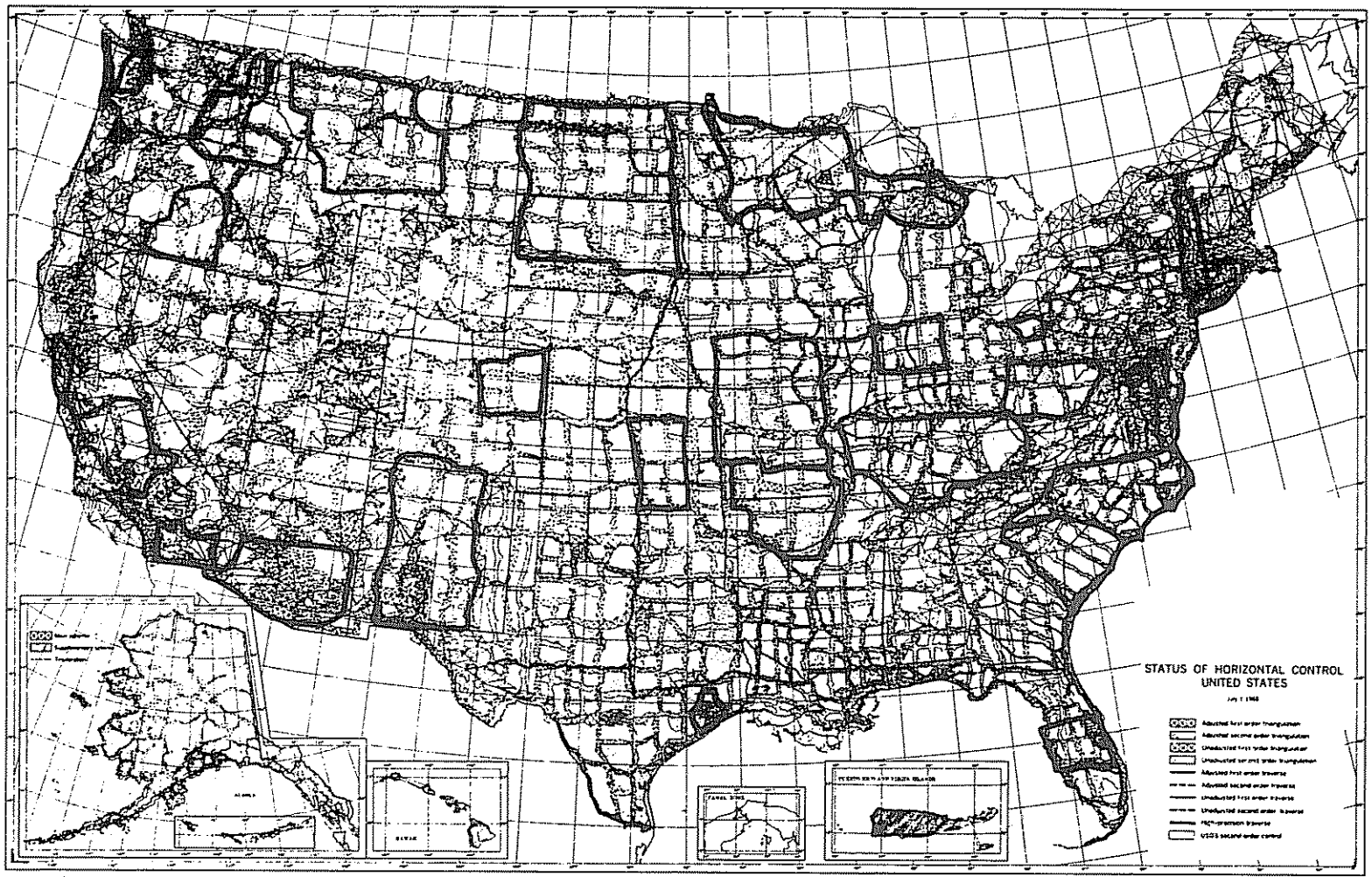


Figure I. Status of horizontal control, United States, 30 June 1931



2319 X

Figure II. North America—Horizontal control, July 1969



2320 X

Figure III. Status of horizontal control, United States, 1 July 1968

position originally determined by extension from the New England Datum.

Figure I shows the extent of the network at the time of the 1927 adjustment. Contrast that with figure II, which shows the basic horizontal control of North America as it exists today. The growth factor, with respect to the number of control points, is almost tenfold in 40 years, but each of you will be quick to respond that it is not enough, that the present density of control is extremely inadequate.

I appreciate your concern and the real needs for greater density, but I also know that you hold a high regard for quality. With this tenfold increase, there have been problems, or "growing pains", some of the same type encountered in the mid-1920s. The chronological step-by-step subdivision of the major loops of the 1927 adjustment has produced distortions, mainly because of lack of uniform distribution of closures. Distortions far greater than the minimum accuracy specifications have resulted from adjustments of many of the new surveys. These new surveys did not lack quality. The difficulty was just the result of this procedure of successive partitioning.

Figure III shows the areas where major regional readjustments have been made during the past 20 or so years just for the purpose of maintaining as high a quality of accuracy as feasible. I recognize that there was some inconvenience to the users because of the revision of co-ordinates, but if nothing had been done, I know there would have been total dissatisfaction with the distorted results of the adjustment.

Other factors must be considered. Today, there are more requirements for higher standards of accuracy than 40 years ago. Engineers have the instrumentation and techniques to achieve these higher standards. We have seen a change in the minimum standard of accuracy for primary surveys from one part in 25,000 to one part in 50,000, and now to one part in 100,000. Many engineers ask that the accuracy of even the secondary surveys approach this highest standard. Thus, we are required to do more than maintain quality. We are being asked to improve the quality.

From this brief review, I hope you follow the reasoning that has been used in developing the world-wide system which will support and control the continental networks. The accuracy of the various parts of the super-control network is of the order of one or two parts per million. The primary triangulation will be strengthened in over-all scale and orientation by these super-control networks. This new adjustment, when made, and hopefully before this decade is ended, will provide a reference system to which new surveys can be accurately adjusted, giving the density of points so urgently needed and maintaining the quality that is fundamental.

In 1928 Bowie stated that one of the major benefits of the 1927 adjustment was its contribution to science. The new values of that date would contribute to a more accurate determination of the size and shape of the Earth. In 1970 we recognize the scientific benefits of the proposed new adjustment, but we consider the primary benefit to be the establishment of an engineering reference system, strong enough to meet the needs of surveying and mapping for at least the next half century.

The major impact, then, will be the availability of a foundation for a more reliable survey network to be used for greater urban development, for further economic expansion, for the demarcation of international boundaries in oceanic areas and for other requirements involving greater accuracy of intercontinental distances and directions. We need not be overly concerned about the old datums or reference systems. There are probably more than 100 million survey markers with co-ordinates on tens of thousands of systems in the United States. I am not suggesting that these be adjusted to the world datum. The courts will continue to recognize their validity. If conversions or transformations of survey co-ordinates are required for updating purposes, even these computed results would increase in value. In looking ahead to the time when co-ordinates on the new adjustment will be available for controlling local surveys, you should plan that all new surveys be referred to the new system. This is a goal we can attain.

CONSTRUCTING A GEODETIC DATUM THAT FITS A CONTINENT

Paper presented by the United States of America[1]

For purposes of a local survey in a neighbourhood or a town, a co-ordinate system treating the Earth as a flat surface is adequate. When the area of a geodetic survey is large enough so that the curvature of the Earth must be considered in the computations, we use an oblate ellipsoid of revolution as the computational reference surface. This conventional agreement goes back to the famous Peru and Lapland expeditions of the French Academy of Sciences in the eighteenth century.

Several different geodetic reference systems (geodetic datums) are in use today in various parts of the world, such as the North American Datum with Clarke 1866 Ellipsoid, the European Datum with the Hayford or International Ellipsoid, the Tokyo Datum with the Bessel Ellipsoid and several others. In each case specific parameters of an ellipsoid are adopted along with the position of a specific point, the datum point (Meades Ranch, Potsdam, Tokyo, in these examples), from where the computations of the survey should start. Each of the ellipsoids had been derived and applied with the underlying assumption that it represented the smoothed figure of the Earth. While the variety of these ellipsoids clearly disproves the assumption, the practical application of the datum within a limited region was not necessarily impaired. This points to a distinction between the scientific interest in an adequate model for the planet Earth, and the practical need for an adequate tool in computing a limited control system. It means that the pertinent part of an ellipsoid may fit well within the limits of the region of interest and a misfit beyond would be of no immediate practical concern.

[1] The original text of this paper, prepared by I. Fischer, Supervisory Research Geodesist, United States Army Topographic Command, Washington, D.C., appeared as document E/CONF.57/L.24.

Good or poor fits

In 1954 the United States Army Map Service (now the United States Army Topographic Command) surveyed in Uganda and the Sudan the last link of the famous 30th meridian arc which Sir David Gill at the observatory on the Cape of Good Hope and also the science fiction writer Jules Verne dreamed about in the last century. Sir David had started the survey from the south up. When it was completed finally in 1954, it represented a most interesting input for our studies of the figure of the Earth.[2] Together with the American arc from Alaska to Chile we now had the first two meridional arcs of about 100° length reaching deep into the southern hemisphere.

Although several other datums are in use along the 30th meridian, such as the South African Datum with the Modified Clarke Ellipsoid of 1880 and the very different Adindan Datum on the same ellipsoid, it was important for our scientific aim to have the whole 100° arc computed on one and the same geodetic datum, and an extension of the European Datum (ED) was a likely candidate. As a result of this study we found that the International Ellipsoid was too big as an Earth model, and we also found that the European Datum did not fit in Africa. Figure I(*a*) shows a geoidal profile of this long arc on ED. The fit in terms of small geoidal separations is good within Europe, but from the Mediterranean Sea towards south the geoid drops away systematically from the ellipsoid to a separation of about 170 m at the southern end. The artificiality of this situation is seen from the comparison with figure I(*b*) where the same arc is referred to another geodetic datum, the 1968 modification of the Mercury Datum,[3] with a good fit all over.

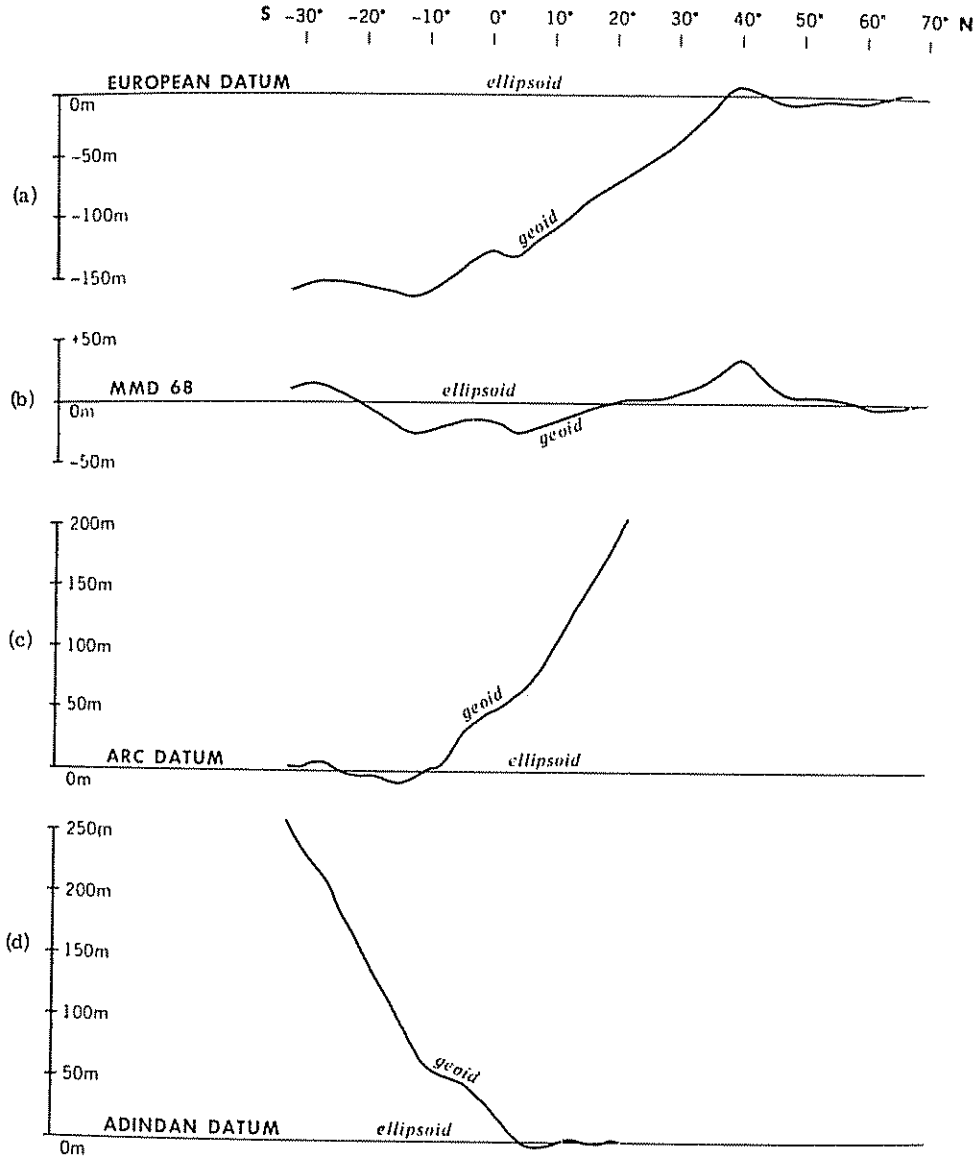


Figure I. The 30th meridian on various datums

[2] I. Fischer, "The Hough Ellipsoid or the Figure of the Earth from Geoidal Heights", *Bulletin géodésique*, No. 54, 1959.

[3] I. Fischer *et al.*, New Pieces in the Picture Puzzle of an Astrogeodetic Geoid Map of the World", *Bulletin géodésique*, No. 88, 1968.

Figures I(*c*) and (*d*) show the interesting case of the South African Datum and the Adindan Datum, each fitting well in its home territory and poorly beyond, although the ellipsoid is the same.

Practical significance of a good fit

Figure II is a schematic explanation of what happens in routine computations if there is a systematic increase in the geoidal separations along the arc and could be insignificant if the latter were small and random. Otherwise, all base lines in the chain should be projected from the centre of the earth onto the ellipsoid above, whereby they are lengthened in proportion to their geoidal height, due to the divergence of the Earth's radii. This causes a systematic shift in the computed geodetic co-ordinates accumulating to GG' at the far end. The shift affects also the size of the deflections of the vertical since these are the differ-

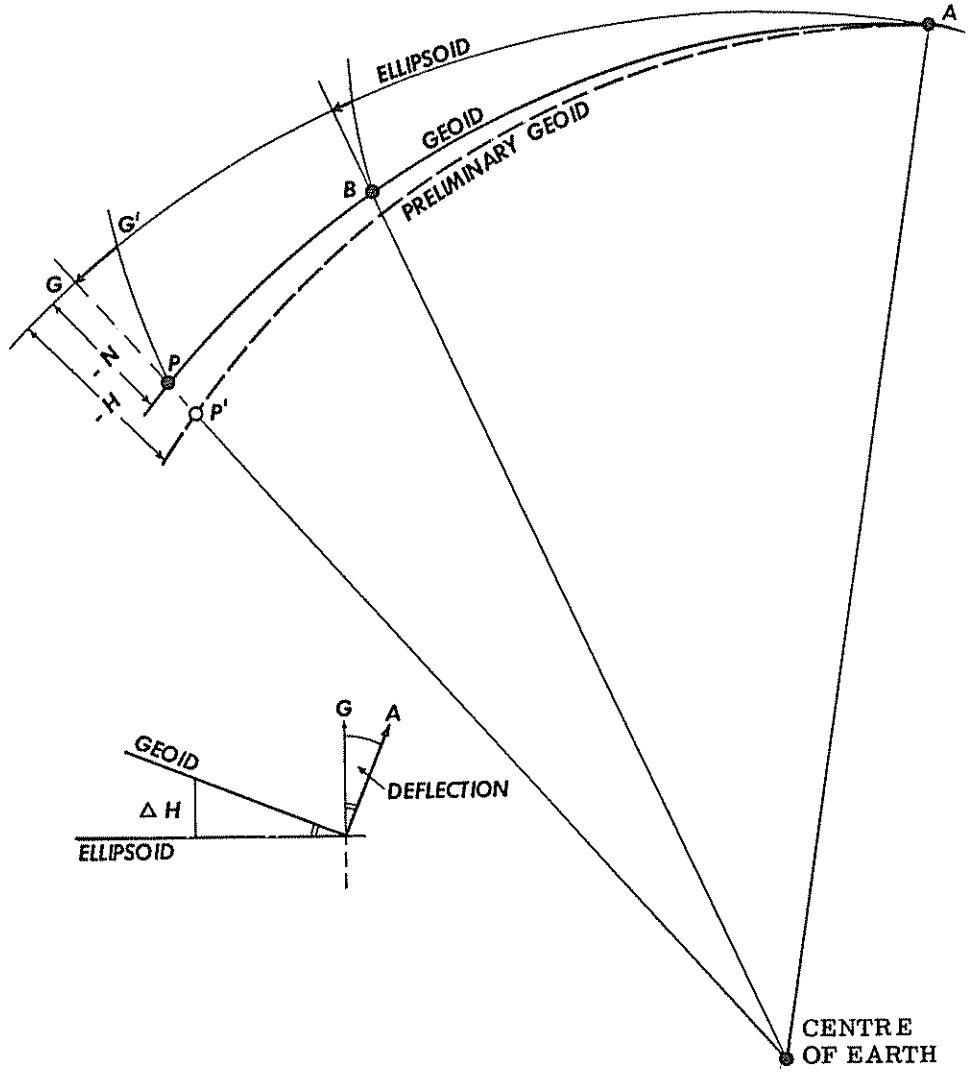


Figure II. Distortions caused by an ill-fitting datum

geoidal separation. Suppose the geoid is below the ellipsoid, and a long arc from the datum point A to a point P has been surveyed on the surface of the Earth and reduced to sea level (the geoid), the chain of angles and distances in this arc is then adjusted on an ellipsoidal surface, because this is mathematically easier to handle than the quite irregular sea-level surface itself. In doing so, the length AP is essentially laid out on the given ellipsoid as the arc AG' of equal length in order to arrive at the geodetic co-ordinate G'. The normal through P, however, intersects the ellipsoid at the correct point G, which terminates the longer arc AG. The discrepancy GG' obviously depends on ences between the astronomic and geodetic positions and, in turn, the preliminary geoidal heights H are changed to the correct values N. The well-known connexion between a deflection and the geoidal increment ΔH which it causes, is shown in the inset of figure II.

In case the geoid is above the ellipsoid, the base lines have to be shortened.

The difference between a good and a poor fit of a geodetic datum can thus be expressed in very practical terms. The complicated correction procedures for distortions caused by an ill-fitting datum are unnecessary in a well-

fitting datum. The latter is not unique, as any datum with small geoidal separations in the area of interest would serve its practical purpose.

In the rather extreme case of figure I(*a*) the correction required at the southern end amounted to more than 5 seconds in position and more than 90 m in geoidal height.

How some datums were chosen

The simplest way of starting a geodetic control system in a geodetically unknown region is to choose an ellipsoid, select a starting point (datum point) and adopt its astronomic position as its geodetic position on that ellipsoid, together with a zero metres geoidal height. Part of the convention is that the minor axis of the ellipsoid of revolution is parallel to the rotational axis of the Earth. Azimuth observations as well as the enforcing of the Laplace equation are supposed to keep it that way. Many national datums are based on these conditions and prove to be quite satisfactory.

Some geodetic datum definitions do not contain the arbitrary stipulation that the astronomic and geodetic positions of the datum point should be the same. That is, the deflection components in the meridian and in the prime vertical need not necessarily be zero. Zero deflections (together with zero geoidal height) mean that the ellipsoid is tangent to the geoid at this point, while non-zero deflections reflect a tilt. Since not all points in a geodetic net have zero deflections (if they had, the ellipsoid and geoid would be identical surfaces), and since the datum point is an arbitrarily selected starting point, non-zero deflections at this point may be quite compatible with a good fit throughout the region.

In the case of the North American Datum the original net in the east was extended over the continent and happened to fit quite well. The position of a centrally located point, Meades Ranch, was then held fixed as the datum point for a new adjustment. Meades Ranch happened to have small non-zero deflection components, and there was no reason to change that.

In the case of the Australian Geodetic Datum preliminary deflections of the vertical were determined in an even distribution throughout the continent, and then minimized to ensure a good continental fit of the new datum.

In the case of the Provisional South American Datum of 1956 the astronomic co-ordinates of the datum point, La Canoa in Venezuela, were modified by a gravity survey within a radius of 75 km, in the hope of achieving a well-fitting datum for a geodetically almost unknown continent (as of that time). As it turned out, this hope was not fulfilled. The underlying assumptions of this approach apparently had been that this gravimetric correction of the astronomic position would lead to the proper geodetic position in relation to the Earth's centre of mass and that a so-determined datum point would lead to a well-fitting datum for the continent. Both assumptions were unwarranted, however. The gravity survey was taken only over an area of 75 km radius, while the theory for computing deflections from gravimetric observations requires global coverage. Even if the effect of the neglected, more distant area had been insignificant (which it was not), the computed deflections depend on the specific gravity formula used, that is, a specific value of the flattening, and are thus related to an assumed gravimetric model rather than a unique centre of mass. If a valid relationship to the Earth's centre of mass had been established, it did not necessarily follow that this would lead to a well-fitting datum for the continent, as may be seen from the Australian example discussed below.

For the establishment of the new South American Datum of 1969 the form of the geoid for the whole continent was studied first, so that a good fit could be assured.

World datums

One of the goals of geodesy ever since its beginnings has been the establishment of a uniform co-ordinate system for the globe (a world datum) for the purpose of studying the Earth as a whole, either with a view to determining the distance and direction between any two points on its surface, or to know the shape and size of our planet, or to serve related sciences such as geophysics.

As the well-known history of geodesy shows, things seemed to be much simpler once upon a time when the Earth was assumed to be practically a sphere, so that one key number, the radius of that sphere, would solve all our problems. As geodesy grew up and capabilities to measure with precision increased, the understanding of concepts increasingly sharpened and the problems became more complicated and diversified. Today, we have an impressive array of geodetic tools including artificial satellites and it is important to keep re-examining what the many numerical results actually mean.

One of the desired features of a world datum is its Earth-centredness: the centre of the Earth ellipsoid should coincide with the Earth's centre of mass, and its minor axis with the rotational axis of the Earth. Each point would then have co-ordinates with respect to the Earth's centre, whether expressed in the traditional geodetic system of latitude, longitude and height above the world ellipsoid, or in a mathematically equivalent Cartesian system with x, y, z co-ordinates.

Dynamic solutions from satellite tracking are related to the Earth's centre of mass through orbit theory. From the observed perturbations of the orbit a generalized form of the geoid causing these perturbations can be derived. Also, geocentric co-ordinates of the observing stations are determined. Thus, it is possible to connect separate survey systems such as those in the western and eastern hemispheres into a single system through satellites.

Geometric satellite projects, such as the BC-4 world net, span the oceans and large transcontinental distances on the principle of a large triangulation. While these solutions are not Earth-centred, the completed and adjusted net is referred to a single consistent datum, which then can be related to the Earth's centre by mathematical transformation.

Satellite geodesy thus provides a global framework for connecting the various separate geodetic control systems into a unified world system (see figure III). We still need the conventional or modernized conventional survey methods to set up the primary units, the detailed control systems for national or continental needs, which then can be referred as a block to a geocentric position.

At the Fourteenth General Assembly of the International Union of Geodesy and Geophysics I presented such a world datum, connecting the separate datum blocks of the western and eastern hemispheres including Australia through a combination of satellite solutions from Doppler and Baker-Nunn observations. Figure [illegible] shows a world

geoid referred to this 1968 modification of the Mercury Datum, reflecting at the same time the areas with available geodetic coverage. You will note that the geoid profile along the parallel at 30° south, computed by Dr. Jones at

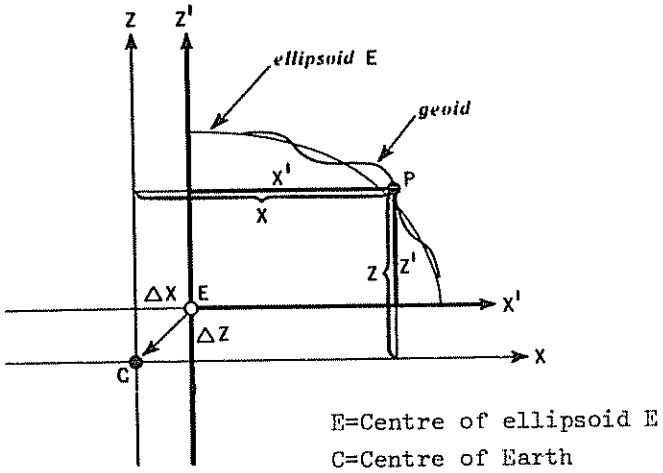


Figure III. Vectorial shift to geocentric co-ordinates

Durban, has been included as a very important contribution in an otherwise rather sparsely covered continent. Figure V gives a global geoid through spherical harmonic expansion, to provide geoidal height estimates where no detailed data are available yet. This study is one out of a series of world datum studies reflecting the increasing amount of information since we first evaluated the scientific significance of the long 30th meridian arc mentioned above.

Different requirements for different purposes

A world datum is usually defined in terms of transformation formulae which change the co-ordinates on the given major datums to those on that particular world datum. These formulae represent the vectorial shifts indicated in figure III and can be expressed as the Cartesian components of that shift pertaining to each conventional datum. Since the stress lies on the uniformity of the world datum, no particular point needs to be singled out as a datum point. By contrast, if field survey is conducted in a certain region, the computation and adjustment is related to a fixed starting point on the respective conventional datum.

The Earth-centred ellipsoid of a world datum, which is meant to be a good over-all approximation to the irregular shape of the world geoid, is not necessarily a close fit within each limited area of special interest. The most striking example is Australia, which appears to be on a tilt of around 80 m on Earth-centred systems such as that shown in figure IV, while it is almost flat on the continental Australian Geodetic Datum.[4]

The reason why Australia did well to use this datum and not a world datum for computing its basic control system has been discussed above: the large tilt would have caused large and unnecessary distortions, which were excluded through the choice of the continental datum. The specification of the purpose for a particular area permitted a closer fit for that area.

[4] I. Fischer *et al.*, "A Preliminary Geoid Chart of Australia", *The Australian Surveyor*, 1967.

Since datum blocks are the basic parts to be joined in a world datum, and constitute also the vital input for its deviation, they are assumed to be internally consistent—an assumption which is not always quite correct. Since geodetic control was established historically along economic priority lines, regional nets were often developed independently, later extended piecemeal and joined with neighbouring nets, which may have involved some shift, rotation and scale change, maybe also a datum change. An over-all adjustment of a larger area in one piece would show the amount of swing or stretch that slipped into the net through the way it had been developed. For local economic or engineering purposes such inaccuracies may be of little concern so long as they affect that local area in the same way and do not disrupt internal relative accuracies. But for large areas of national or continental extent the gradual accumulation of inconsistencies may lead to incorrect distances and directions.

The various national geodetic nets on different datums in Europe were superseded by the uniform European Datum of 1950. Inaccuracies in the North American Datum started plans for a complete readjustment from observations. In South America, distances computed from satellite solutions differed by 50 to 100 m from those computed on the Provisional South American Datum of 1956, due to large distortions inherent in the latter. Therefore, it was decided to abandon this datum as useless and start again from observations with a consistent over-all adjustment on a new datum.

The adjustment of the horizontal positions (latitude and longitude) is not the whole task. The geoidal height of a particular point is part of its height co-ordinate. Its neglect makes the position in three-dimensional space incorrect. These three-dimensional positions are needed for deriving the vectorial Cartesian shift to a world datum. And geoidal heights at satellite tracking stations must be included in the conversion to Cartesian co-ordinates of these stations to evaluate the satellite solutions.

Astrogeodetic geoid charts

The geodetic literature is full of various types of geoid charts: satellite derived world geoid charts, gravimetric geoid charts from terrestrial gravity observations and their hypothetical extrapolation into unobserved areas, combinations of both types, astrogeodetic geoid charts on various datums and combinations of these with satellite and/or gravimetric charts.

For our purpose of defining the geodetic co-ordinate of a point on a specific datum, we start with comparing its geodetic latitude and longitude with its astronomic counterpart. This astrogeodetic deflection of the vertical produces an increment in astrogeodetic geoid height over a certain distance, as shown in the inset of figure II. The summation of these linear increments over the whole area of interest, starting at the arbitrarily selected but then adopted datum point with the arbitrarily adopted zero value, leads to the construction of an astrogeodetic geoid chart.

The construction should cover the whole area, but obviously depends on the distribution of the available deflections, which will influence the choice of procedure. J. F. Hayford[5] designed a graphical procedure, starting

[5] J. F. Hayford, *The Figure of the Earth and Isostasy from Measurements in the United States*, Washington, 1909.

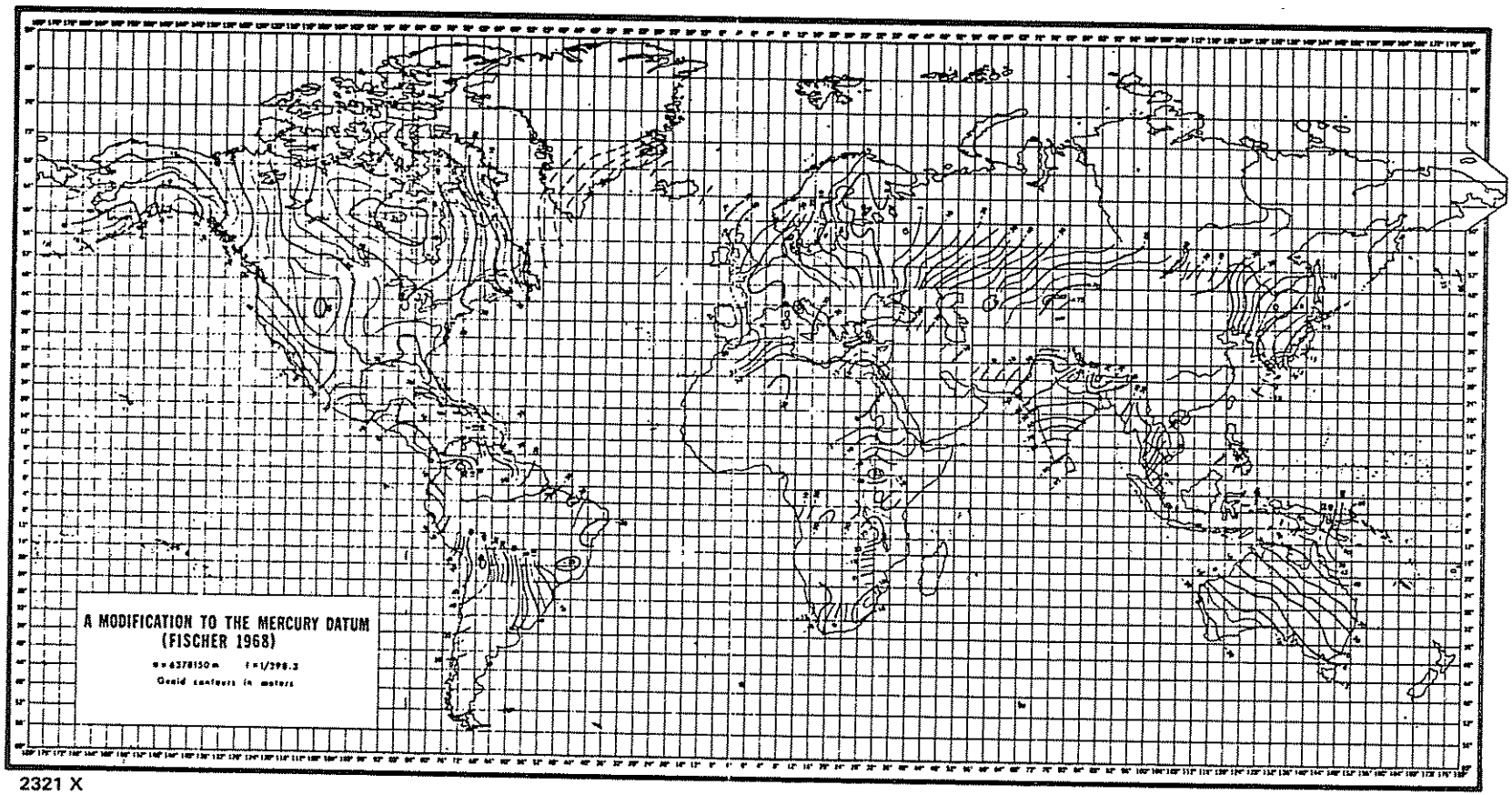
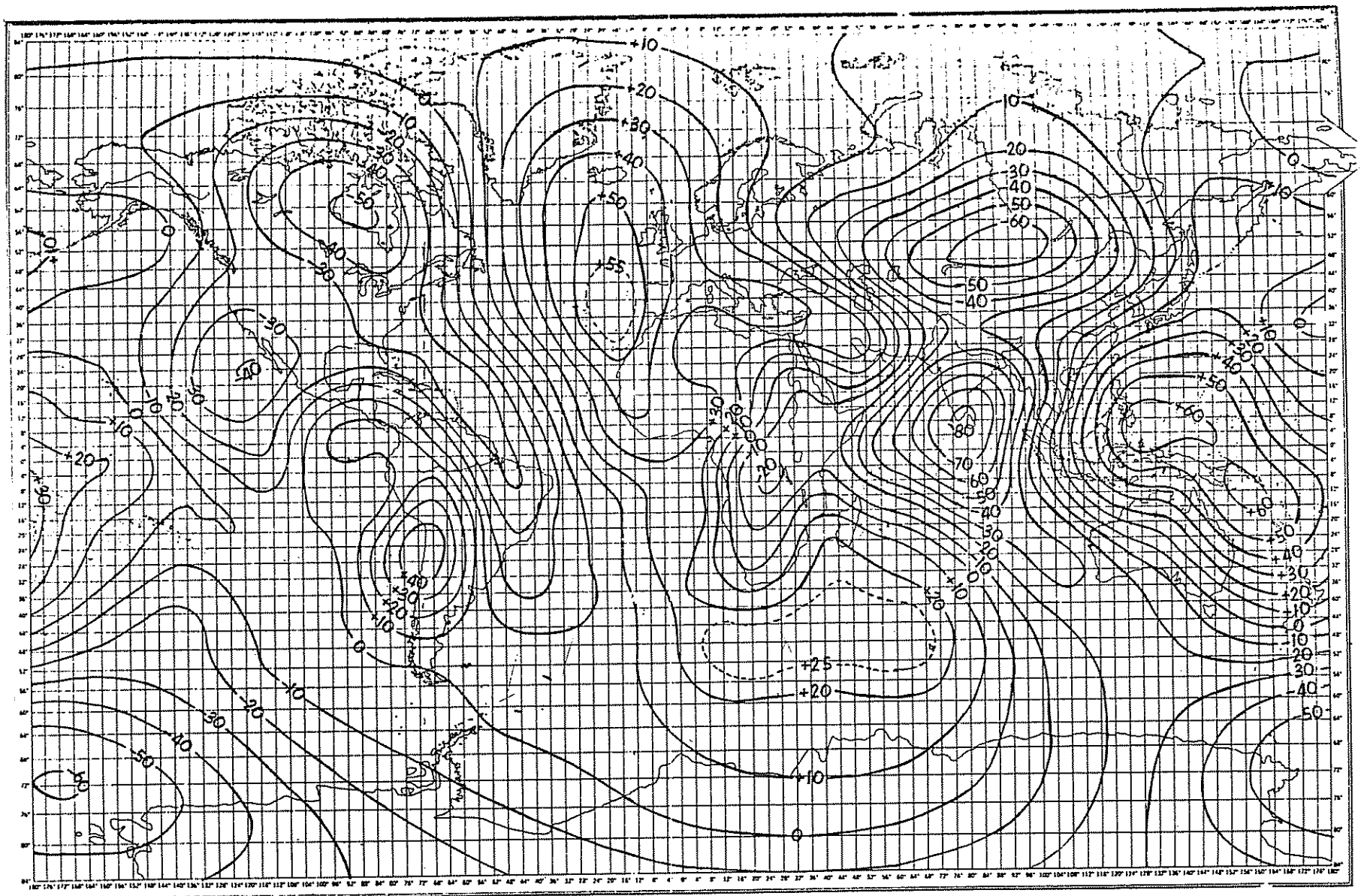


Figure IV. A modification of the Mercury Datum (Fischer, 1968)



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Figure V. Global geoid chart by spherical harmonic expansion to (13,13) of a modification of the Mercury Datum (Fischer, 1968)

with a geoid profile along a first meridian and proceeding to the next meridian at a fixed interval, adjusting it and proceeding further. I employed this method in constructing a geoid chart for North America in 1957.[6] Ten years later, I updated this chart,[7] using an electronic computer instead of the graphic approach. Programmes for geoidal profiles along meridians and parallels, considering the curvature of the Earth, were developed and applied in chequerboard fashion at 1° intervals. An adjustment between the two values at each crossing point was made with weights reflecting the number of deflection values affecting each 1° line increment.

The construction of the Australian geoid chart in 1967[8] on the basis of the astrogeodetic deflections available at that time required a different approach due to their specific distribution in several big loops (figure VI). We first computed geoidal profiles along these loops, studying their closures. We could then select certain very large loops with insignificant closure errors and adopted them as a fixed framework. From the very small geoidal heights on these loops and wherever else they could be computed, one could see that the choice of the continental datum had indeed been a fortunate one, and a tentative interpolation seemed justified. For this purpose we employed the same chequerboard approach as for North America, based on tentative deflection charts. As we had already established a fixed framework, we only used the computed increments inside the loops and adjusted them to their endpoints on the framework.

In 1965 I constructed the South American geoid[9] on the Provisional South American Datum of 1965, because that was the datum of the existing control. The distribution was again different. There was only the loop around the northern half of the continent (see figure VII) and the arc in Chile, nothing else. We started from the datum point in Venezuela towards east and west, continuing towards south and around the big loop. Closures were not good, but the strong systematic increase in the size of the deflections and geoidal heights was unmistakable. Corrections for distortions according to figure II amounted in Chile to 4.5 seconds in latitude and 45 m in geoidal height, almost as extreme as for the European Datum in South Africa. The corrected geoid was then referred, through mathematical transformations, to a number of other reference datums in order to show that such distortions could be avoided. We were then asked by the Pan American Institute for Geography and History (PAIGH) to continue the study with additional data which should become available before the next PAIGH Assembly in 1969, at which time the question of a new South American Datum would be considered.

For the derivation of the South American Datum of 1969 (SAD 69) we had much additional triangulation as seen in figure VII. There also were satellite-tracking stations as seen in figure VIII. The essential arrangement was now in two huge loops, braced by long satellite lines. The geoid computation followed this arrangement, starting at the Brazilian datum point, Chua. The independent net at the southern tip was tentatively tied in by BC-4 satellite solutions, and estimates of geoid heights in the unsurveyed areas of the Amazonas basin and Patagonia were obtained from the geoidal world chart in figure V. Thus the main geoidal features of the whole continent were investigated, and the new datum could be chosen accordingly. This internally consistent geoid of continental extent is a very important contribution to the derivation of an improved world datum.

Africa as a continent is geodetically known least. The 30th meridian is still the geodetic backbone, now connected with east–west profiles along the Mediterranean coast; the 12th parallel north, the 6th parallel south, and the 30th parallel south. Some existing triangulation is not yet connected to any of these, and there are no big loop connexions to check the accuracies of what we have. An internally consistent control system, covering this huge land mass at least in big loops, adjusted on a reasonably well-fitting datum, would be a tremendous scientific contribution.

A 1968 MODIFICATION OF THE MERCURY DATUM[10]

At the Fourteenth General Assembly of the IUGG at Lucerne, September 1967, a paper "The Geopotential to (14,14) from a Combination of Satellite and Gravimetric Data" was presented by R. H. Rapp, which contained a geoid chart computed from surface gravity only. The data used by him represent the current holdings at Ohio State University and include the older data collections of

[6] I. Fischer, "A map of Geoidal Contours in North America", *Bulletin géodésique*, No. 57, 1960.
[7] I. Fischer, "A revision of the Geoid Map of North America", *J. Geophys. Res.*, vol. 71, No. 20, 1966.
[8] Op. J. F. Hayford, *op. cit.*
[9] I. Fischer *et al.*, "On Estudio del Geoide en Sud America", *Revista Cartográfica*, No 14, 1965.
[10] I. Fischer, "New Pieces in the Picture Puzzle of an Astrogeodetic Geoid Map of the World", addendum to a paper presented to the IUGG Assembly, Lucerne, 1967.

Type of solution	*Datum shift*				*Equatorial radius*	
	From	Δx	Δy	Δz	$f = 1/298.25$	$f = 1/298.3$
		(m)	(m)	(m)	(m)	(m)
10. Astrogeodetic and Rapp	NAD	−43	+106	+165	6378159.8	6378155.6
	ED	−72	−68	−126		
	AGD	−105	−28	+78		
A modification of the mercury datum (Fischer, 1968)						
11. Weighted mean satellite and surface, MMD 68	NAD	−18	+145	+183	6378149.0	6378147.8
	ED	−81	−104	−121	$\sigma = 7$ m	
	AGD	−105	−44	+94	standardized: 6378150 m	

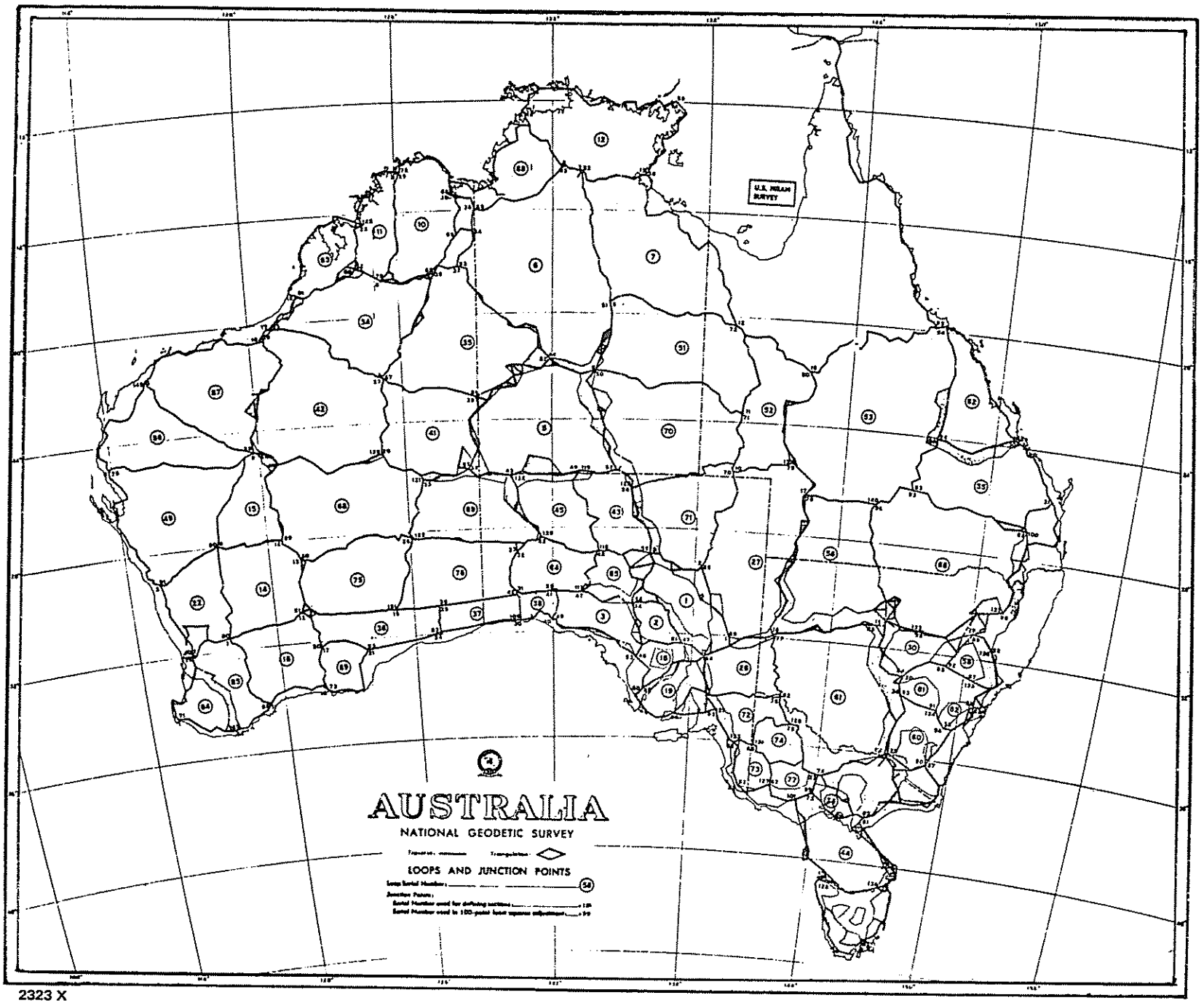


Figure VI. Australia: National Geodetic Survey

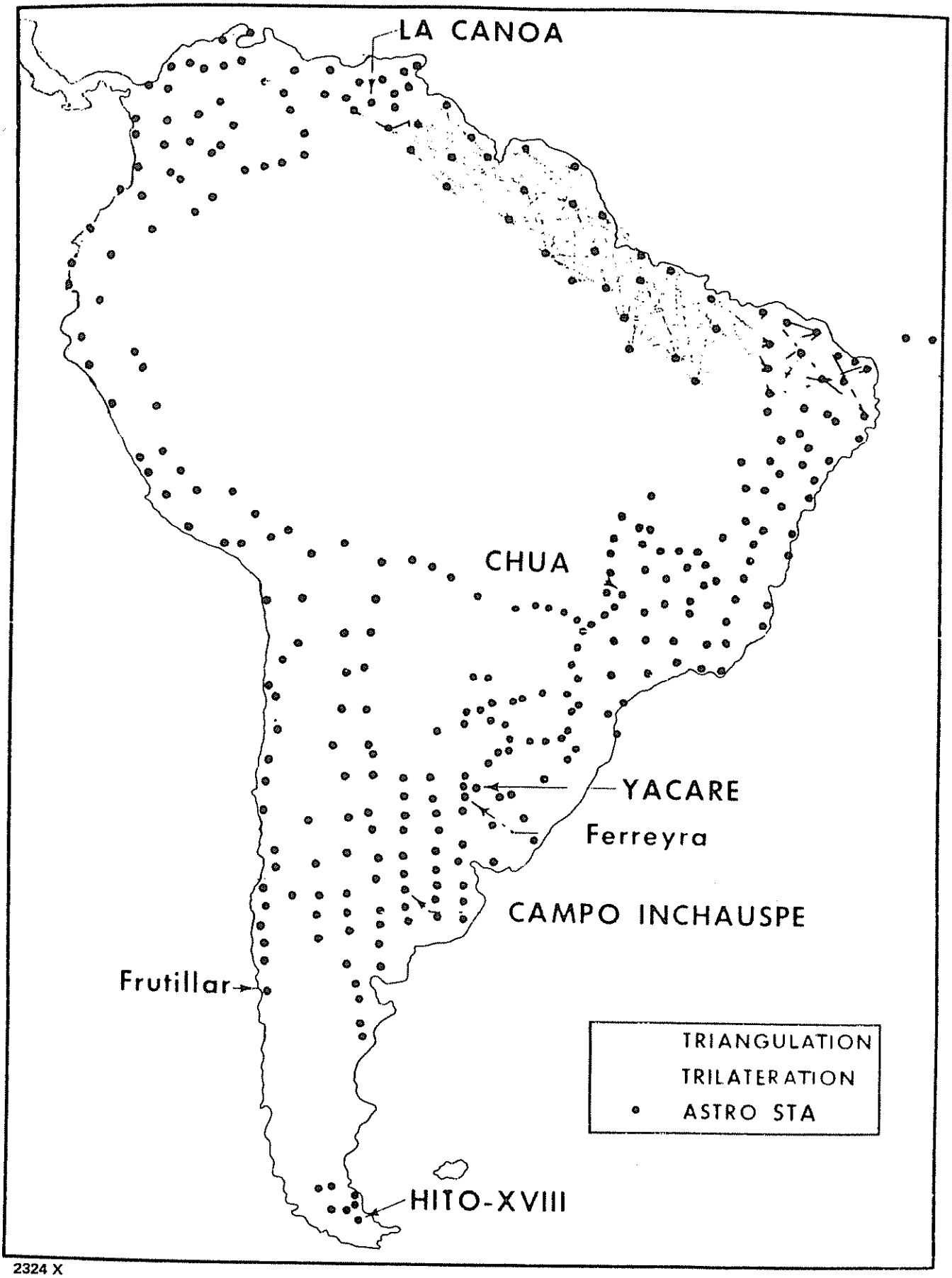
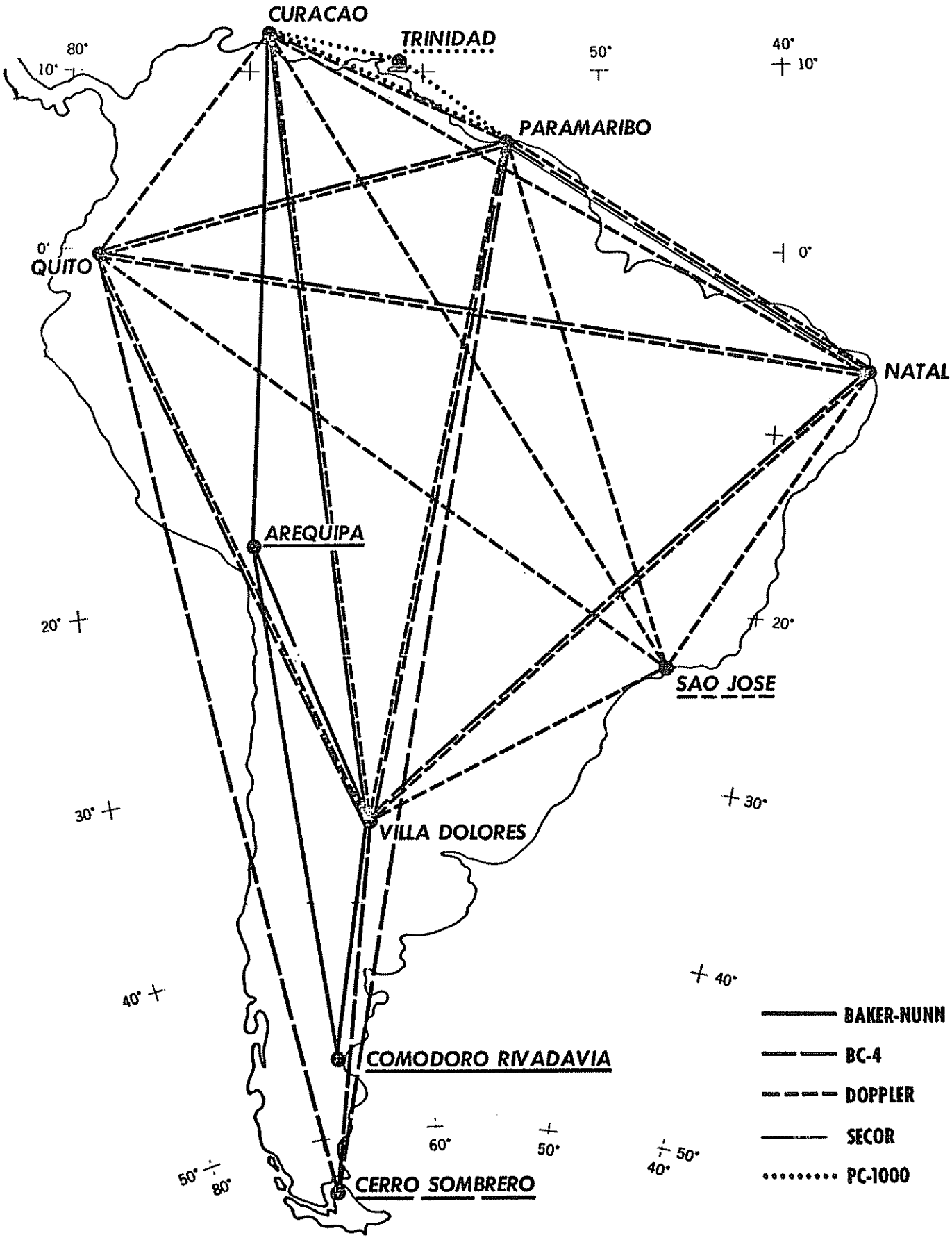


Figure VII. South America: Triangulation



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Figure VIII. South America: Satellite connexions

Uotila and Kivioja, which we used in the form of Levallois' two geoid charts. We therefore replaced these by Rapp's chart and proceeded as before.

The solution derived from a geoid match at the 644 astrogeodetic points with Rapp's values is given below, along with the final solution containing the replacement. The standardized rounded parameters $a = 6378150$ m and $f = 1/298.3$ are recommended for practical applications, where the fluctuations in the last digit are of no significance. Geoid contours on this 1968 Modification of the Mercury Datum are shown above. A spherical harmonic expansion for global geoid coverage as well as details on various datum transformations are in preparation.

HELICOPTER GRAVITY-MEASURING SYSTEM (HGMS)

Paper presented by the United States of America[1]

For over a decade, various government agencies and private industries have attempted to measure gravity from a moving fixed-wing aircraft. A system was desired that could collect gravity data rapidly throughout the world to satisfy geodetic requirements and to assist in geophysical exploration for minerals and oil. The authors feel that not much improvement has been made using fixed-wing aircraft since the Flags tests of the late 1950s.

During the mid-1960s, a different air frame was examined—the helicopter. Several feasibility trials were accomplished using various gravity instruments, navigation techniques and altimetry systems. These efforts have culminated in the design and selection of instruments for the HGMS.

History

The first attempt at measuring gravity from a helicopter was made in 1963 by GMX and LaCoste & Rhomberg. No successful results were reported. In April 1965, a United States Naval Oceanographic Office (NAVOCEANO) LaCoste & Rhomberg gimbal-suspended gravity meter was flown at Fort Hood, Kileen, Texas. Several good gravity values were measured in the hover mode. These values compared to within ± 5 mgal when reduced from the 50-ft hover height to the ground. In May 1966, NAVOCEANO made a more serious attempt to develop a complete helicopter system. This test was performed with a LaCoste gimbal meter, the prototype Aero Service-Spectra-Physics laser altimeter and precision radar tracking from a single station NASA radar.

Forty hovers were made throughout Maryland and Virginia with accuracies of ± 3 mgal when compared to the ground. Profile data collected at speeds from 75 to 150 knots looked extremely good and were reduced to give cross-checks of several milligals. This test demonstrated that a helicopter with an auto-pilot could provide a remarkably stable vehicle while flying at relatively high survey speeds. The laser altimeter proved its capability over water. One line, for example, flown over the Chesapeake Bay measured a maximum altitude deviation of only 3 ft in 80 miles. These small deviations were of a short period—7 to 15 seconds—and when filtered, using the gravity meter functions, produced no vertical acceleration that affected the gravity sensor. This test marked the beginning of a concentrated United States Government effort to develop a helicopter-borne gravity-measuring system.

By early 1967, three more feasibility trials had been accomplished and, with all these results, procurement was initiated for the components of the HGMS.

Instrumentation

Gravimeter

Six different types of gravity meters have been flown over the past two years and two more examined to determine which meter to select for the HGMS. Those flown are the LaCoste & Rhomberg gimbal-suspended meter, the LaCoste & Rhomberg platform meter, the Texas Instruments stable-platform meter, the Bell Aerosystems prototype accelerometer meter, the Bell Aerosystems miniaturized BGM-2 and the modified LaCoste & Rhomberg stable-platform meter with rapid read-out. The Graf Askania sea/air meter and the AMBAC gravity meter have also been studied.

The meter selected after these tests was the conventional LaCoste & Rhomberg stable-platform meter. During the year 1967, changes in the system weight and read-out components made it completely compatible with the HGMS design. Basically, its noise and temperature insensitivity, its low power requirement, good reliability and excellent factory support made it very adaptable to the system. Tests were started on this instrument in March 1968, and results in the helicopter environment were 0.1 mgal in the stationary mode, little or no drift, and tare free.

The standard LaCoste & Rhomberg stable-platform gravity meter has been modified by LaCoste since the beginning of the HGMS tests. The auto reader system usually incorporated in this type of meter has been eliminated. Its long time constant required great lengths of settling time and was a great disadvantage at 100–150 knots. A short reader system was constructed that gives instantaneous spring tensions and total correction with 30 seconds of filtering. The total correction is the sum of the cross-couplings and the beam velocity derivative. These parameters are recorded at 1-second intervals on magnetic tape and can be filtered using a variety of techniques. While flying, the instrument can now be settled down to read after a large course change in 1 to 3 minutes of time.

Another change was the modification of the platform to cut off acceleration output during course alterations at the end of a survey line. This allows the platform to stay essentially erect around the turns, and allows the next survey line to begin sooner.

An on-board general purpose computer is on order to be incorporated with the LaCoste & Rhomberg gravity meter. This is a recent development of LaCoste & Rhomberg and will enable data to be filtered with a more

[1] The original text of this paper, prepared by W. R. Gumert, Geophysicist, and G. E. Cobb, Electronic Technician, United States Army Topographic Command, Washington, D.C., appeared as document E/CONF.57/L.27.

optimum filter for the helicopter noise environment during actual flight.

Another meter, the Texas Instruments system, was flown early in the programme—in October 1966—with fair response in hovers but, during flight, it was not possible to obtain readings due to large fluctuations in the beam movement. This instrument was a LaCoste & Rhomberg gimbal gravity sensor on a Texas Instruments stable-platform. This type of system component mating is not likely to produce a usable gravity meter. This test and many Air Force results have demonstrated the difficulty of mixing systems.

Briefly, with regard to the other meters flown, the LaCoste & Rhomberg gimbal performed well but, of course, is inferior to the LaCoste & Rhomberg stable-platform. The Graf Askania has been examined, but shipboard experiences indicate that it would not meet the requirements for a helicopter-borne meter.

The final meter considered is the AMBAC unit. Attempts were made in the spring of 1969 to fly this instrument on the helicopter, but last minute schedule changes disallowed the flights. Negotiations are still open with AMBAC to fly this meter in the tests at present under way. Manufacturer reports are optimistic. The latest field data collected by Woods Hole Oceanographic Institute (WHOI) and TOPOCOM, aboard the *Atlantis II* in the Caribbean, December 1969, indicate that it warrants a try in the airborne mode. Dr. Bowin and Mr. Allen Follensbee of WHOI report that drift was low—0.5 mgal a day—and readings at sea compared well to the LaCoste & Rhomberg stable-platform meter on board.

Altimetry

The altimetry subsystem selected for the HGMS is a combination of the Spectra-Physics laser altimeter, a 35-mm strip tracking camera, and the Rosemont Engineering Corporation pressure port calibrator. These components were chosen after flight tests of available altimeters and a search of the field for useful equipment.

During the several short feasibility tests prior to early 1967, flight tests were made with the prototype laser altimeter, the Minneapolis Honeywell HG-9050 radar altimeter (best radar altimeter for helicopters determined in 1966 United States Army tests), a hypsometer, Rosemont pressure port calibrator and a pressure device developed by Aero Service.

Since procurement of this subsystem, strict laboratory and field calibrations have been performed. In 1967, the pressure port calibrator was laboratory tested for response time against an accelerometer altitude deviation sensor belonging to the Ocean Dynamics Division of NAVOCEANO. Both sensors were installed on a vertical tester and checked for response and amplitude. The pressure port calibrator followed exactly the accelerometer device. Further laboratory tests at TOPOCOM show that the instrument is capable of differential pressure measurement equivalent to an elevation change of 3 inches.

The laser has been tested and calibrated over a measured range at Bolling AFB, Washington, D.C. The TOPOCOM Gravity Division surveyed in a precise line, good to a fraction of a centimetre, along an unused runway. The line is 6,000 ft long with 100 ft and 1,000 ft increments. The laster altimeter was set up on this range and checked for response, accuracy and colour sensitivity. The accuracy is as the manufacturer states—1 part in 10,000. On the range, at 6,000 ft, a maximum error of 6 inches was measured. The response was checked with a rotating, chopping disc that was placed in the laser light path and rotated at various speeds. The response was instantaneous on the recording system used—a light beam oscillograph and digital voltmeter.

The instrument was found to be colour-sensitive in the sense that once a different coloured target was introduced, the amount of return signal changed. If the instrument was adjusted to bring the signal return level to optimum, the distance measurement changed; in short, gain sensitivity. In the maximum case using a green target, this error amounts to 7 inches in 1,000 ft. In an operation, this would not be seen, as the gain is peaked once and not changed with signal level.

The helicopter is a pressure-noisy aircraft. The rotors create draughts and eddy currents that do not allow precise pressure monitoring in the vehicle's stream. TOPOCOM has constructed an extendable probe to put the pressure probe 6 ft in front of the rotor tips. The CH3E helicopter used in the programme can be mounted with a refuelling probe and a tube was designed to fit this mount. After take-off, the tube can be extended 10 ft to place a vaned pressure sensor into the virgin air in front of the vehicle. This finned probe is designed to follow the air stream and small holes in the side sample the static air pressure.

The altimetry subsystem is designed to give the HGMS a continuous altitude above ground from the laser accurate to 1 ft, and to give deviations from a pressure surface to 3 inches. A typical mission occurs when, at the survey altitude, the flight path of the survey line is directed over a height reference surface on the ground, i.e. a river, highway or other such linear well-surveyed feature. The laser would record the distance between aircraft and reference, giving the height above MSL. The pressure port calibrator is zeroed at this time and the aircraft continues on its flight down the barometric surface. Several reference laser heights are recorded along the line and, with these absolute data, the barometric surface is computed to determine absolute MSL height variations for vertical acceleration computation to apply to the gravity sensor. Since the flight lines in this system are no greater than 100 miles, the barometric surface is expected not to change much on good flight days.

Navigation

Many navigation systems have been examined for use in the HGMS. After a literature search in 1966, it was determined that no inertial system was available, or in sight, that would provide the necessary accuracy for airborne gravity. The decision was made to restrict the system usage to ground-based radio navigation system, but still to keep an open mind.

Tested in the programme to date are single-tracking precision radar for range and azimuth, on-board radar, LORAC, Raydist, SHORAN, HIRAN, on-board Doppler and Cubic Autotape. All of the above have been rejected for use, except HIRAN and Cubic. The Raydist and LORAC systems will provide adequate navigation over water, but are not at all usable over land because of terrain effects. One other system that is being investigated is the recently announced Motorola unit which has received favourable reports from tests in Arizona, Canada and the Arctic.

SHORAN was the system used in the 1969 test programme of the HGMS. It appears to be one of the weak points in the test programme. The system operated well,

but lack of adequate gain control casts doubt on the data accuracy.

Since late 1969, a subsystem test programme has been conducted at Forbes Air Force Base, Kansas, to define the accuracy available in the helicopter with HIRAN, the SHORAN with constant signal gain adjusting. Results of this test show accuracy of 50 ft CEP, and track accuracy of 0.3 to 0.5 of a degree in course and 0.3 to 0.5 of a knot in speed. The HIRAN system used is the conventional RCA unit, built in 1954, but with a modification by TOPOCOM to provide instant digital output on magnetic tape. Two shaft encoders were geared to the HIRAN drive gears and calibrated to give a digital output accurate to less than 6 ft. This modification shows no gear backlash and has suffered not a single data dropout in six months.

TOPOCOM is at present testing Cubic Autotape for use in this programme. Advantages of this system are its much lighter weight—75 lb to 500 lb for the airborne unit and 25 lb to 1,500 lb for the ground station. Because of the altitudes planned for the HGMS surveys of 2,500 to 5,000 ft, a line-of-sight system with a range of 60 to 90 miles is all that is required. TOPOCOM's tests of Cubic Autotape show that it meets this requirement. The accuracy of Cubic is as good as, or better than, HIRAN (± 2 m repeatability in TOPOCOM tests). Further testing of Cubic and HIRAN are in progress and final evaluation of weight, accuracy and cost will determine which is used in the HGMS.

Helicopter

Many different types of helicopters have been tested. These are the CH34, single piston engine; CH37, twin-piston engine; S-61, single turbine; UH1D, single turbine, and CH3E, twin turbine. In over-all evaluation, the CH3E is the best all-around aircraft. The most advantageous feature is the well co-ordinated auto-pilot available on this aircraft. Its disadvantages are its high cost and maintenance.

The UH1D is reported to have a suitable auto-pilot available, and attempts have been made to arrange a flight check of its stability. The UH1D would be a good aircraft if its flight stability could be maintained by automatic control. Maintainance and operating costs are low. Its disadvantage would be its range of only 200 to 250 miles.

System configuration

The entire HGMS package as presently configured weighs a total of 1,000 to 1,500 lb and requires about 17 amperes of 100 volts, 60-cycle power. It can easily be transferred from vehicle to vehicle. The 500 lb variation is dependent upon the navigation system used, i.e. HIRAN as compared to Cubic. Two operators can handle the system when Cubic is used, but four are required with HIRAN.

Data handling

All data are recorded through a Lancer digital data acquisition system. This component samples all data at a one-second interval and provides the basic time reference for all other subsytems. Recorded on the magnetic tape are a reference mark, all necessary gravity meter information, laser height, pressure height and navigation. All data are immediately read and printed on a Litton high-speed printer for system monitoring purposes. All data are recorded on strip chart recorders for easy visual surveillance and as a redundant data recording available for backup processing.

After each flight, the data magnetic tapes are sent to the home office for computer reduction. In the field, the strip camera film and light-beam oscillograph paper are processed and laser check-point elevations are selected. A daily field evaluation is made of all the data to determine if they meet requirements.

The magnetic tape is processed through a computer programme that edits, computes, compares and adjusts the data. Final output is a gravity value at elevation with a position. The programme is developed for an 1108 computer and is scheduled to require only one pass through the computer. For each one hour of flight time, about 1 to 4 min of computer time are scheduled. Absolute altitude inputs will be made using cards giving the laser reference altitude at a particular fiducial mark. Data will be printed and each line plotted with navigation (Eötvös), gravity value and other pertinent information clearly represented for rapid scanning by a trained observer.

Test results

Since the tests that are considered developmental—in this report, those prior to mid-1968—there has been an intensive flight, modify, reflight schedule. The entire HGMS, as described, was first installed in October–November 1968 in a CH3E helicopter at Philadelphia, Pennsylvania. Shakedown flights were made in November–December to test all components. Every item was functioning well, except the SHORAN navigation system, when the HGMS moved to Patuxent River, Maryland, to fly detailed tests over Maryland and Virginia and out over the continental slope.

Results of this test, computed in the field by hand calculations, show cross-checks of several milligals. Adjacent flight lines in the grid pattern show anomalies through the pattern at the proper spacing and with the correct amplitude.

Two lines were flown along the same flight path over a 34-mgal domal anomaly in Virginia. These data show the anomaly at the amplitude and with the period of the known ground feature. Unfortunately, the computer results are not available at this time for the remaining lines.

Tests of the gravity meter in the hover mode, using a UH1D helicopter, show that three to six stations can be measured in one hour with an accuracy of better than 1 mgal. These trials were performed at Fort Belvoir in March 1969. The helicopter would hover in ground effect, 5 to 15 ft above the ground or water, the meter would be erected and stabilized, and 5 to 10 minutes of good record would be obtained. Elevation changes were monitored by the pressure port calibrator and were negligible. Several sites were reoccupied in this manner and the 1 mgal accuracy was determined. The only problem encountered on this test was that vibration affected the meter during the first day. Adequate shock mounts were installed and the instability disappeared. Profiles were attempted but with no auto-pilot it was impossible to control the vertical variations of the helicopter.

Testing has been completed at Forbes AFB on the altimetry subsystem and the HIRAN navigation. The HIRAN tests involved the evaluation of an on-board straight line plotter to assist in running a true grid survey pattern. This plotter provides an instantaneous signal to the pilot to inform him of course variations. The problem

exists that too many or too much of a variation may affect the gravity meter platform and input errors to the gravity sensor.

The altimetry system has been tested in an attempt to increase the altitude capability from the present 3,000 ft to 7,000 or 8,000 ft. Tests have been performed on ram air effects on the pressure probe to ensure that only static air pressure is being sampled. These tests continued until late April. The entire system was installed for tests in Kansas over the mid-continent gravity high, with final testing in Maryland and Virginia to satisfy field operation evaluation.

Tests were performed with an HGMS in the Ottawa, Canada, vicinity for a fixed-wing aircraft test. This was a co-operative effort with the Dominion Observatory. During this test, Cubic Autotape was used for navigation and the modified LaCoste & Rhomberg stable-platform and meter was used. This test in Canada lasted three to four weeks.

Data reduction programmes were completed in April. With these programmes, data can be computed in one day after receipt of magnetic tapes. System adjustments can be made to compensate for deficiencies pointed out by the data reduction.

Additional plans include the substitution of an infra-red scanner for the strip camera. This instrument would allow night operation that would alleviate many HGMS problems. The air is much more stable at night, the laser altimeter receives a much stronger, cleaner signal and can go higher and the navigation system range can be extended.

Conclusion

In conclusion, TOPOCOM feels that this system contains the best available equipment for airborne gravity measurements. These extensive tests of the improved equipment should confirm, by late summer of 1970, if it will be possible to measure accurately short period gravity features using airborne techniques. Airborne techniques are certainly required and it is highly desirable to get a system working and in the field.

PRECISION DISTANCE MEASUREMENT BY LASER GEODIMETER

Paper presented by Japan[1]

The electronic distance-measuring (EDM) instruments belonging to the Geographical Survey Institute (GSI) are classified into two categories: electro-magnetic and electro-optical instruments. Among the electro-magnetic devices there are several models of tellurometer and electrotape by which measurement of longer distances is possible, but these are regarded as less accurate than the electro-optical devices. They are not used for the side lengths of the first triangulation net or other equivalent measurements.

By using geodimeter model 2, the oldest type of electro-optical system, GSI measured twenty-six sides of the first triangulation nets of Japan. This work forms a part of the first-order triangulation resurvey started, just after the Second World War, from Kyushu and finished in Hokkaido in 1967.[2] The purpose of this work is to investigate the crustal movement of Japan by using the values of the old survey completed approximately sixty years ago.

In 1968, GSI began the work of the second resurvey from Kyushu, again using the model 2 geodimeter. In 1969, the laser geodimeter model 8 was used for the first time. Three side lengths of the first triangulation nets have been measured, ranging from 30 km to 40 km during about one month.

Geodimeter model 8

As the light source of the instrument, the laser has replaced the conventional tungsten or mercury vapour lamp. The sharpness of the laser emission itself and the projection optics of two lenses have reduced the beam width to within 0·1 mm radians, or 1 m spread of light at a distance of 10 km. Owing to the high intensity of light, a long range of 47 km was measured in 1969, whereas 39 km was the longest distance that could be measured in 1956 with the model 2 geodimeter.[3]

Calibration of the constant

The accuracy of EDM instruments is influenced by two types of errors. One is the zero error, which is independent of the measured distance. The other is dependent on or proportional to the distance.

To eliminate the proportional error the signal frequencies, F_1, F_2, F_3, were checked before and after the length measurement of triangulation nets. The accuracy of the frequency counter is kept within 10^{-8} for a measuring frequency. It was found that the differences from the nominal frequencies were smaller than 30 Hz, or an order of 10^{-6} per signal frequencies. The measured distance has been corrected for the frequency difference from nominal values though the corrections were generally very small.

As for the zero error the instrument constant must be calibrated. This constant can be found by the following method; measure a straight line, L_1, then divide it into two parts, L_2, L_3, and measure them. Obtaining the measured values, l_1, l_2 and l_3 for lines, L_1, L_2, L_3, respectively, we have:

$$\begin{aligned} l_1+c &= L_1 = L_2+L_3 \\ l_2+c &= L_2 \\ l_3+c &= L_3. \end{aligned}$$

From these equations we can find the required constant;

$$c = l_1-(l_2+l_3)$$

[1] The original text of this paper, prepared by the Geographical Survey Institute, Tokyo, appeared as document E/CONF.57/L.31.

[2] T. Harada, "Precise readjustment of old and new first-order triangulations and the result in relation with destructive earthquakes in Japan", *Bulletin of the Geographical Survey Institute*, vol. 12, 5–64, 1967.

[3] GSI, "Base-line measurement by geodimeter", *Bulletin of the Geographical Survey Institute*, vol. 1–11, 1962.

This equation means that the instrument constant c is obtained without knowing the true values of lengths, L_1, L_2, L_3.

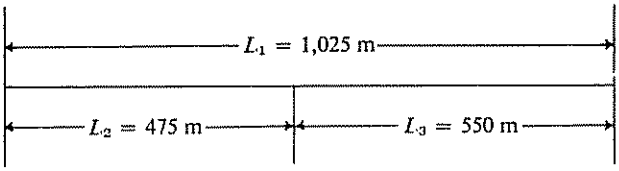
The constant was calibrated by this method at the same time as the frequency check with the Akitamachi base line located in the suburbs of Tokyo.

A new instrument constant +0.213 m was found by this calibration, while the manufacturer had determined +0.210 m as the constant for this instrument on 29 October 1968. There is a slight difference of 3 mm between the two values. Taking into consideration that there are some fluctuations in our measurements, the value established by the manufacturer was adopted.

On the other hand, in 1965, this base line had been measured by invar wire for ranges L_1, L_2, L_3, and the following results were obtained:

$$L_1 = 1{,}024.877 \text{ m}$$
$$L_2 = 474.951 \text{ m}$$
$$L_3 = 549.926 \text{ m}$$

From these values, we could have six values for geodimeter constant. Their mean was +0.195 m smaller than by the previous method. The difference in the two suggests to us that some movement may have occurred in this base line since 1965. This should be clarified in the future.



Akitamachi base line

17 September 1969 Temperature 26°C

	L_1	L_2	L_3
1	1,024.689	474.755	549.722
2	700	757	722
Mean	1,024.694	474.756	549.722

$$C_1 = -(474.756+549.722)+1{,}024.694 = 0.214$$

27 November 1969 Temperature 11°C

	L_1	L_2	L_3
1	1,024.691	—	—
2	687	474.749	549.728
Mean	1,024.689	474.749	549.728

$$C_2 = -(474.749+549.728)+1{,}024.689 = 0.212$$

Mean of C_1, C_2 . . . . . +0.213 m
The value determined by the manufacturer . . +0.210 m

Measurement of sides of the first-order triangulation nets

In 1969, three sides of the first-order triangulation nets in the Kyushu district were measured. Two or three days were spent for each side observation to minimize the atmospheric correction errors. The meteorological conditions, temperature, atmospheric pressure and humidity, were observed every 15 min at both ends of the line.

The computation was made by using the electric computer NEAC-2206, which GSI owns.

The atmospheric correction is:

$$\left(308.6-107.92\frac{P}{273.2+t}+\frac{15.02e}{273.2+t}\right)10^{-6}$$

where t = °C, P = mm Hg and e = mm Hg (partial water vapour pressure).

Observed values are reduced to the reference ellipsoid by the following formula:

$$D-\frac{h^2}{2D}-\frac{DHm}{R_\alpha}-\frac{h^4}{8D^3}+\frac{h^2Hm}{2R_\alpha D}+\frac{D}{16R_\alpha}(5h_1^2+6h_1h_2+5h_2^2)$$
$$-\frac{D^3Hm}{8R_\alpha^3}+\frac{D^3}{24R_\alpha}(1-K)^2$$

where h_1, h_2 = heights of both stations

$$Hm = \frac{h_1+h_2}{2}$$

D = observed value
$h = h_1-h_2$
K = coefficient of refraction (generally 0.2)

$$R_\alpha = \frac{N\,Rm}{N\cos^2{}_\alpha+Rm\sin^2{}_\alpha}$$

Rm = radius of curvature in meridian
N = radius of curvature in prime vertical
α = azimuth from h_1 to h_2

Quadrilateral measurement

Another significant task was the quadrilateral measurement by the model 8 geodimeter. Since 1964, nine quadrilaterals have been established in Japan. The purpose of this work is the detection of crustal movement which should be related to earthquakes. The observations are being carried out by geodimeter models 2, 4 or 6. The result of the Mizusawa Quadrilateral was reported in the Bulletin of the GSI in 1965.[4] Generally, the first measurements of each quadrilateral are compared with the second, carried out after one year. If the movement is recognized to be significant the observations are repeated.

The Tanna Quadrilateral is located in Shizuoka Prefecture on a hill in Hakone through which both tunnels of the new and old Tokaido lines pass. A famous geological dislocation, called the Tanna Fault runs along a ridge of the hill. In February 1969 the first observation was carried out with the model 8, which was the first work of quadrilateral measurement using the laser geodimeter. In February 1970, the second was taken with the same instrument. The results are as follows:

[4] GSI, "Quadrilateral measurement by Geodimeter II", *Bulletin of the Geographical Survey Institute*, vol. 35–41, 1965.

Side	(1) February 1969			(2) February 1970			Adjusted length (2) minus adjusted length (1)
	Observed length m	Correction mm	Adjusted length m	Observed length m	Correction mm	Adjusted length m	mm
21–23	3,336.131	−1	3,336.130	3,336.150	0	3,336.151	+21
21–22	3,915.164	−1	3,915.163	3,915.759	0	3,915.182	+19
22–24	3,236.772	−1	3,236.771	3,236.759	0	3,236.759	−12
23–24	3,644.323	−1	3,644.322	3,644.340	0	3,644.340	+18
22–23	4,791.338	+3	4,791.341	4,791.352	+1	4,791.353	+12
21–24	5,213.426	+3	5,213.429	5,213.450	+1	5,213.451	+22

Side	Date	Length by model 8 m	S.D. M.E. mm	Length hitherto adopted m	Difference m
G. Nagauramura R. Hachirodake	5/6 October 1969	28,940.832	41 10	28,940.315	0.517
G. Maruyama R. Bozumiyama	12–16 October 1969	31,887.607	13 4	31,887.452	0.155
G. Mominokiyama R. Motokoshiyama	23–25 October 1969	35,642.518	34 9	35,642.394	0.123

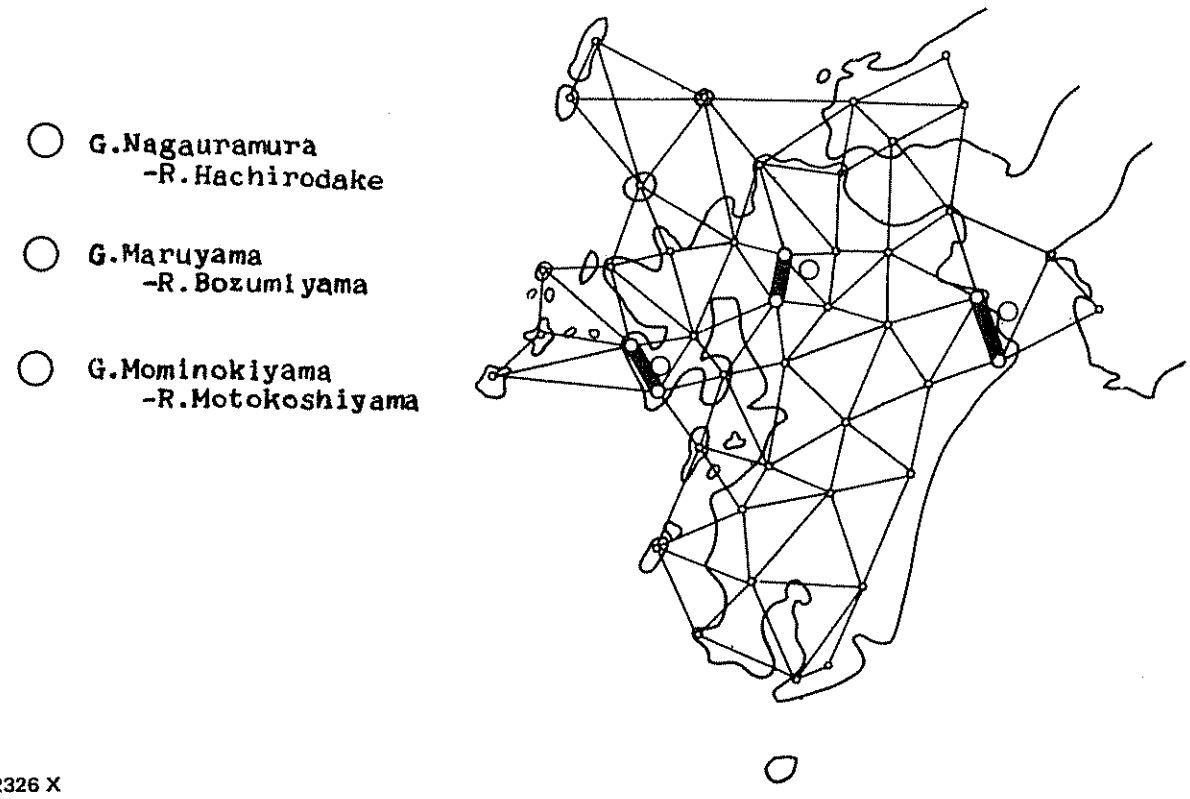
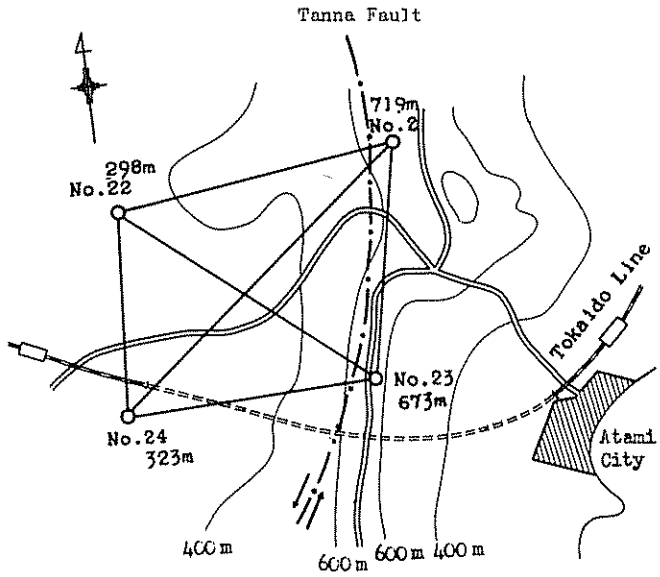
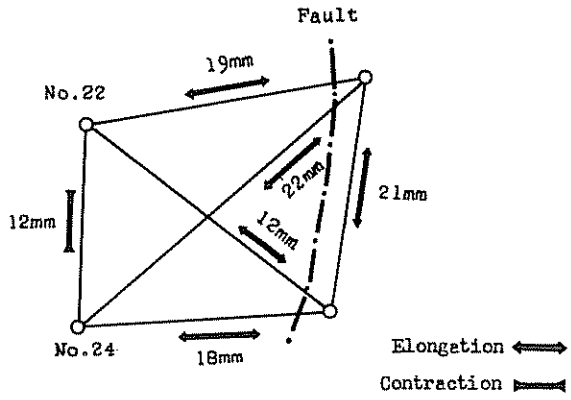


Figure I



Tanna Quadrilateral



Deformation between two surveys

Figure II

REPORT ON THE COMPLETION OF THE 12TH PARALLEL SURVEY: AFRICA

Paper presented by the United States of America[1]

The United States Government is pleased to report the completion of the 12th Parallel Survey. The completion of this project fulfils long-standing desires of many nations as expressed repeatedly at international meetings of scientific interest.

The concept of the 12th Parallel Survey was first introduced as a resolution at a meeting of the Scientific Council for Africa South of the Sahara, held in Bukavu, Democratic Republic of the Congo,[2] November 1953. The resolution placed emphasis on the importance of "An arc of the parallel extending from the east to the west coast of Africa approximately following the 12th parallel (north) and tying to the 30th meridian".

In August 1960, at the meetings of the International Association of Geodesy (IAG) during the XIIth General Assembly of the International Union of Geodesy and Geophysics (IUGG), at Helsinki, Finland, the member nations adopted a resolution which considered the initiation of a primary traverse across Africa following generally along the 12th parallel (north). The primary purpose of the survey was to provide more and better data for defining the size and shape of the Earth and to provide the geodetic data required for referencing various independent surveys in Africa to a common datum.

At the First United Nations Regional Cartographic Conference for Africa, held in Nairobi, Kenya, July 1963, the IUGG resolution was endorsed by the African nations with the object of completing the 12th Parallel Survey at an early date.

The United States Government, realizing the scientific value of the survey and the benefit of a common datum to the African countries involved through the route of the survey, agreed to finance the major portion of the project.

In December 1964, a United States representative visited each country concerned, to discuss preliminary bilateral considerations. Shortly thereafter, a second visit was made to finalize more specific arrangements. As a result of these beneficial discussions, the United States Corps of Engineers proceeded to activate the project. An assessment of the survey capabilities of several agencies was made as well as a cost analysis. Shortly thereafter, the Institut géographique national (IGN), Paris, France, was selected as the contractor for the field survey operations in all concerned countries except Nigeria, where separate arrangements were made. The work in Nigeria was performed by the Federal Survey Department in conjunction with a limited number of technical supervisors from the United States.

The accuracy of the survey was controlled by a most rigid set of specifications consistent with the present state-of-the-art, surveying equipment and observational techniques. A model 4-D geodimeter, transmitting a pulsed light wave, was employed as the primary distance-measuring instrument. Its modulation frequencies were monitored constantly on a precise frequency counter throughout the periods of operation. Each course of the traverse was double measured in accordance with first-order electro-optical base line procedures with a maximum probable error of one part per million allowed. Additionally, check measurements of each distance were made with the tellurometer, which utilizes a modulated electromagnetic wave, to guard against undetected errors caused by possible ambiguities in the geodimeter measurements. The tellurometer measurements were required to agree with the corresponding geodimeter measurements to within 20 cm plus three parts per million.

Modified first-order astronomic positions plus first-order astronomic azimuths were observed at selected stations along the traverse at average intervals of 30 km with no interval exceeding 40 km. These observations permitted deflection of the vertical determinations and Laplace azimuth orientation at each observed point. Maximum closure between consecutive Laplace azimuths was not allowed to exceed 2 seconds of arc.

Vertical control connexions were required between bench-marks of level lines of third- or higher-order accuracy and stations at which astronomic position determinations were made. Trigonometric elevations were carried through intermediate stations.

Survey towers up to 34 m in height were used, where required, to obtain unobstructed line-of-sight for angle and distance measurements.

Had it become necessary, the United States would have introduced recently developed laser geodimeter instruments into this project to penetrate the troublesome Harmattan haze existing in the project area. However, prudent selection of the station locations and shortening of the lines in some cases made it possible to complete observations with the conventional instruments.

Field survey operations by IGN, under United States inspection, began in eastern Chad in January 1967 with the border tie to the Sudan basic control. The survey progressed westwards two-thirds of the way across Chad by April of that year when work was terminated at the end of the first survey season. Work was resumed at this point in January 1968 and continued to the west, completing the remaining portion of Chad as well as the narrow corridor of northern Cameroon by March 1968. At this time, the border tie with Nigeria was completed through the co-operative efforts of Nigeria, the United States and the IGN contractor. This work force then convoyed across northern Nigeria and completed the border tie with Niger at a point south-east of Niamey during April 1968, prior to the close of the second survey season.

The Department of Federal Surveys of Nigeria, with monetary and technical assistance provided by the United States, began a year-round operation on the Nigerian portion of the survey in the fall of 1968. These efforts began at the Niger border tie and progressed eastward generally along the 12th parallel reaching the Cameroon border tie stations in April 1970.

Simultaneously, with the beginning of the concentrated efforts in Nigeria, and at the request of the United States, the IGN fielded two parties in November 1968. One party began at the Niger–Nigerian border tie and worked westward through Niger and into Upper Volta, while the second party began at the westernmost point of the

[1] The original text of this paper, prepared by J. S. McCall, United States Corps of Engineers, Department of Defense, Washington, D.C., appeared as document E/CONF.57/L.41.

[2] Now the Republic of Zaire.

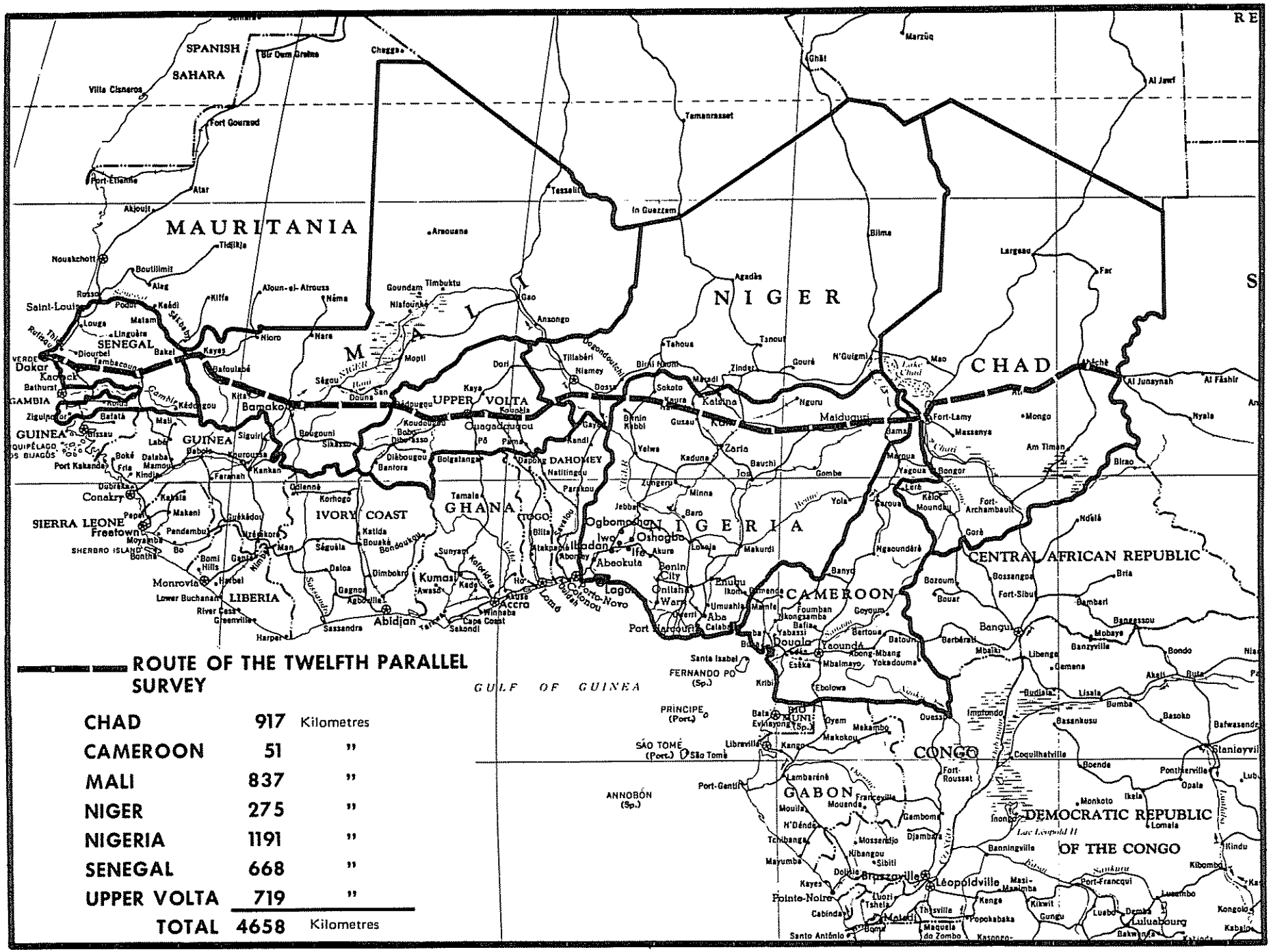
traverse at Dakar and worked eastward through Senegal. During this third season, the east party reached a point in Upper Volta 100 km west of Ouagadougou; the west party progressed across Senegal and, with the assistance of the Institut national de topographie (INT) of Mali, completed the tie across the Senegal–Mali border at a point near Keyes in April 1969. The third season's operations ceased at this point in time.

In November 1969, the contractor again resumed operations utilizing two parties to expedite the closure of the approximately 1,000 km gap remaining across Mali and Upper Volta. These parties met at a point just east of Bamako, Mali, in April 1970, thereby completing one of the most extensive and precise geodetic surveys ever undertaken.

It should not be overlooked that each station along the route of the traverse is permanently monumented in concrete or outcropping bedrock with a minimum of two similarly monumented reference marks and an azimuth mark. Each of these marks is adequately described, and photo-identified where possible, to facilitate the ease of future recovery. In addition, owing to the precise nature of the survey, each traverse course virtually constitutes a Laplace-oriented first-order base line to be used as desired in the future to extend first- or lower-order control for the mapping and economic development purposes of each of the countries concerned.

Although we are reporting today the successful conclusion of a large and difficult task and considering here the benefits to be derived internationally as a result, we would be remiss if we did not temper our collective pride in accomplishment with one sobering thought. This project did not progress without mishap. Three employees of the Federal Survey Department of Nigeria lost their lives as a result of two accidents, one vehicular and one involving the collapse of an observing tower. We sincerely regret this unfortunate turn of events.

We have seen the 12th Parallel Survey progress from its origin at the Sudan–Chad border westward through seven nations to its terminus at Dakar, Senegal—a distance of 4,658 km. We have observed the successful merger of personnel, equipment and skills of nine nations into a common work force employed towards a common goal. If there was one outstanding factor which contributed most to our successful conclusion of this project, it was international co-operation. We sincerely hope that the spirit of co-operation which served us all so well on the 12th parallel will continue, and we look forward to the day when we may once again employ it in other areas of mutual endeavour.



2327 X

Route of the Twelfth Parallel Survey

GEODETIC SURVEYING IN AUSTRALIA

Paper presented by Australia[1]

HIGH-PRECISION TRAVERSING

A network of high-precision traverses coinciding with the network of geoidal profiles as shown in figure I is being measured by the Division of National Mapping.

Except for a section of 500 km in New South Wales, the high-precision work follows existing geodetic traverses observed during the period 1958–1965 with tellurometer models 1 and 2.

The high-precision survey consists of re-measuring of all distances with modern precision EDM equipment and observing of simultaneous reciprocal azimuths. Horizontal and vertical angles from the original survey are adopted.

The survey started in 1966 and, until the successful introduction of laser model 8 geodimeters in late 1969, measurements of lines were carried out with MRA4 tellurometers in two days. The present specifications stipulate that distances shall be measured with a laser geodimeter or, where this is impracticable, with MRA4 tellurometers.

Each line has to be measured in two days, and the measuring frequencies have to be checked with a frequency counter every two weeks.

Astronomical azimuths are determined simultaneously from both ends of a line by observations to *Sigma octantis* on two nights. Wild T3 theodolites are used in this work.

Priority is being given to the survey of the two Pageos satellite triangulation base lines in Australia. Work on the 3,200 km-long east–west base line was completed in December 1969. The survey of the 2,600 km-long north–south base line will be completed in December 1970.

A comparison of the free adjustment of the high-precision survey of the east–west base line with corresponding values of the 1966 national geodetic adjustment is given below:

	Chord distance of E-W base line
National adjustment 1966	3 163 625.133 m
Free adjustment 1969 (high-precision survey)	3 163 623.540 m
Difference	+1.593 m or +0.5 × 10^{-6}

The maximum discrepancies occur near the middle of the base line, amounting to 4.5 m in the direction of the line and 5.1 m at right angles to it.

ACCURACY OF ASTRONOMICAL OBSERVATIONS

First-order astronomical observations have been made at about 1,200 stations since 1950. For the first twelve years, Wild T4 theodolites were used for latitude and longitude determinations by Talcott's method and by meridian transits, respectively, and 255 stations were observed by these methods. Since 1962, Kern DKM3A theodolites have been used for latitude determination by circum-meridian altitudes, and longitude determination by the almucantar method (similar to Zinger's method). Azimuths were observed mainly with the Wild T3, although before 1962 a few single-ended observations were made with the Wild T4 and after that date a number of simultaneous reciprocal observations were made with Kern DKM3A instruments.

At each astronomic station at least sixteen pairs of latitude stars and sixteen pairs of longitude stars are observed. For azimuth observations twenty-four zeros are observed, a zero being all observations made at one position of the horizontal circle. Longitudes and azimuths are spread over at least two nights. Latitudes are normally spread over two nights, but may be all observed on one night. At any station the range of the ten best pairs of latitude stars may not exceed 2.0 seconds of arc. On any one night the range of the best six pairs of longitude stars may not exceed 0.2 seconds of time and the mean may not differ by more than 0.12 seconds of time from the mean of the best six pairs on another night. These re-observation limits are seldom approached.

Over the last 20 years re-observations for latitude and longitude have been made at 100 stations for accuracy comparisons. In latitude, the average difference between the determinations is 0.43″, with a standard error of 0.38″ for a single determination. In longitude, the average difference is 0.86″ with a standard error of 0.76″ for a single determination.

On the 156 simultaneous reciprocal azimuths observed on the Pageos base lines, the average difference between the forward and reverse azimuths is 1.16″, with a standard error of 1.42″ for a single determination from one end of a line.

All astronomic observations have been reduced to the conventional international origin.

DETERMINATION OF THE GEOID IN AUSTRALIA

Approximately 1,200 astrogeodetic stations will have been observed in Australia by the end of 1970, and a revision of the geoid determination on the Australian geodetic datum (AGD) will be completed by the Division of National Mapping in early 1971.

Geoidal profiles of closely spaced astrogeodetic stations will form a primary framework which will be subdivided by secondary profiles in which some stations will rely on gravimetric calculation for their values of the deflexions of the vertical. An adjustment of all the geoidal profiles, with a weighting system based mainly on station spacing, will provide values of the geoid–spheroid separation (N) for all astrogeodetic stations on the AGD.

Values of N for all regions inside the loops formed by the geoidal profiles will be obtained gravimetrically and will be in sympathy with the values of N at the previously adjusted astrogeodetic stations.

AUSTRALIAN LEVELLING ADJUSTMENT

About 85,000 km of levelling forming 270 loops will be rigorously adjusted by least squares at the end of 1970. Observed differences in elevation corrected by the orthometric correction for the non-parallelism of equipotential surfaces will be used.

Levelling data recorded on special data forms by the

[1] The original text of this paper appeared as document E/CONF 57/L.49.

Figure 1. Australia: Primary geoidal profiles

observing authorities are being received by the Division of National Mapping and are punched on data cards without further transcription. By the end of September 1970 about 80 per cent of the information had been received.

The adjustment will be carried out in two phases. In the first phase, five regional nets of about 140 junction points each will be adjusted separately by the method of observation equations. The second phase combines the five networks into a whole by a condition-equation adjustment. Variance–covariance matrices will be computed for each regional net and for the whole net.

All computer programmes written in Fortran IV have been tested and proved on a CDC-3600 computer on which the adjustment will be carried out.

The adjustment programmes allow the differences in height at each tide gauge between the bench-mark and mean sea level to be allocated any weight between zero and infinity.

Mean sea level has been determined at some thirty tide gauges around Australia for the common three-year period from 1 January 1966 to 31 December 1968.

Figure II shows a preliminary comparison of levelling with mean sea level right around the coastline of Australia.

The determination of the Australian height datum will be obtained from the adjustment of the whole levelling network linked to mean sea level at the tide gauges with weights at gauges varying between zero and infinity.

"Deep" bench-marking

The Division of National Mapping has been establishing stable "deep" bench-marks constructed of vertically driven copper-coated tubular steel rods sealed at both ends against moisture and protected at ground level by a loose-fitting concrete collar.

Recent development of a suitable stainless-steel-clad rod and fittings by Tubemakers of Australia, Limited—B.T.M. Division—now provides a cheaper bench-marking material which tests have shown to be more corrosion-resistant than the copper rods.

Rods are driven vertically by an Atlas Copco petrol-driven "Cobra" rock drill breaker installed on a truck-mounted vertical-driving rig. Two men are able to complete the installation of a 12-ft deep bench-mark in less than 15 minutes at a total cost of about $5.34.

Third-order levelling procedures

Levelling parties of the Division of National Mapping, working under good weather conditions and in reasonably flat country, have each been able to complete up to 22 miles of one-way third-order levelling during a normal working day.

Each party, comprising an instrument man and two staff men, is equipped with two vehicles. The staff men, each driving a vehicle, "leap-frog" along the levelling route with the backsight staff man picking up and driving the instrument man to the next set-up before proceeding to his next forward staff position.

Electronic computing

A brief description follows of some major computer programmes written in the Division of National Mapping. All programmes are written in Fortran for a CDC-3600.

Reduction of distances measured electronically

TELLYHT computes tellurometer distances and trigonometrical heights, or either separately, along a traverse.

GEODIMET computes sea-level distances from geodimeter 8 observations.

Co-ordinate conversion

TMCOORD converts latitudes and longitudes to eastings and northings and the reverse on any transverse Mercator grid.

LAUF converts rectangular co-ordinates from one grid to another.

Distance and azimuth on the spheroid

ROBBINS computes distance and forward and reverse azimuth, given the latitude and longitude of two points, from Robbin's formulae for lines up to 1,000 miles.

AZARC is similar to the ROBBINS programme, but Rudoe's and Sodano's fourth formulae are used for extremely long lines on the spheroid.

Traverse on the spheroid

CLARKROB computes traverses on the spheroid. It lists closures in latitude, longitude and azimuth round loops of traverses in networks of any complexity.

Astronomy

STARCORD updates star co-ordinates to the instant of observation. The fourth fundamental catalogue for 1950 is held on magnetic tape.

LATCOMP computes circum-meridian latitude observations. After rejecting latitudes beyond a specified limit, the mean, the range, standard deviation and standard error of the mean area computed.

ALMUCOMP computes astronomical longitudes from almucantar observations. After rejecting longitudes beyond a specified limit, the mean, range, standard deviation and standard error of the mean are computed.

ASTRO combines the STARCORD, LATCOMP and ALMUCOMP programmes into a single programme.

SIGMA computes astronomic azimuths observed from *Sigma octantis*. The right ascension and declination and the curvature corrections are computed internally.

ALMUPRED predicts stars for almucantar longitude observations.

MERIPRED predicts stars transiting the meridian.

Horizontal adjustments

VARYCORD is a computer programme for the least-squares adjustment of angles, azimuths and distances on the spheroid. It is designed to adjust traverses, triangulation, Hiran and Aerodist trilateration, separately or in combination. It does not adjust heights.

Height adjustment

A series of programmes is being finalized to adjust large levelling, trigonometrical height and similar networks. The two main programmes are based on least-squares adjustment in phases. The phase I adjustment is by observation equations and the phase II adjustment by condition equations. Variance–covariance matrices are computed.

MT. ENA TUNNEL SURVEY

Paper presented by Japan[1]

The main transportation networks, such as the new Tokaido line and the Tokyo–Kobe Expressway, are being constructed through the four main islands of Japan. Chuo Expressway is one of the network routes and will run through the mountainous area in the central part of the main island. This route will require the construction of the longest road tunnel in Japan, the Enasan tunnel. The Enasan tunnel will be about 8.5 km long and it will be the second longest road tunnel in the world. It is being constructed by Japan Highway Public Corporation (JHPC) on a six-year plan. The construction cost is estimated about $4 million per kilometre.

Purpose of survey

The work is planned to start from both ends of the tunnel at the same time. The purpose of the survey is to make the discrepancy as small as possible at the middle point, in other words: (*a*) to determine the correct direction at both tunnel entrances, and (*b*) to orient the direction accurately in the tunnel. At present the first stage is completed.

Planning of survey

The survey was planned to establish the triangulation net including both entrances for determining the direction of the entrances, to determine the height differences between the entrances with a direct levelling survey to pass over the Kamisaka ridge at about 1,600 m height and to establish the three bench-marks for each entrance and five other bench-marks along the levelling routes for checking the three main bench-marks.

Survey method

Horizontal control

The Mt. Yokokawa national control point (*A* of figure I) was chosen for the origin of the plane co-ordinate of this survey. Two sets of horizontal angles, the angle between Ena national first-order control point and point *G* and the angle between national second-order control point and point *G* were measured at point *A*. The mean values were adopted for the base azimuth.

Reconnaissance

The basic network is shown in figure I and consists of an irregular polygon with interior point. Using *B*, *C*, *H* and *G* for known points, the sub-networks were established. One of these nets is shown in figure II. Points *M* and *L* are the controls to determine the direction of the entrances.

Monumenting

The control points for the direction of the entrances were made with concrete piers and concrete blocks with metal marks were set in the ground for other controls points.

Angle observation

Wild T3 theodolites were used for the horizontal and vertical angle observation. Night observation was adopted as a rule for the horizontal angle observation. One group of observations consists of three direction observations with six positions at each station. GSI third-order triangulation rule was adopted for vertical angle observation.

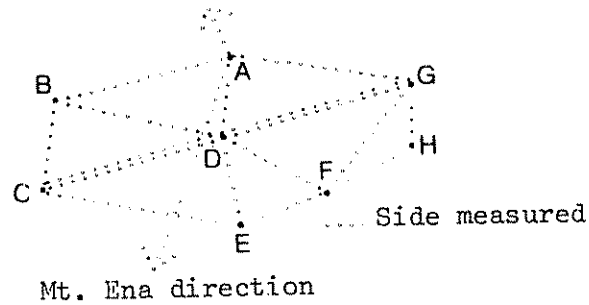


Figure I. Basic net

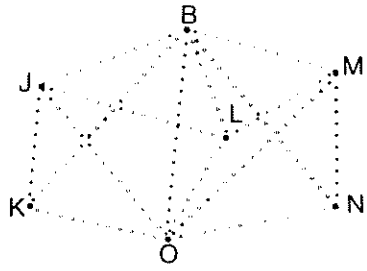


Figure II. Sub-net

Length observation

Hitherto, for the control survey of such a long tunnel, base measurements with the invar-tape were used to give the scale, but for this survey several side-length, night-time measurements with the model 6 geodimeter were used. The examples are shown in the following table:

Distances between C and D (In m)		*Distances between H and G (In m)*	
First set 19 h	5,415.107	First set 20 h	2,176.192
Second set 20 h	5,415.105	Second set 21 h	2,176.190
Third set 22 h	5,415.113	Third set 23 h	2,176.201
Fourth set 24 h	5,415.101	Fourth set 24 h	2,176.193

Calculation and accuracy

Calculations in the field

(*a*) Station adjustment for horizontal angle: The mean correction was ±1.1″ per angle;

(*b*) Eccentricity correction;

(*c*) Correction for aximuth depends on the height of the station;

(*d*) Calculation of the spherical excess;

(*e*) Check of the triangle closure error: the mean error of the triangle closure was ±2.65″;

(*f*) Calculation of the trigonometric levelling (rough estimation). Trigonometric levelling with the closed route which connected each control point was conducted to

[1] The original text of this paper, prepared by T. Koshiyama, Tokyo Aero Survey Co., Tokyo, appeared as document E/CONF.57/L.56.

obtain the height in order to reduce the position on the reference ellipsoid. The closure error was 21 cm.

Calculations in the office

The final simultaneous adjustments of the angles, distances and the other calculations were done with the electronic computer.

(*a*) Position calculation with three sets of weights. The positions were calculated with three sets of weights as follows:

	Angle weight	*Distance weight*
(1)	1	0.5
(2)	0.5	1
(3)	Mean error of the observed angle	Nominal mean error by the manufacturer

The differences between the results are shown in the following table (first weight sets are adopted for the base):

Station	(2) [*In cm*]	(3) [*In cm*]
A (origin)	0.00	0.00
B	0.25	0.52
C	0.22	0.42
D	0.01	0.03
E	0.03	0.12
F	0.06	0.10
G	0.08	0.10
H	0.16	0.16

(*b*) Number of conditional equations. The numbers of angle and side conditional equations for the basic net are:

Angle conditional equation	7
Side conditional equation	4

The observed values were adjusted with these conditional equations simultaneously.

(*c*) Standard level surface. The height of the road surface of this tunnel is about 700 m above mean sea level. The 700 m level surface was adopted for the base level surface for the convenience of the tunnel work.

(*d*) Comparison with Geographical Survey Institute control point. The comparison with GSI control point was made and differences of several centimetres were found. The main reasons for these differences are assumed to depend on the crustal movement of that area over a long period, the GSI control point having been established about 50 years ago.

Conclusion

On a survey project of this type, the most important objects are to use the best instruments available in order to obtain the greatest accuracy and to be economical. The adoption of the combination of the Wild T3 theodolite and the model 6 geodimeter was believed to be reasonable.

A FORTRAN PROGRAMME FOR THE COMPUTATION OF CO-ORDINATES ON THE UTM REFERENCE SYSTEM

Paper presented by Indonesia[1]

Introduction

The electronic computer has revolutionized man's ability to handle data. Not long ago, when all computations and least-squares adjustment of large geodetic networks were carried out by hand or electric calculating machines, the computations required a great deal of labour and entailed high costs. Real progress was made with the use of electronic computers, which make possible substantial cuts in working time and expenses.

The theoretical and practical difficulties of solving complex problems, as in geodetic computations, make it necessary to carefully select appropriate numerical methods and programming in order to: (*a*) suitably exploit the properties of the electronic computer and in particular make proper use of external memory and of input and output devices; (*b*) obtain sufficiently accurate results; (*c*) control efficiently large quantities of input data and intermediate and final results; and (*d*) work out all the computations automatically; man's intervention should be limited to the preparation of input data and basic care of the computer.

The purpose of this paper is to describe computer programmes designed for geodetic computations for the Universal Transverse Mercator (UTM) reference system, which require the conversion of geodetic co-ordinates to co-ordinates of the UTM system and vice versa. No attempt has been made here to add anything new to the theory of map projections or to derive the formulae used. With regard to the formulae in existing publications, Fortran IV programmes are written for electronic computations that replace manual handling. We must now supply the necessary input data and organize them in accordance with the proposed format.

It should be noted that the UTM system, which is a standard projection system for three-quarters of the world's countries, is being used for the first time in Indonesia for the new topographic maps at 1:50,000 prepared as part of the national mapping programme of the first five-year development plan.

UTM projection system

In the analysis of suitable projection systems, two basic criteria—conformity and continuity—limit the selection of projection types. No system can maintain a uniform scale for any great distance.

In conformal projection, the angles of direction of the sight lines around a given point are retained unaltered, and the uniformity of scale in the neighbourhood of each point on the map is consequently assured, the variations being slow and progressive as the distance from the centre of the projection increases.

One of the conformal projections that will be considered here is the Universal Transverse Mercator (UTM) projection. It can be visualized as a spheroid projected upon a

[1] The original text of this paper, prepared by J. Rais, Diponegoro University, Semarang, appeared as document E/CONF.57/L.73.

cylinder the axis of which is in the equatorial plane. The cylinder is made secant to the spheroid so that it cuts the latter along two lines parallel to the central meridian of projection. These two north–south lines are located 180,000 m west and 180,000 m east of the central meridian.

The scale of the intersected spheroid and the scale of the intersecting cylinder are the same along the two north–south lines mentioned above; the scale factor remains equal to unity, whereas the scale factor for the central meridian is 0.9996.

The UTM system, as it is usually called today, was previously known as the Universal Military Grid System, which was developed by the United States of America and its allies shortly after the Second World War. It was based on the criteria provided for a military reference system, received rapid acceptance and is now in general use. For a description of the basic characteristics of the UTM reference system, the reader should refer to existing publications.

Formulae for conversion of co-ordinates

The basic formulae for conversion of geodetic co-ordinates to co-ordinates of the UTM grid reference system, and vice versa, are those given in *The Universal Grid Systems*, AMS TM-5 (1951), and in *Conformal Projections in Geodesy and Cartography* by Paul D. Thomas, United States Coast and Geodetic Survey special publication No. 251 (1952).

The meridional distance S is computed from the formula given in most textbooks on geodesy. The equation for the convergence of the meridians is also given by Thomas, whereas the equation for the scale factor is given by A. G. Bomford in the *Empire Survey Review*, July 1962. Rainsford's direct solution is used for computation of footpoint latitude (*Bulletin géodésique* N.S. 37, 1955).

Function of the programmes

Two programmes are described in this paper, one for the conversion of geodetic co-ordinates to UTM grid co-ordinates and the other for the reverse operation.

Programme 1 is used to compute the false easting and the false northing for all points in any UTM zone, as well as the scale factor and the meridian convergence at the computed point. The central meridian is defined by the given zone number. This programme makes it possible to compute values at any latitude from the equator up to 80° north or south. Values can also be computed beyond the normal limit of 3° of longitude from the central meridian, but with reduced accuracy.

Programme 2 is used to compute the geodetic co-ordinates from the given false grid co-ordinates in any UTM zone defined by its central meridian. This programme also makes it possible to compute the scale factor and the convergence of the meridians at any given point.

No programme has been developed for direct zone-to-zone conversion, although this conversion can be worked out indirectly by the reverse method; however, this reverse method and the direct zone-to-zone conversion should be compared from the viewpoint of accuracy of results before any conclusion can be reached.

The formulae used are based on the indicated accuracy as they were specified in the references mentioned earlier. Examples from the United States Department of the Army manual TM5-241 were used for an accuracy check. These checks indicate that the accuracy is at least 1/10,000 second for latitude and longitude and 1/10,000 m for the false co-ordinates. The accuracy of convergence and scale appears to be equally high.

Important mnemonic terms used in the Fortran programmes

The following important mnemonic terms are used in the Fortran programmes:

ELL1, ELL2, ELL3	Name of spheroid
A	Equatorial radius
RF	Inverse flattening
KO	Scale factor at the central meridian
In programme 1	
NRTTK	Number and name of station (point)
NOZ	Zone number
LOZ	Longitude of the central meridian
BDEG, BMIN, BSEC	Degrees, minutes and seconds of geodetic latitude, respectively
ALDEG, ALMIN, ALSEC	Degrees, minutes and seconds of geodetic longitude, respectively
E, Y or N	False easting and false northing, respectively
K	Scale factor at computed point
ND, NM, NS	Degrees, minutes and seconds of meridian convergence, respectively
In programme 2	
NRT	Number and name of station (point)
E, N	False easting and false northing, respectively
CM	Longitude of the central meridian
LAT	Designation of latitude: +1 indicating north and −1 indicating south
SK	Scale factor at computed point
LPHI, LPHIS, LPHIM	Degrees, minutes and seconds of geodetic latitude, respectively
LAM, LAMM, FLAMS	Degrees, minutes and seconds of geodetic longitude, respectively
LGAM, LGAMD, GAMS	Degrees, minutes and seconds of meridian convergence, respectively

Input data

Programme 1

Card No. 1: A, RF, ELL1, ELL2, ELL3
Card No. 2: NRTTK, BDEG, BMIN, BSEC, ALDEG, ALMIN, ALSEC, NOZ

Card No. 2 is punched on an IBM card with the following field specifications:

Columns 1 to 12: number and name of the station (point)
Columns 13 and 14: —
Columns 15 to 17: degrees of latitude with sign
Columns 18 and 19: minutes of latitude
Columns 20 to 24: seconds of latitude; the decimal point is between columns 21 and 22

Column 25: —
Columns 26 to 29: degrees of longitude with sign
Columns 30 and 31: minutes of longitude
Columns 32 to 36: seconds of longitude; the decimal point is between columns 33 and 34
Columns 37 to 39: zone number

Additional cards are the same as No. 2. The final card has a zero in the NOZ field which stops the programme.

Programme 2

Card No. 1: A, RF, ELL1, ELL2, ELL3
Card No. 2: NRT, E, N, LAT, CM, with the following field specifications:

Columns 1 to 12: number and name of station (point)
Columns 13 to 15: —
Columns 16 to 28: false grid easting
Columns 29 to 41: false grid northing
Column 42: —
Columns 43 to 45: designation of latitude: +1 for north, −1 for south
Column 46: —
Columns 47 to 49: longitude of the central meridian

Additional cards are the same as No. 2. The final card has a zero in the CM field which stops the programme.

Source programmes in basic Fortran IV language

Annex I lists the Fortran IV instructions of the source programme for programme 1 and annex II lists the equivalent instructions for programme 2. This programme has been compiled and run on an IBM system 360 model 30. It should be noted that these are double-precision programmes written in basic Fortran IV language.

ANNEX I

```
C     COMPUTATION OF UTM GRID CO-ORDINATES FROM GEODETIC CO-ORDINATES
C
      DOUBLE PRECISION A,RF,ESQ,ESQI,EPSQ,KO,RAD,BDEG,BMIN,BSEC,ALDEG,ALMIN,ALSEC,PHI,LAMBDA,P,TG,
     1 TG2,SN2,TG4,CS2,CS4,ETAS,W,MO,NO,AA,BB,CC,DD,S,COFI,COFII,COFIII,COFIV,COFV,COFA6,COFB5,Y,EP,E,
     2 CP1,CP11,CP12,CP13,CP2,CP3,C,D,DM,DS,RM2,K
      DIMENSION NRTTK(3)
C
C     ELLIPSOID'S PARAMETERS,SCALE FACTOR AT CENTRAL MERIDIAN
      READ(1,23) A,RF,ELL1,ELL2,ELL3
      WRITE(3,24)ELL1,ELL2,ELL3,A,RF
      WRITE(3,25)
      ESQ=2.0D0*(1.0D0/RF)-(1.0D0/RF)**2
      ESQI=1.0D0-ESQ
      EPSQ=ESQ/ESQI
      KO=0.9996D0
      RAD=1.0D0/0.572957795131D2
C     INPUT DATAO NAME/NUMBER OF STATION,LATITUDE AND LONGITUDE
C
      KOUNT=0
    9 READ(1,26)(NRTTK(I),I=1,3),BDEG,BMIN,BSEC,ALDEG,ALMIN,ALSEC,NOZ
      IF(NOZ) 10,28,10
   10 KOUNT=KOUNT+1
      LBDEG=BDEG
      LBMIN=BMIN
      LDEG=ALDEG
      LMIN=ALMIN
      PHI=(DABS(BDEG)+(BMIN/60.0D0)+(BSEC/3600.0D0))*RAD
      LAMDA=(DABS(ALDEG)+(ALMIN/60.0D0)+(ALSEC/3600.0D0))*RAD
      IF(NOZ-30) 11,11,12
   11 LCZ=-16*(30-NOZ)+3)
      LAMDA=-LAMDA
      GO TO 13
   12 LOZ=6*NOZ-183
   13 P=DABS(LAMDA-DFLOAT(LOZ)*RAD)
      TG=DSIN(PHI)/DCOS(PHI)
      TG2=TG*TG
      TG4=TG2*TG2
      SN2=DSIN(PHI)*DSIN(PHI)
      CS2=DCOS(PHI)*DCOS(PHI)
      CS4=CS2*CS2
      ETAS=EPSQ*CS2
C
C     COMPUTATION OF RADII OF CURVATURE
      W=DSQRT(1.0D0-ESQ*SN2)
      MO=A*ESQI/(W*W*W)*KO
      NO=A*KO/W
```

```
C
C       COMPUTATION OF MERIDIONAL DISTANCE
        AA=1.0D0+0.75D0*ESQ+45.0D0*ESQ*ESQ/64.0D0+175.0D0*ESQ*ESQ*ESQ/256.0D0
        BB=0.75D0*ESQ+15.0D0*ESQ*ESQ/16.0D0+525.0D0*ESQ*ESQ*ESQ/512.0D0
        CC=15.0D0*ESQ*ESQ/64.0D0+105.0D0*ESQ*ESQ*ESQ/256.0D0
        DD=35.0D0*ESQ*ESQ*ESQ/512.0D0
        S=A*ESQI*(AA*PHI-BB*DSIN(2.0D0*PHI)/2.0D0+CC*DSIN(4.0D0*PHI)/4.0D0-DD*DSIN(6.0D0*PHI)/6.0D0)
C
C       COMPUTATION OF COEFFICIENTS I,II,III,IV,A6 AND B5
        COFI=K0*S
        COFII=N0*DSIN(PHI)*DCOS(PHI)/2.0D0
        COFIII=N0*DSIN(PHI)*DCOS(PHI)*CS2*(5.0D0-TG2+9.0D0*ETAS+4.0D0*ETAS*ETAS)/24.0D0
        COFIV=N0*DCOS(PHI)
        COFV=N0*DCOS(PHI)*CS2*(1.0D0-TG2+ETAS)/6.0D0
        COFA6=N0*DSIN(PHI)*DCOS(PHI)*CS4*(61.0D0-58.0D0*TG2+TG4+270.0D0*ETAS-330.0D0*TG2*ETAS)/720.0D0
        COFB5=N0*DCOS(PHI)*CS4*(5.0D0-18.0D0*TG2+TG4+14.0D0*ETAS-58.0D0*TG2*ETAS)/120.0D0
C
C       COMPUTATION OF UTM GRID CO-ORDINATES
        IF(BDEG) 15,14,14
   14 Y=COFI+COFII*P*P+COFIII*P**4+COFA6*P**6
        GO TO 16
   15 Y=1.0D7-(COFI+COFII*P*P+COFIII*P**4+COFA6*P**6)
   16 EP=COFIV*P+COFV*P**3+COFB5*P**5
        IF(LAMDA-DFLOAT(LOZ)*RAD) 17,19,18
   17 E=5.0D5-EP
        GO TO 20
   18 E=5.0D5+EP
        GO TO 20
   19 E=5.0D5
C
C       COMPUTATION OF MERIDIAN CONVERGENCE
   20 CP1=P*DSIN(PHI)+DSIN(PHI)*P**3*CS2/3.0D0*(1.0D0+3.0D0*ETAS+2.0D0*ETAS*ETAS)
        CP11=P**5*DSIN(PHI)*CS4/15.0D0
        CP12=2.0D0-TG2+15.0D0*ETAS+35.0D0*ETAS**2-15.0D0*ETAS*TG2+33.0D0*ETAS**3
        CP13=-50.0D0*ETAS**2*TG2+11.0D0*ETAS**4-60.0D0*TG2*ETAS**3-24.0D0*TG2*ETAS**4
        CP2=CP11*(CP12+CP13)
        CP3=P**7*DSIN(PHI)*CS2*CS4/315.0D0*(17.0D0-26.0D0*TG2+2.0D0*TG4)
        C=CP1+CP2+CP3
        D=DABS(C)/RAD
        ND=D
        DM=(D-DFLOAT(ND))*60.0D0
        NM=DM
        DS=(DM-DFLOAT(NM)*60.0D0
        IF(C) 21,22,22
   21 ND=-D
   22 RM2=N0*M0
C
C       COMPUTATION OF SCALE FACTOR
        K=K0*(1.0D0+EP*EP/(2.0D0*RM2)+EP**4/(24.0D0*RM2*RM2))
C
C       OUTPUT
        WRITE(3,27)KOUNT,(NRTTK(I),I=1,3),LBDEG,LBMIN,BSEC,LDEG,LMIN,ALSEC,E,Y,K,ND,NM,DS,NOZ
        GO TO 9
   23 FORMAT(F11.3,1X,F10.6,1X,3A4)
   24 FORMAT(//28X,'COMPUTATIONS OF UTM GRID CO-ORDINATES FROM GEODETIC CO-ORDINATES'/28X,'PROGRAMMED
    1 BY J.RAIS - DIPONEGORO UNIVERSITY'/28X,'PROGRAM NR UTM00I'///40X,'ELLIPSOID',3A4/40X,'A =',
    2 F12.3/40X,'1/F =',F8.3//)
   25 FORMAT(//40X,'RESULTS'//1X,'NO',4X,'STATION',6X,'LATITUDE',5X,'LONGITUDE',11X,'E',12X,'N',8X,
    1 'SCALE',5X,'CONVERGENCE',2X,'ZONE'/19X,'D',3X,'M',3X,'S',6X,'D',3X,'M',3X,'S',9X,'METER',7X,
    2 'METER',17X,'D',2X,'M',3X,'S'//)
   26 FORMAT(3A4,2X,F3.0,F2.0,F5.3,1X,F4.0,F2.0,F5.3,I3)
   27 FORMAT(I3,1X,3A4,1X,I4,I3,F7.3,1X,I4,I3,F7.3,2F13.3,F11.8,I4,I3,F7.3,I4)
   28 STOP
        END
```

Computations of UTM grid co-ordinates from geodetic co-ordinates (programmed by J. Rais, Diponegoro University) programme NR UTMOOI

Ellipsoid Clarke 1866
A = 6378206.400
1/F = 294.979

Results

No	Station	Latitude D	M	S	Longitude D	M	S	E Metre	N Metre	Scale	Convergence D	M	S	Zone
1	SABANG	5	45	20.232	95	15	20.232	749803.577	636643.287	1.00037249	0	13	34.768	46
2	MEULABOH	4	15	17.211	96	0	31.114	167894.147	470903.485	1.00096558	0	13	19.699	47
3	BAGANSIAPI	2	17	10.732	101	0	0.0	722421.720	252846.567	1.00021247	0	4	47.349	47
4	PACANG	0	46	2.123	100	16	17.221	641481.210	84820.540	0.99984781	0	1	1.303	47
5	SINGAPORE	1	48	10.424	104	1	12.421	391010.636	199291.387	0.99974705	0	1	50.993	48
6	MUNTOK	−2	0	0.0	105	0	0.0	500000.000	9778953.122	0.99960000	0	0	0.0	48
7	SINGKAWANG	1	10	21.242	108	59	2.123	275658.756	129676.606	1.00022310	0	2	28.586	49
8	PONTIANAK	0	0	0.0	109	15	14.316	305678.921	0.0	1.00006749	0	0	0.0	49
9	KUALAKARUNG	0	50	24.413	113	32	27.144	782801.776	92944.041	1.00059022	0	2	14.207	49
10	ASTRO POINT	−8	0	0.0	123	25	26.248	546720.757	9115733.959	0.99962701	0	3	32.417	51
11	ASTRO POINT	−10	21	11.149	132	10	17.182	190220.724	8854244.176	1.00078767	0	30	31.463	53
12	BIAK AIRPORT	−1	20	24.427	136	0	0.0	611251.624	9851863.111	0.99975322	0	1	24.203	53
13	NN1	34	15	34.742	−96	2	43.158	772075.812	3794702.172	1.00051259	1	39	51.627	14
14	NN2	−34	15	34.742	−96	2	43.158	772075.812	6205297.828	1.00051259	1	39	51.627	14
15	NONAME 1	25	0	0.0	7	0	0.0	298150.508	2766279.175	1.00010320	0	50	43.884	32
16	NONAME 2	26	0	0.0	8	0	0.0	399917.377	2875904.110	0.99972368	0	26	16.268	32

ANNEX II

Disk-operating System/360 Fortran—360N-FO-451 32

```
C      COMPUTATION OF GEODETIC CO-ORDINATES FROM UTM GRID CO-ORDINATES
C
       DOUBLE PRECISION A,RF,ESQ,ESQI,EPSQ,RHODEG,PHIP,PHI,S,CM,KO,E,N,EP,Q,TG,TG2,TG4,SN2,CS2,CS4,WO,
     1 MO,NO,ETA2,COFVII,COFVIII,COFIX,COFX,COFE5,DELAM,PHIM,PHIS,FLAM,FLAMM,FLAMS,COFD6,GT1,GTP1,GT2,
     2 GAM,SK1,SK2,GAMD,GAMS,SK3,F,SK
       DIMENSION NRT(3)
       COMMON A,F,ESQI,EPSQ,RHODEG,CM,S,PHIP
C
C      ELLIPSOID'S PARAMETERS, SCALE FACTOR AT CENTRAL MERIDIAN
       READ(1,17) A,RF,ELL1,ELL2,ELL3
       KO=0.9996D0
       F=1.0D0/RF
       ESQ=2.0D0/RF-(1.0D0/RF)**2
       ESQI=1.0D0-ESQ
       EPSQ=ESQ/ESQI
       RHODEG=0.57295779513082321D2
       WRITE(3,18) ELL1,ELL2,ELL3,A,RF
       WRITE(3,19)
C
C      INPUT DATA: NAME/NUMBER OF STATION,GRID CO-ORDINATES,CENTR MERIDIAN
       KOUNT=0
    5  READ(1,120)(NRT(I),I=1,3)E,N,LAT,CM
       IF(CM) 6,22,6
    6  KOUNT=KOUNT+1
       IF(E-5.D5) 7,7,8
    7  EP=5.0D5-E
       GO TO 9
    8  EP=E-5.0D5
    9  IF(LAT) 10,11,12
   10  N=1.0D7-N
       GO TO 12
   11  PHIP=0.0D0
       GO TO 13
   12  S=N/KO
```

```
C
C     COMPUTATION OF FOOTPOINT LATITUDE BY SUBROUTINE FOTLAT
      CALL FOTLAT
   13 TG=DSIN(PHIP)/DCOS(PHIP)
      TG2=TG*TG
      TG4=TG2*TG2
      SN2=DSIN(PHIP)*DSIN(PHIP)
      CS2=DCOS(PHIP)*DCOS(PHIP)
      CS4=CS2*CS2
      ETA2=EPSQ*CS2
C
C     COMPUTATION OF RADII OF CURVATURE
      WO=DSQRT(1.0D0-ESQ*SN2)
      MO=A*KO*ESQI/(WO*WO*WO)
      NO=A*KO/WO
      Q=EP/NO
C
C     COMPUTATION OF COEFFICIENTS VII,VIII,IX,X,D6 AND E5
      COFVII=TG*RHODEG*(1.0D0+EPSQ*CS2)/2.0D0
      COVIII=TG*RHODEG*(5.0D0+3.0D0*TG2+6.0D0*EPSQ*CS2-6.0D0*EPSQ*SN2-3.0D0*EPSQ*EPSQ*CS4-9.0D0*EPSQ*
     1 EPSQ*CS2*SN2)/24.0D0
      COFIX=RHODEG/DCOS(PHIP)
      COFX=RHODEG*(1.0D0+2.0D0*TG2+EPSQ*CS2)/(6.0D0*DCOS(PHIP))
      COFD6=TG*RHODEG*(61.0D0+90.0D0*TG2+45.0D0*TG4+107.0D0*EPSQ*CS2-162.0D0*EPSQ*SN2-45.0D0*EPSQ*
     1 TG2*SN2)/720.0D0
      COFE5=RHODEG*(5.0D0+28.0D0*TG2+24.0D0*TG4+6.0D0*EPSQ*CS2+8.0D0*EPSQ*SN2)/(120.0D0*DCOS(PHIP))
C
C     COMPUTATION OF GEODETIC CO-ORDINATES
      DELAM=COFIX*Q-COFX*Q*Q*Q+COFE5*Q*Q*Q*Q*Q
      PHI=PHIP*RHODEG-(COFVII*Q*Q-COVIII*Q*Q*Q*Q+COFD6*Q*Q*Q*Q*Q*Q)
      LPHI=PHI
      PHIM=(PHI-DFLOAT(LPHI))*60.0D0
      LPHIM=PHIM
      PHIS=(PHIM-DFLOAT(LPHIM))*60.0D0
      IF(E-5.D5) 14,14 15
   14 FLAM=CM-DELAM
      GO TO 16
   15 FLAM=CM+DELAM
   16 LAM=DABS(FLAM)
      FLAMM=(DABS(FLAM)-DFLOAT(LAM))*60.0D0
      LAMM=FLAMM
      FLAMS=(FLAMM-DFLOAT(LAMM))*60.0D0

C
C     COMPUTATION OF MERIDIAN CONVERGENCE
      GT1=Q-(Q*Q*Q/3.0D0)*(1.0D0*TG2-ETA2-2.0D0*ETA2*ETA2)
      GTP1=(2.0D0+5.0D0*TG2+2.0D0*ETA2+3.0D0*TG4+TG2*ETA2+9.D0*ETA2**2)
      GT2=Q**5/15.0D0*GTP1
      GAM=TG*(GT1+GT2)*RHODEG
      LGAM=DABS(GAM)
      GAMD=(DABS(GAM)-DFLOAT(LGAM))*60.0D0
      LGAMD=GAMD
      GAMS=(GAMD-DFLOAT(LGAMD))*60.0D0
C
C     COMPUTATION OF SCALE FACTOR
      SK1=1.0D0+(0.5D0*Q*Q)*(1.0D0+ETA2)
      SK2=(Q**4/24.0D0)*(1.0D0+6.0D0*ETA2+9.0D0*ETA2**2+4.0D0*ETA2**3)
      SK3=Q**6/720.0D0
      SK=KO*(SK1+SK2+SK3)
      LCM=CM
      IF(LAT) 23,24,25
   23 N=1.0D7-N
      LPHI=-LPHI
      GO TO 25
   24 N=0
      LPHI=0.0D0
   25 IF(FLAM) 26,27,27
```

```
   26 LAM=-LAM
   27 IF(GAM) 28,29,29
   28 LGAM=-LGAM
C
C     OUTPUT
   29 WRITE(3,21)KOUNT,(NRT(I),I=1,3),E,N,LPHI,LPHIM,PHIS,LAM,LAMM,FLAMS,LGAM,LGAMD,GAMS,SK,LCM
      GO TO 5
   17 FORMAT(F11.3,1X,F10.6,1X,3A4)
   18 FORMAT('0',28X,'COMPUTATION OF GEODETIC CO-ORDINATES FROM UTM GRID CO-ORDINATES'//29X,'PROGRAMMED
    1 BY J.RAIS - DIPONEGORO UNIVERSITY'/29X,'PROGRAM NR UTM002'///40X,'ELLIPSOID',3A4/40 X,'A =',
    2 F12.3/40X,'1/F =',F8.3//)
   19 FORMAT('0','NUMBR',4X,'STATION',10X,'E',10X,'N',10X,'LATITUDE',7X,'LONGITUDE',6X,'CONV.
    1 MERIDIAN',1X,'SCALE FACTOR',1X,'C.M'///)
  120 FORMAT(3A4,4X,2F13.3,1X,13,1X,F3.0)
   21 FORMAT(1X,I4,2X,3A4,2X,F11.4,1X,F12.4,2X,I4,I3,F7.3,1X,I4,I3,F7.3,1X,213,F7.3,3X,F9.7,3X,I3)
   22 STOP
      END
```

Disk-operating System/360 Fortran—360N-FO-451 32

```
      SUBROUTINE FOTLAT
      DOUBLE PRECISION A,F,ESQ1,EPSQ,RHODEG,AL1,A1,PHI1,B,BET1,SALF,SIG1,CALF2,USQ,A0,A2,A4,B0,B2,B4,
     1 B6,SIG0,S,SIG,TWOSM,C2,C4,C6,SSIG2,SIG3,COF2,COF4,COF6,SIGI,DIF,SIG2,SINB0,COSB0,SINB2,SIN2B2,
     2 COS2B2,COSB2,TANB2,BET2,PHI2,CHEK,PHIM,PHIS
      COMMON A,F,ESQI,EPSQ,RHODEG,AL1,S,PHI2
      A1=0.0D0
      PHI1=0.0D0
      CHEK=0.00002D0/206264.81D0
      B=A*DSQRT(ESQI)
      BET1=DATAN(DSQRT(ESQI)*(DSIN(PHI1)/DCOS(PHI1)))
      SALF=DSIN(A1)*DCOS(BET1)
      SIG1=DATAN((DSIN(BET1)/DCOS(BET1))/DCOS(A1))
      CALF2=1.0D0-SALF*SALF
      USQ=EPSQ*CALF2
      A0=1.0D0-(F/4.0D0)*(1.0D0+F)*CALF2+(3.0D0*F*F*CALF2*CALF2)/16.0D0
      A2=(F*(1.0D0+F)*CALF2)/4.0D0-(F*F*CALF2*CALF2)/4.0D0
      A4=(F*F*CALF2*CALF2)/32.0D0
      B0=1.0D0+USQ/4.0D0-3.0D0*USQ*USQ/64.0D0+5.0D0*USQ*USQ*USQ/256.0D0
      B2=-USQ/4.0D0+USQ*USQ/16.0D0-15.0D0*USQ*USQ*USQ/512.0D0
      B4=-USQ*USQ/128.0D0+3.0D0*USQ*USQ*USQ/512.0D0
      B6=-USQ*USQ*USQ/1536.0D0
      N=0
      SIG0=S/(B*B0)
      SIG=SIG0
  101 TWOSM=2.0D0*SIG1+SIG
      C2=DCOS(TWOSM)
      C4=2.0D0*C2*C2-1.0D0
      C6=4.0D0*C2*C2*C2-3.0D0*C2
      SSIG2=2.0D0*DSIN(SIG)*DCOS(SIG)
      SIG3=3.0D0*DSIN(SIG)-4.0D0*DSIN(SIG)**3
      COF2=DSIN(SIG)*C2
      COF4=SSIG2*C4
      COF6=SIG3*C6
      SIGI=SIG0-(B2*COF2+B4*COF4+B6*COF6)/B0
      DIF=SIGI-SIG
      IF(DABS(DIF)-CHEK) 200,200,201
  201 SIG=SIGI
      N=N+I
      IF(N-5) 101,200,200
  200 SIG2=SIG1+SIG
      SINB0=DSIN(SIG1)*DSIN(BET1)+DCOS(SIG1)*DCOS(BET1)*DCOS(A1)
      COSB0=DABS(SALF)
      SINB2=SINB0*DSIN(SIG2)
      SIN2B2=SINB2*SINB2
      COS2B2=1.0D0-SIN2B2
      COSB2=DSQRT(COS2B2)
```

```
TANB2=SINB2/COSB2
BET2=DATAN(TANB2)
PHI2=DATAN(TANB2/DSQRT(ESQI))
RETURN
END
```

Computation of geodetic co-ordinates from UTM grid co-ordinates (programmed by J. Rais, Diponegoro University) programme NR UTMOO2

Ellipsoid Clarke 1866
A = 6378206.400
1/F = 294.979

No.	*Station*	*E*	*N*	*Latitude*			*Longitude*			*Conv. meridian*			*Scale factor*
1	ASTRO POINT 1	772075.8120	3794702.1730	34	15	34.742	−96	2	43.158	1	39	55.259	1.0005126
2	ASTRO POINT 2	772075.8120	6205297.8270	−34	15	34.742	−96	2	43.158	1	39	55.259	1.0005126
3	POINT 1	404023.8270	2771793.3020	25	3	36.727	8	2	54.497	0	24	11.162	0.9997138
4	POINT 2	500996.7750	2886199.1110	26	5	47.123	9	0	35.885	0	0	15.785	0.9996000
5	POINT 3	530555.9880	7830022.0260	70	34	29.692	15	49	23.526	0	46	34.876	0.9996114
6	POINT 4	610830.5620	7966759.3980	71	46	35.574	24	10	35.309	3	1	3.940	0.9997502
7	POINT 5	500000.0000	9219992.8450	83	1	57.662	3	0	0.0	0	0	0.0	0.9996000
8	POINT 6	535011.1760	9332591.9720	84	1	59.006	12	1	4.276	3	0	5.630	0.9996150
9	POINT 7	511529.4160	9224233.8870	83	4	11.667	3	51	21.152	0	50	58.648	0.9996010
10	POINT 8	464658.2240	9339872.2160	84	5	52.867	0	4	47.341	3	3	48.794	0.9996153
11	POINT 9	472191.5240	9236914.6270	83	10	47.037	0	54	7.944	2	4	58.709	0.9996094
12	POINT 10	473182.6690	9354358.0350	84	13	52.497	0	36	34.932	2	22	41.590	0.9996088
13	POINT 11	491126.0240	9257907.9820	83	22	18.599	2	18	41.026	0	41	2.408	0.9996010
14	POINT 12	493931.2410	9404276.7420	84	40	59.094	2	24	48.302	0	35	2.613	0.9996004
15	SABANG	749803.5770	636643.2870	5	45	20.232	95	15	20.232	0	13	35.185	1.0003725
16	MFLABOH	167894.1470	470903.4850	4	15	17.211	96	0	31.114	0	13	20.423	1.0009656
17	BAGANSIAPI-2	722421.7200	252846.5670	2	17	10.732	101	0	0.000	0	4	47.466	1.0002125
18	PADANG AIRPT	641481.2100	84820.5400	0	46	2.123	100	16	17.221	0	1	1.313	0.9998478
19	SINGAPORE	391010.6360	199291.3870	1	48	10.424	104	1	12.421	0	1	51.004	0.9997471
20	MUNTOK	500000.0000	9778953.1220	−1	59	60.000	105	0	0.0	0	0	0.0	0.9996000
21	SINGKAWANG	275658.7560	129676.6060	1	10	21.242	108	59	2.123	0	2	28.647	1.0002231
22	PONTIANAK	305678.9210	0.0	0	0	0.0	109	15	14.316	0	0	0.0	1.0000675
23	KUALAKARUNG	782801.7760	92944.0410	0	50	24.413	113	32	27.144	0	2	14.295	1.0005902
24	BIAK AIRPORT	611251.6240	9851863.1110	−1	20	24.427	136	0	0.000	0	1	24.212	0.9997532

AN IDEA OF A NATIONAL FUNDAMENTAL NETWORK AS A DENSIFICATION TO THE WORLD-WIDE SATELLITE TRIANGULATION SYSTEM

Paper presented by Indonesia[1]

INTRODUCTION

Geodetic networks which form the unitary basis for national geodetic operations or which are established as international links to facilitate international scientific investigations such as the determination of the Earth's dimensions are defined as fundamental networks.

This paper briefly describes the Indonesian triangulation system, its progress, difficulties and future plans.

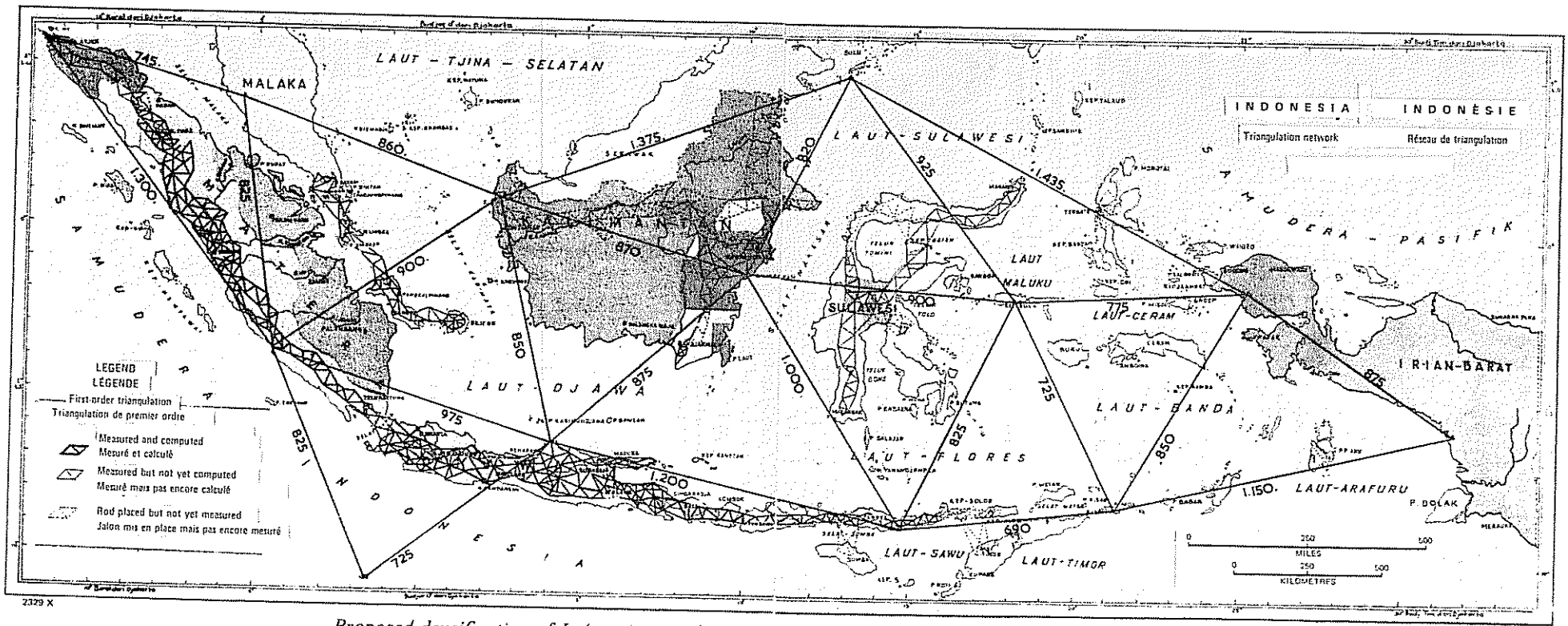
Within the framework of international co-operation and assistance, we hope to complete the work which we started a century ago, not only in the interest of science, but also to exploit our known resources, both human and natural, for the benefit of our people and for the entire world. In fact, recourse must always be had to maps in order to obtain the accurate information required for efficient economic and technical development plans. Moreover, geodetic control is needed for the preparation of reliable maps, which are even more useful to developing countries than to their more affluent neighbours.

Brief history of the Indonesian triangulation network

Indonesia is an island nation stretching from 95° to 114° east longitude, or about 3,000 km from east to west, and from 6° north latitude to 11° south latitude. The land area comprises about 1,905,000 km², and the territorial waters some 3,005,000 km².

Geodetic activities in Indonesia began in 1866, when the Government issued a decree to undertake triangulation work and systematic mapping of the archipelago, particularly on the island of Java. These activities were carried out until the outbreak of the Second World War and ceased entirely during the war. Since the first decade of the post-war period was devoted to national unification, little was done in geodesy and cartography aside from training

[1] The original text of this paper, prepared by J. Rais, Diponegoro University, Semarang, appeared as document E/CONF.57/L.74.



Proposed densification of Indonesian geodetic network to the world-wide satellite triangulation net

of scientific and technical personnel to replace the foreign personnel who had been doing this work before the war. In the following decade efforts were mainly directed towards rehabilitation and planning for the future.

In 1969, when the Government started the first five-year development programme, the situation could be summed up as follows: (*a*) the geodetic network covered about 30 per cent of the country, but it did not yet constitute a cohesive system; (*b*) about 40 per cent of the country was adequately mapped (1:50,000), but most of the maps were out of date and had to be revised. With the exception of the island of Java, most of the maps were compiled from surveys carried out from 1900 to 1940 and were not based on geodetic control

Even though the triangulation network of Java was established with great care, the required accuracy was not achieved because the personnel did not fully understand the value of this work. Base measurements were taken in three places (west, central and east Java), and twenty-four orientation determinations were made, but the results were unsatisfactory since the azimuth discrepancy ranges from 18″ to 24″, which is partly due to the faulty positioning of the triangulation and target rods.

When the triangulation was extended from Java to Sumatra, to the west, and to the western Sunda Isles, to the east, by using the fundamental point of Java at Gunung Genuk (6° 26′ 53.4″ south latitude and 110° 55′ 5″ east longitude), some doubts arose in connexion with the determination of this point, since the computations were carried out in the 1890s and were never checked afterwards.

An analysis of the documents prepared at the time of this determination revealed the reasons for this uncertainty: (*a*) the longitude was not determined at the reference point, but at Djakarta, with some 4° of difference in longitude, by telegraphy and relay to the reference point by angle measurements; (*b*) an error was made in the calculation of declination for latitude determination; and (*c*) some errors were probably due to piecemeal adjustment and disregard of the Laplace equation. To date, the triangulation of Java has been used as the basis for mapping, but the existing discrepancies do not facilitate more accurate work. Owing to lack of funds and personnel, the current triangulation of Indonesia was never revised since it was established.

Another difficulty was encountered when we attempted to connect the networks of the larger islands to each other, because of the limitations of ordinary measuring instruments such as the theodolites. To solve this problem we are planning to use a new tool developed in the space age, namely, the triangulation satellite.

Proposed densification programme of the world-wide satellite triangulation system

If we may conclude from reports concerning the world-wide satellite triangulation project undertaken by the United States Coast and Geodetic Survey that this world net will be completed at the end of 1970 and that the cameras and personnel will then be available for densification programmes, we would like to ask those responsible for international co-operation and assistance to consider a densification programme for the developing countries in general and for the countries of South-east Asia in particular. We are aware that it might be more expedient in some cases to densify control only in those areas which have a pressing need for it. It is therefore advisable that more developing countries should get together to consider ways in which links to the existing control nets could be effected with a minimum of effort and errors.

Indonesia for its part puts forward its project for a national network whose sides measure from 800 to 1,400 km (see the map). The conventional chains of triangulation would be placed between two adjacent satellite stations and the space between them would be filled with triangulation network stations. This new procedure will make it possible to readjust the existing triangulation and establish a single geodetic system for the entire country. We are eager to finish our basic network since it forms the basis for all other work.

METHODS FOR COMPUTING THE BEST-FITTING REFERENCE ELLIPSOID

Paper presented by Indonesia[1]

Summary

Two formulae for transformation of geodetic positions from one datum to another are compared in this paper: the projective and the development methods of transformation formulae. The two methods are different in nature. This comparison is made in order to analyse the validity of the formulae with respect to the area.

Both formulae expressed in terms of the deflection of the vertical components can be used for computing the elements of the best-fitting reference ellipsoid by the least-squares method. To this end, the deflection data must be used. Since no data on deflection of the vertical are available in Indonesia, the author used United States Coast and Geodetic Survey data: 1,708 meridian deflections and 1,490 prime vertical deflections, or a total of 3,198 observation equations with a maximum of five and a minimum of three unknowns by the least-squares method of adjustment.

Geodetic datum

A geodetic datum may be considered as the basic element of a computation system and the definition of the surface on which the computations are carried out. To define such a datum, a point must be selected as the origin of the system and its position must be determined with respect to a reference ellipsoid whose parameters are the equatorial radius a and flattening f. The parameters defining this point, designated as the basic point of the system, are the geodetic latitude and longitude, B_o and L_o, the azimuth of a direction at this point, A_o, and its height above the ellipsoid, H_o. Further, it will be assumed that the rotation axis of the ellipsoid is parallel to the mean rotational axis of the Earth.

The simplest geodetic datum consists of only five parameters: B_o, L_o, A_o, a and f. In this case, it is assumed that

[1] The original text of this paper, prepared by J. Rais, Diponegoro University, Semarang, appeared as document E/CONF.57/L.75.

the reference ellipsoid passes through the initial point. Changing any one of these parameters will change the datum, as well as the geodetic latitude and longitude of all points on the datum. This can be interpreted to mean that a new datum can be defined in terms of the corrections to the geodetic co-ordinates of the initial point and the parameters of the existing ellipsoid: dB_o, dL_o, dH_o, dA_o, da and df. The first three corrections can also be expressed in terms of the corrections to the deflection components and to the undulation.

Transforming geodetic positions from one datum to another

The formulae for transforming the geodetic positions from one datum to another have been developed and analysed by several authors. These transformation formulae can be grouped into two categories, the development method and the projective method.

In the development method, measured lengths are reduced to the geoid by ellipsoidal normals. Measured angles are plotted to the geoid without any reduction, except in high latitudes where normal skew correction may be applied. Starting from the basic point of the datum, the undulating surface of the geoid is transformed into a smooth surface on the ellipsoid for the area concerned so that the lengths and azimuths on the geoid remain unchanged throughout the process.

The projective method involves orthographic projection of points from the Earth's surface onto the reference ellipsoid. There are two possibilities to be considered, namely, Helmert's projection and Pizetti's projection. The difference between the two systems is small, however, so that for most purposes it may be ignored.

We have compared the two transformation formulae and the computations of the elements of the best-fitting reference ellipsoid by using both methods. In the development method, the formulae of Milan Bursa (1957) are used, whereas in the projective method, the rigorous formulae of Rapp (1968) are used.

Elements of the best-fitting reference ellipsoid

The best-fitting reference ellipsoid may be defined as the ellipsoid that most closely approximates the geoid. This ellipsoid must meet the following conditions: (*a*) the mean value of the N deviations of the geoid from the ellipsoid is zero; or (*b*) the sum of the squares of the N deviations of the geoid from the ellipsoid is a minimum; or (*c*) the sum of the squares of the components of the astrogeodetic deflections of the vertical with respect to the best-fitting ellipsoid is a minimum.

Conditions (*b*) and (*c*) represent the most rational solution based on the least-squares method of adjustment. In this paper, we have used condition (*c*) to compute the elements of the best-fitting reference ellipsoid by using astrogeodetic deflections exclusively.

The components of the deflections of the vertical with respect to the best-fitting ellipsoid, $\bar{\zeta}$ and $\bar{\eta}$, can be written in terms of the components of the deflections of the vertical with respect to the existing ellipsoid and the differential corrections resulting from the transformation of the datum, i.e.:

$$\begin{aligned} \bar{\zeta}_i &= d\zeta_i + \zeta_i \\ \bar{\eta}_i &= d\eta_i + \eta_i \end{aligned} \tag{1}$$

Equation (1) can be used in the same way as the observation equations whose mathematical model in matrix form is:

$$V = AX + L \tag{2}$$

where V = the matrix of the residuals;
A = the matrix of the differential coefficients;
X = the matrix of the unknown parameters;
L = the matrix of the observed quantities.

It should be emphasized here that the residuals are not residuals in the sense in which this is intended for the observation equations. They are actually the quantities which fulfil the minimum sum of the squares condition (*c*). The term "observed quantities" is used to describe all astrogeodetic deflections of the vertical with respect to the existing ellipsoid. The word "observed" is not used in its proper sense here since the astrogeodetic deflections are not directly observed quantities. The observed quantities are in fact the astronomic positions, the angles and base-line measurements of the triangulation being used to compute the geodetic positions. The astrogeodetic deflections are therefore computed quantities; however, equation (1) will subsequently be used in the same way as the observation equations, as mentioned earlier, and we will refer to the terms "observation equation", "observed quantities" and "residuals".

The differential corrections $d\zeta_i$ and $d\eta_i$ can be written in terms of the corrections to the initial point, i.e. ($d\zeta_o$, $d\eta_o$, dN_o, da and df) in the projective method, and ($d\zeta_o$, $d\eta_o$, dA_o, da and df) in the development method. These corrections are unknown parameters in the mathematical model (2).

Thus, in general, the computations of the elements of the best-fitting reference ellipsoid involve the calculation of the corrections of the orientation and of the parameters of the size and shape of the existing reference ellipsoid to which all geodetic quantities are plotted. The corrections of the orientation are applied to the initial point of the system.

In fact, there are two groups of observation equations, one representing the meridian component, and the other the prime vertical component of the deflections. The normal equations were established for these two groups and then added.

Development method observation equations

The differential formulae established by the development method and in terms of the deflection components may be written as follows:

$$\begin{aligned} d\zeta_i &= P'_1\, d\zeta_o + P'_2\, d\eta_o + P'_3\, ds_i \\ &\qquad + P'_4\, dA_o + P'_5\, da/a + P'_6\, df \\ d\eta_i &= Q'_1\, d\zeta_o + Q'_2\, d\eta_o + Q'_3\, ds_i \\ &\qquad + Q'_4\, dA_o + Q'_5\, da/a + Q'_6\, df \end{aligned} \tag{3}$$

where the subscript o refers to the initial point, and the subscript i to any other point of the net. For the definition of the coefficients P' and Q' the reader should refer to the available publications.

There are five parameters to be determined, i.e. $d\zeta_o$, $d\eta_o$, dA_o, da and df, whereas ds_i can never be considered as a parameter since it varies with every point. For the solution of the observation equations, two cases have been investigated, namely (*a*) $ds_i = 0$, according to the definition of the development method; and (*b*) $ds_i = -N_{av}\, s_i/R$, where N_{av} is the average undulation between point i and

the initial point with respect to the existing reference ellipsoid, s_i being the length of the line between the initial point and any other point i on the existing ellipsoid and R being the approximate average radius of the Earth's curvature for the area concerned.

Further, if Laplace's condition must hold at the initial point, the number of parameters is reduced by one, since dA_o can be substituted by $(-\tan B_o\, d\eta_o)$. If, on the other hand, the flattening of a new ellipsoid is set at 1/298.25, based on a combination of gravimetric, astrogeodetic and satellite data, the number of parameters is again reduced by one.

Projective method observation equations

The projective method transformation formulas may be written in terms of the components of the deflections of the vertical as follows:

$$\begin{aligned} d\xi_i &= E_1' \, d\xi_o + E_2' \, d\eta_o + E_3' \, dN_o + E_4' \, da + E_5' \, df \\ d\eta_i &= F_1' \, d\xi_o + F_2' \, d\eta_o + F_3' \, dN_o + F_4' \, da + F_5' \, df \end{aligned} \qquad (4)$$

An observation equation can be formed for each deflection component. Since the coefficients of dN_o and da are almost equal, an instable matrix for the normal equation should be expected. The computation shows that this is indeed the case, and therefore in the subsequent computations dN_o and da were combined into one parameter. In order to determine the correction to be made to the equatorial radius, the quantity dN_o should be obtained in another way.

Rapp (1967) has a formula for computing the undulation of a volume ellipsoid of one flattening from the undulation of a volume ellipsoid of another flattening, namely:

$$N'' = N' + a_o \, df(\sin^2 B - \tfrac{1}{3}) \qquad (5)$$

where N' = partial geoid undulation computed from Stokes' equation with the anomalies plotted to a flattening of the reference gravity formula
N'' = N', but with a flattening of the new volume ellipsoid
a_o = equatorial radius of the reference ellipsoid
df = difference in flattening between the new and existing ellipsoids.

In this case, dN_o must be computed in terms of the flattening obtained by the adjustment starting from the unknown undulation of a volume ellipsoid with given flattening. However, in the comparison of the equatorial radius obtained by the development method with that obtained by the projective method, dN_o in the latter method should be equal to zero. The reason for this is that in the development method the undulation at the initial point is zero.

Influence of height on the deflection components

In order to compute the coefficients E_i' and F_i' of the projective method formulae the height H of every point above the ellipsoid must be known. This height is generally not available. For this reason, since the maximum undulation is relatively small compared to the highest elevation, the latter will be used instead of H.

To ascertain whether the deflections are significantly affected in this way, the coefficients E_i and F_i were calculated with and without height, respectively, for several points.

Assuming that the highest elevation is 10,000 ft, or approximately 3,050 m, computations have shown that for an average latitude of 40° the difference of the coefficient E_1 with and without H is about 0.0004. The same value is obtained for E_2. This results in variations of 0.0004″ and 0.0002″, respectively, on the meridian and prime vertical components of the deflection at any point for a variation of 1″ for each deflection component at the initial point. This effect is negligible. For the coefficients E_3, E_4 and E_5 as well as for F_3, F_4 and F_5, the effect of H is also negligible; the difference is $1 \cdot 10^{-10}$. In subsequent computations H will be assumed to equal zero.

Comparison of both transformation formulae

For this purpose a test area was selected with an initial point having the following co-ordinates: latitude (B_o) 40° north and longitude (L_o) 100° west. This point is close to the initial point of the United States astrogeodetic net, namely, Meades Ranch. Test points were chosen at regular intervals on three profiles passing through the initial point, namely: (*a*) points on the 100° west meridian; (*b*) points on the 40° north parallel; and (*c*) points on an azimuth line of 45°.

In order to compare the two transformation formulae, the following assumptions were made: (*a*) $H = 0$, (*b*) $dH = 0$, (*c*) $ds = 0$ and (*d*) the Laplace condition holds at the initial point, so that $dA_o = \sin B_o \, dL_o$. The reference surface used for computations was the North American Datum (NAD), with equatorial radius $a = 6{,}378{,}206.4$ m and flattening $f = 1/294.9789$. All computations were carried out in Fortran IV on the IBM 7094 computer.

Table 1. Difference between the projective and development methods for a north-south profile, an east-west profile and a profile along a 45° azimuth line through the initial point

Change of initial data	Δ_I Arc distance			Δ_{II} Arc distance		
	N–S	Az 45°	E–W	N–S	Az 45°	E–W
	In degrees					
$dB_o = 1''$	25	34	26	"Any"[a]	20	"Any"
$dL_o = 1''$	"Any"	32	"Any"	20	31	25
$da = 200$ m	26	46	39	"Any"	23	24
$df = -0.0000372$	31	38	48	"Any"	24	25
Combined	35	35	28	20	20	28

[a] "Any" means that the arc distance can have any value since the difference between the results of the two transformation formulae is zero.

For arbitrarily selected variations of the initial data, that is, $dB_o = 1''$, $dL_o = 1''$, $da = 200$ m and $df = 1/298.25 - 1/294.9789 = -0.0000371811$, the changes in geodetic positions, dB_i and dL_i were computed for points located at 10° intervals on the three profiles mentioned above for each transformation formula and the results were compared. In this paper, Δ_I designates the difference between dB_i computed by the projective method, abbreviated dB-proj., and by the development method, abbreviated dB-dev. Similarly Δ_{II} designates the difference between dL-proj. and dL-dev.

The Δ's are then constrained to 0.1″ and the value of the area pertaining to the constraint is analysed. Table 1 shows the results computed for each change of the initial data as well as for combined changes.

From the foregoing results it may be concluded that the two transformation formulae could be considered to agree with each other up to 30° of arc distance. However, it should be emphasized that the two methods are different in nature since the terms ds_i and dA_o in the development method are lacking in the projective method and conversely the term dN_o, which does not exist in the development method, is present in the projective method.

By starting from the initial point whose geodetic coordinates are 100° west and 40° north, complying with the specified constraint and changing the initial data, the area of application for the formula is as follows: (*a*) a 30° arc distance along the 40° north parallel comes to a point whose longitude is about 60° west; (*b*) a 30° arc distance along the 100° west meridian comes to a point whose latitude is about 70° north.

Since the formulae are also valid for the other quadrants, the total applicable area extends from 60° west $\leqslant L \leqslant$ 140° north $\leqslant B \leqslant$ 10° north. This area covers the entire continent of Central and North America, excluding Alaska.

Comparison of elements of best-fitting ellipsoid computed from both methods

The data used to find the solution are those of the deflections of the vertical in the United States applied to NAD 1927 (Clarke 1866 spheroid). There are 1,815 stations, of which 1,708 are latitude stations for the meridian deflections and 1,490 are longitude stations for the prime vertical deflections, that is, a total of 3,198 observations of deflections of the vertical.

The *a posteriori* residuals were analysed by using all the above-mentioned data. By taking a value of three times the standard error as the rejection criterion, forty-four observations ranging from 13.0″ to 30.0″ had to be rejected from the data sample because they exceeded that value. The rejection of large residuals had been noted in Hayford's work (1910).

It is difficult to determine from the above data whether the rejected deflections are errors or really unusually large deflections as mentioned by Hayford. Since the effects of topography and isostasy were not taken into account in our computations, the above-mentioned deflections were ignored for the computation of the adjustment.

Tables 2 and 3 show the results of the calculation of the best-fitting reference ellipsoid for the United States.

The results obtained by the two methods (development and projective) lead to the following conclusions:

(*a*) The development method gives a smaller value for $\sum vv$ than the projective method, which was to be expected since the astrogeodetic deflections are handled by the development method. In other words, the development method is more appropriate for processing the deflection data than the projective method (compare solutions I.2 and III.2 and solutions I.3 and III.3);

(*b*) Solutions with a condition set between parameters give a larger $\sum vv$ than the solutions of free parameters (compare solution I.1 with the other I solutions and solutions III.2 and III.3);

(*c*) All II solutions (i.e. where $ds = 0$) give a smaller $\sum vv$ than solution I (i.e. where $ds = 0$);

(*d*) The difference in equatorial radius obtained by the development and projective methods is small; it is 3.5 m between solutions I.2 and III.2 ($dN_o = 0$) and 2.8 m between solutions I.3 and III.3 ($dN_o = 0$);

(*e*) The difference in equatorial radius obtained by the solutions with imposed flattening and with free flattening is about 12 m in the two methods;

(*f*) The difference in the reciprocal of the flattening is also very small, i.e. 0.02 between solutions I.2 and III.2;

(*g*) Solution IA.1, i.e. the one obtained by using unequal weights for the observation groups, gives a smaller value for the equatorial radius than solution I.1, i.e. the one obtained by using equal weights; the difference is 15.3 m.

In general, we may conclude that the two formulae give essentially similar results and that in many cases the differences may be considered negligible. However, the development method yields the best results.

Goodness-of-fit test

The *chi* square test has been used to determine how well the theoretical distribution, in this case the normal distribution, fits the empirical distribution, i.e. the one obtained from the sample data.

For the purpose of testing, only one sample was selected, namely, the residuals from solution I.1 (free solution for five parameters by the development method), since this solution gives the parameters as stated in all the available documents without any condition set between them. Table 4 shows the residuals from solution I.1 and the *chi* square method.

The theoretical number is computed by using a zero mean and a standard error of 3.93″ derived from the adjustment. At the 5 per cent significant level test: *chi* square 10,0.05 = 18.31, but the computed *chi* square = 72.87, from which it can be concluded that the residuals differ significantly from the expected distribution at this level; the fit is not so good as to be implausible. This leads us to suspect that systematic errors remain in the adjustment which cannot be eliminated.

As Hayford points out, this systematic error might be due to the fact that the effect of isostasy was not taken into account in the computations. Another source of systematic errors might be the geodetic and astronomic positions themselves. This matter will require new research in the future.

Conclusion and recommendations

For computing the elements of the best-fitting reference ellipsoid, the two formulae give essentially the same result.

Table 2. Summary of results of the determination of the elements of the best-fitting ellipsoid for the United States of America by the development method

Solution No.	Conditions and number of parameters	Values obtained and standard errors				New initial data and ellipsoid parameters				Number of observations equations	$\sum vv$	Standard error of unit weight
		$d\xi_0$	$d\eta_0$	dA_0	da (metres)	$\bar{\xi}_0$	$\bar{\eta}_0$	$\bar{a} = 6{,}378$ (metres)	$1/f$			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
I.1	$ds = 0$ 5 parameters	0.83″ ± 0.11″	1.17″ ± 0.11″	−4.12″ ± 0.45″	−183.9 ± 14.7	−0.19″	2.96″	022.4 ± 14.7	299.51 ± 0.4	3,154[a]	48,580	± 3.93″
I.2	$ds = 0$ Laplace cond. 4 parameters	0.72″ ± 0.11″	1.11″ ± 0.11″	—	−183.8 ± 14.8	−0.30″	2.90″	022.6 ± 14.8	299.68 ± 0.4	3,154	49,411	± 3.97″
I.3	$ds = 0$ Laplace cond. $f = 1/298.25$ 3 parameters	0.53″ ± 0.10″	1.08″ ± 0.11″	—	−195.9 ± 14.5	−0.49″	2.87″	010.5 ± 14.5	[298.25][b]	3,154	49,615	± 3.97″
I.4	$ds = 0$ $f = 1/298.25$ 4 parameters	0.67″ ± 0.10″	1.25″ ± 0.08″	−4.18″ ± 0.45″	−194.4 ± 14.4	−0.35″	2.93″	011.9 ± 14.5	[298.25]	3.154	48,735	± 3.93″
IA.1	$ds = 0$ $G = 4$; $G = 1.56$ 5 parameters	0.85″ ± 0.06″	1.25″ ± 0.08″	−4.33″ ± 0.23″	−199.2 ± 10.2	−0.17″	3.04″	007.1 ± 10.2	299.74 ± 0.4	3,154	$\sum pvv = 48{,}041$	± 3.91″
II.1	$ds \neq 0$ 5 parameters	0.82″ ± 0.11″	1.13″ ± 0.11″	−4.07″ ± 0.44″	−180.9 ± 14.7	−0.17″	2.95″	025.5 ± 14.7	299.50 ± 0.4	3,154	48,289	± 3.92″
II.2	$ds \neq 0$ Laplace cond. 4 parameters	0.71″ ± 0.11″	1.09″ ± 0.11″	—	−181.0 ± 14.8	−0.31″	2.88″	025.3 ± 14.8	299.72 ± 0.4	3,154	49,245	± 3.95″
II.3	$ds \neq 0$ Laplace cond. $f = 1/298.25$ 3 parameters	0.52″ ± 0.10″	1.06″ ± 0.11″	—	−193.4 ± 14.5	−0.50″	2.85″	012.9 ± 14.5	[298.25]	3,154	49,458	± 3.96″
II.4	$ds \neq 0$ $f = 1/298.25$ 4 parameters	0.65″ ± 0.10″	1.12″ ± 0.11″	−4.12″ ± 0.45″	−193.1 ± 14.3	−0.36″	2.91″	013.2 ± 14.3	[298.25]	3,154	48,630	± 3.93″

[a] 1,692 observations and 1,642 observations. [b] The fixed value is enclosed in brackets.

Table 3. Summary of results of the determination of the elements of the best-fitting reference ellipsoid for the United States of America by the projective method

Solution No.	Conditions and number of parameters	Values obtained and standard errors			New initial data and ellipsoid parameters				Number of observations equations	$\sum vv$	Standard error of unit weight (seconds)
		$d\xi_0$	$d\eta_0$	$(dN_0 + da)$ (metres)	$\bar{\xi}_0$	$\bar{\eta}_0$	$\bar{a} = 6{,}378$ (metres)	$1/f$			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
III.1	N_0 conditions: 5 parameters	Unstable matrix; correlation between the coefficients of dN_0 and da			—	—	—	—	—	—	—
III.2	dN_0 and da combined; 4 parameters			−187.30 ± 14.95	−0.33	2.88	019.1 ± 15.0[a] 044.2[b]	299.9 ± 0.4	3,154	49,510	± 3.97
III.3	dN_0 and da combined; $f = 1/298.25$ 3 parameters			−198.72 ± 14.65	−0.52	2.84	007.7 ± 14.7[a] 025.7[c]	[298.25][d]	3,154	49,720	± 3.97

[a] $dN_0 = 0$. [b] $dN_0 = -25.1$. [c] $dN_0 = -18.0$. [d] The fixed values are enclosed in brackets.

Table 4. Residuals from solution I.1 and the *chi* square method

Class interval	Actual No. of residuals n_k	Theoretical No. of residuals d_k	$(n_k - d_k)$	$\frac{(n_k - d_k)^2}{d_k}$
More than −11.0″	19	7.2	11.8	19.34
−11.0″ to −9.0″	32	25.1	6.9	1.90
−9.0″ to −7.0″	87	80.6	6.4	0.51
−7.0″ to −5.0″	165	199.6	−34.6	6.00
−5.0″ to −3.0″	331	381.5	−50.5	6.68
−3.0″ to −1.0″	556	562.6	−6.6	0.08
−1.0″ to +1.0″	732	640.3	91.7	13.13
+1.0″ to +3.0″	579	562.6	16.4	0.48
+3.0″ to +5.0″	370	381.5	−11.5	0.35
+5.0″ to +7.0″	160	199.6	−39.6	7.86
+7.0″ to +9.0″	73	80.6	−7.6	0.72
+9.0″ to +11.0″	33	25.1	7.9	2.49
+11.0″ and over	17	7.2	9.8	13.33
	3,154		*chi* square =	72.87

With regard to the flattening of the ellipsoid, it would seem that the best result cannot be obtained by using only astrogeodetic data, mainly because the astrogeodetic nets cover only a small portion of the Earth and are concentrated along a latitude belt located at about 40° north. It is therefore advisable to derive the flattening separately by using gravimetric and satellite observations in conjunction with the astrogeodetic data.

For further investigation it is recommended that new computations should be made (*a*) by taking into account the effects of topography and isostasy; and (*b*) by applying corrections by transforming development-processed data into projective-processed data if they are used in the projective method.

REFERENCES

Bursa, Milan. (In Russian, summary in German) Ausdrucke fur Differential-quotienten der Gradmessungsgleichungen als Funktionen Ausschliesslich von Ellipsoidischen Koordinaten. *Studia Geophysika et Geodetika*, I, 1957, 1.

———. Bestimmung der Dimensionen des Erdellipsoids aus den Europaischen Astronomisch-geodatischen Netzen. *Studia Geophysica et Geodetika*, 3, 1959.

Hayford, J. P. *The figure of the Earth and isostasy from measurement in the United States*. U.S. Coast & Geodetic Survey, spec. publ. No. 82, 1909.

———. *Supplementary investigation in 1909 of the figure of the Earth and isostasy*. U.S. Coast & Geodetic Survey, spec. publ. 1910.

Rapp, Richard H. The equatorial radius of the Earth and the zero-order undulation of the geoid. *J. of geophysical res.*, vol. 72, No. 2 (Jan. 1967).

———. Lectures on advanced geometric geodesy. Unpublished classroom notes, The Ohio State University (1968).

Wilcox, L. E. The development and the projective methods. *Bulletin géodésique*, N.S. 68 (1963).

Zhongolovich, I. D. *The determination of the dimensions of the general terrestrial ellipsoid*. Trudy Instituta Theoretischeskoy Astronomy, Moscow, 1956.

GEODETIC SURVEYS IN THE MEKONG DELTA

Paper presented by the Republic of Viet-Nam[1]

Historical note on the existing geodetic network

The geodetic network of the Republic of Viet-Nam, which has been in existence since 1889, consists of meridian and parallel chains extending from the Sino-Vietnamese frontier to 11° north latitude. Many beacons and benchmarks have been destroyed over the years.

During the period 1960–1964 the National Geographic Department, in close collaboration with the United States Army Map Service, re-established, consolidated and readjusted the existing network with a view to preparing a 1:50,000 base map, in 297 sheets, covering the entire territory of the Republic of Viet-Nam.

Geodetic surveys in the Mekong Delta

The present situation of the Republic of Viet-Nam as a country at war is not favourable for field work in the remoter mountain areas.

In the Mekong Delta, south of 11° north latitude, security is relatively assured, and it is easy to move about.

The geodetic control points are too few in number and inconsistent. There are some, established either by the cadastral service of Cochin China or by local authorities, which have co-ordinates based on uncertain origins and that do not belong to a single projection system.

Since 1968, the National Geographic Department has concentrated its geodetic survey effort in this delta, a fertile plain of over 60,000 km².

The traversing method was chosen on account of the topography of the flat terrain and the security which exists in the built-up areas (provincial and district capitals), chosen as sites for traverse points.

High structures such as church steeples, water towers and flat roofs of buildings have been used to minimize the need for constructing Bilby towers.

Technical data

Angular observation

Instrument: Wild T3 theodolite;

Method: Round of horizon (two sets of time-spaced observations, each set consisting of two series of eight readings);

Discrepancy between the two series of each set: <0.04 seconds of arc;

Discrepancy between the two sets: <0.03 seconds of arc.

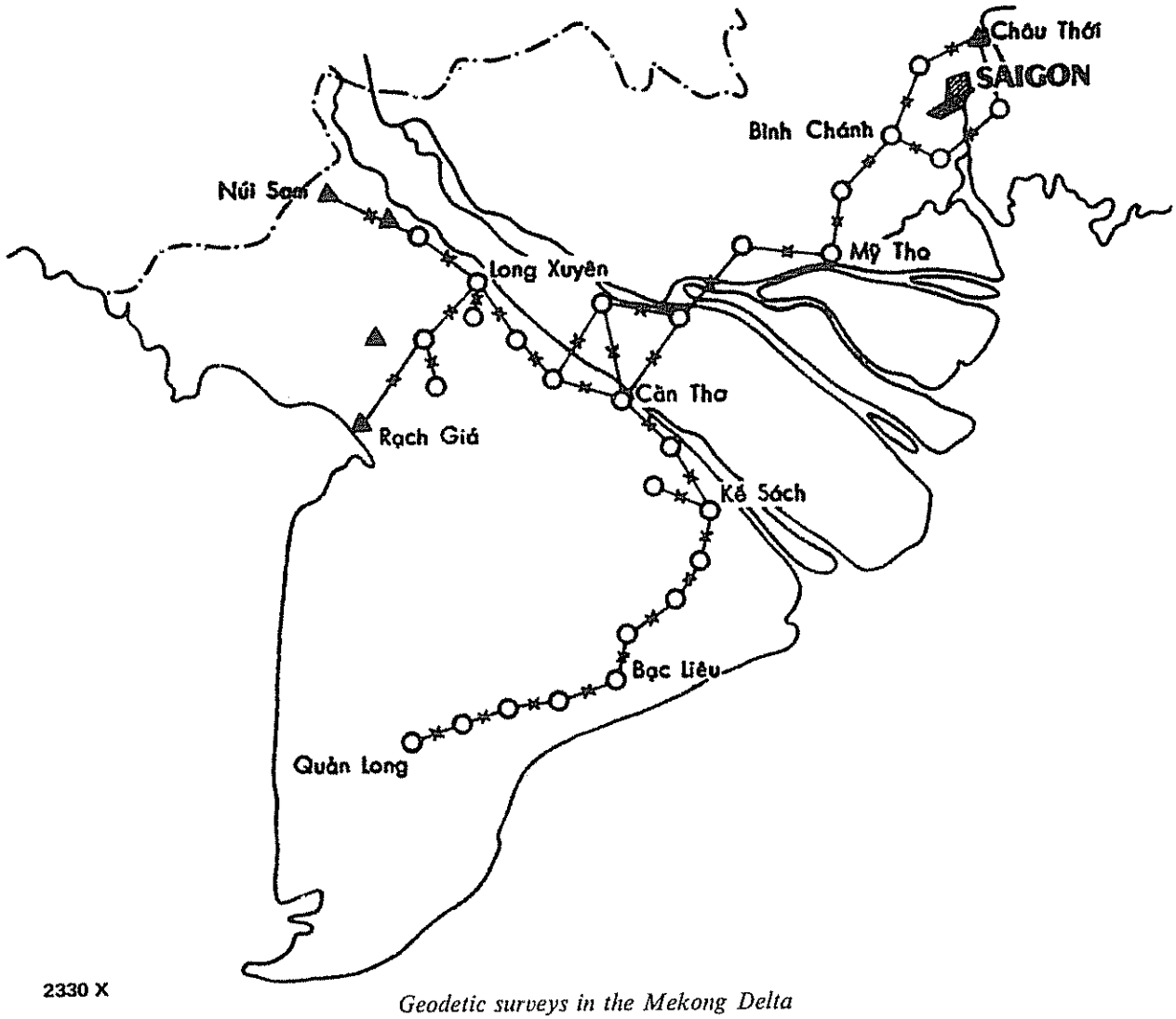
Distance measurement

Instrument: Electronic microchain MC-8;

Method: Difference (reading of two slightly different distances on the same side);

Discrepancy between the two sets of observations: $< \frac{D}{150{,}000}$

[1] The original text of this paper appeared as document E/CONF. 57/L.82.



Geodetic surveys in the Mekong Delta

Results (see the figure)

In 1968–1970 the National Geographic Department carried out:

In the north, a closed traverse 100 km long with five control points:

Aximuth closure: 0.7″

Position closure: $\varepsilon x \simeq 0.02$ m

$\varepsilon y \simeq 0.08$ m

In the south, some open traverses and bearing and distance measurements over more than 600 km with twenty-seven stations.

Difficulties encountered

As this work cannot be done at night, most of the readings were taken in the daytime. The MC-8 electronic instrument is too delicate for transport over rough roads and often requires repair and adjustment. Local masking trees, which are sometimes sacred, are not always easy to deal with. The 100-ft metal Bilby towers vibrate in strong winds in coastal areas, appreciably affecting the accuracy of observations.

CONCLUSION

Although the country has been constantly at war, the National Geographic Department has, in spite of its limited resources, concentrated its efforts on establishing control points in the delta. In the near future, when observations have been taken of Laplace stations and traverses have been closed and adjusted, a single uniform geodetic network will have been established in the delta.

These traverses will help to interrelate all previous field work and at the same time will contribute to the current 1:5,000 and 1:10,000 mapping programmes for the Mekong Delta, which is intended to provide an essential tool for the country's pacification and economic development.

DEVELOPMENT OF SURVEYING IN HUNGARY THROUGH RANGE-FINDERS

Paper presented by Hungary[1]

Electronic range-finders can be used in several branches of geodesy and surveying; they undoubtedly play an important role in the recent development of geodesy. They have been used for twenty years to measure basic geodetic networks in Hungary. The following types have been especially valuable: the Hungarian GET-B1 microwave range-finder, the Swedish NASM-6 and NASM-6A geodimeters (AGA Company), and the Soviet electro-optical range-finder EOD-1. The electronic range-finders have also been used to accelerate surveying work.

In the course of a first large-scale survey in Hungary, the mapping was completed by the photogrammetric method. Aerotriangulation by bands was used for setting up the models; to that end, pass-points had to be determined at the edges of the bands. The control points are generally spaced 4 to 5 km from one another, and between them pass-points are determined by traversing. The most favourable spot thus determined does not always coincide with the position indicated by photogrammetry, which means that 10 to 20 per cent more points than are needed must be determined. The average distance between points is 1 km, measured by electro-optical range-finders. The checks for accuracy carried out on the determined points have shown satisfying results. On one of the territories in question 164 new points were determined. The total length of the lines was 309 km and the number of break points was 104. The average angle-closing error was 0.94″ (old measurement per break angle) and the average linear-closing error was 1.3 cm per km (maximum value 2.5 cm). The break angles were measured by MOM TE-B1 theodolites. The results were satisfactory even in the case of a check on the relative accuracy of adjacent points: between 1/20,000 and 1/50,000 in 30 per cent of the cases; between 1/50,000 and 1/100,000 in 45 per cent of the cases; and above 1/100,000 in 25 per cent of the cases.

In comparison with classical triangulation methods, costs can be reduced by about 40 per cent. The cost of determining ninety-two points over a territory of 15,400 ha was compared with the cost of using the triangulation method:

Phase of work	*Cost of densification by control points*		*Amount saved*
	By triangulation	*By traversing*	
	(in forints)		
Observation	34,300	21,200	+13,100
Building	546,000	216,800	+329,200
Measuring	55,500	106,800	−51,300
	635,800	344,800	+291,000

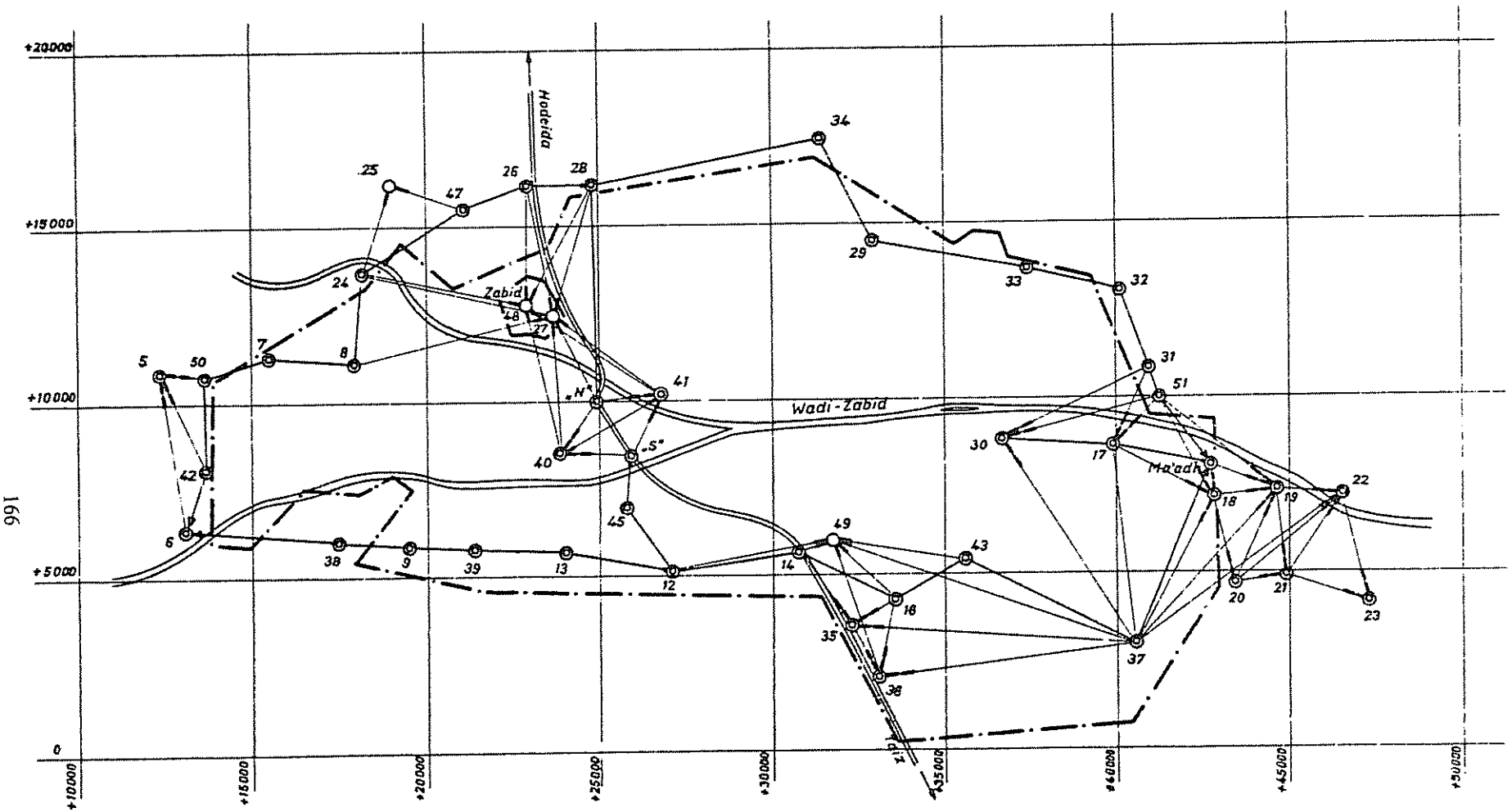
In another, similar branch of work the comparison was made according to the kind of costs in relation to a determined control point.

Kind of cost	*Cost (in forints) of densification*	
	By triangulation	*By traversing*
Salary	1,935	1,150
Transportation	2,620	2,040
Materials	2,370	564
Missions	744	448
Other	230	135
	7,899	4,337

In large-scale surveying work savings are very important, and it must be stressed that through this method the time required to do the work is also reduced, which results in a proportionate decrease in salaries. This reduction in hours of work is significant because the amount of time spent on the work has always constituted a difficult problem in cartography.

The same conclusions may be drawn from the work completed in a territory where climatic conditions differ

[1] The original text of this paper, prepared by F. L. Raum, Technical Director, Hungarian Geodetic and Mapping Company, Budapest, appeared as document E/CONF.57/L.87.



LEGEND

Boundary of project area

Main road

Control

LÉGENDE

Limite de la région du projet

Route principale

14 Contrôle

2331 X

Yemen Arab Republic: Wadi Zabid project; plan of controls

from those prevailing in Hungary, for example in the Yemen Arab Republic. A detailed map had to be established for a few months in the southern part of the Tihama plain for an irrigation project, over a territory of 250 km². The photogrammetric pass-points were determined on the basis of a polygon network. The sides were measured with a GET-B1 microwave range-finder. An average of 94 km with 3,073 m side lengths were measured; the longest side was 6,695 m and the shortest 413 m.

The measurements lasted nine days in September 1969 and five days in October 1969. About 4 or 5 hours were available per day to measure 3 to 5 sides. In addition to the climatic difficulties, there were problems of access to the place of work: 2 to 3 hours were often required.

The accuracy obtained was satisfactory in view of the aim; the mean square error of the distances was ±6.09 cm. Since no data are available for comparison with the conventional method of triangulation, the time needed to complete the work can only be estimated on the basis of experience. According to our estimates the time needed was cut in half by application of the GET-B1 microwave range-finder in comparison with the triangulation method.

HORIZONTAL AND VERTICAL GROUND-CONTROL NETWORKS IN HUNGARY

Paper presented by Hungary[1]

In Hungary work on the horizontal and vertical ground-control networks began in the 1850s and continued for about 60 years. On the basis of investigations carried out after the end of the First World War, it became necessary to establish a new horizontal and vertical control network to comply with modern requirements. As a result of this work carried out in the period between the two world wars, the complete new levelling network and two-thirds of the first-order triangulation net were established. Unfortunately, during the Second World War the control points and the data of measurements and calculations were almost entirely destroyed, and it therefore became necessary to resume work on the establishment of a modern geodetic control network.

PRIMARY HORIZONTAL GROUND-CONTROL NETWORK

Hungary's main new triangulation network was completed during the period 1949–1962. A first-order chain of triangulation consisting of 112 points is the basis of the network (see figure I). Six base lines of 6 to 8 km each were measured and seventeen Laplace points were determined. The first-order angles in the chain were measured by the Schreiber method, by using a weight of $p = 24$. In the areas delimited by the chains of triangulation a third-order triangulation was carried out and the first-order angles were derived from the third-order angles by the Hazay–Regõczi method. The triangulation network with an average side length of 7 km thus established satisfies modern requirements. The Ferrero standard error in the first-order chain is $m_{\text{Ferrero-first}} = \pm 0.46''$; and in the third-order triangulation network, it is $m_{\text{Ferrero-third}} = \pm 0.63''$.

Since 1964 we have been investigating the existing network and its development. Additional angle and astronomic measurements, as well as measurements of sides of some first-order triangles by electronic range-finder have been carried out. On the basis of these data we are calculating the first-order surface astrogeodetic network of Hungary. Figure II shows this network as well as the spots where additional measurements were made, when the distances of the sides were determined with a relative error of 1/500,000, and the astronomic measurements were carried out with the following mean square errors: $m\varphi = \pm 0.07''$; $m\lambda = \pm 0.08''$; and $m\alpha = \pm 0.17''$.

[1] The original text of this paper, prepared by I. Joó, Director, Geodetic Department, National Office of Lands and Mapping, Budapest, appeared as document E/CONF.57/L.88.

Work was begun on the fourth-order triangulation net on the basis of the primary triangulation network. A density of one point per 0.5 km² in the inhabited areas and of one point per 2 km² in the uninhabited areas is required. At the present rate, about 4 to 5 per cent of the country's area is being covered by the fourth-order network every year. By the end of 1970 this work should be completed over about 30 per cent of the country's territory.

The fourth-order control points were determined partly by triangulation and partly by long-side traversing, where the distances are measured by electronic range-finders. Use of this method made it possible to reduce costs by about 40 per cent.

Long-side traversing resulted in the following data: $m_{\text{Ferrero}} = \pm 1.8''$; average standard directional error, $\pm 1.2''$ per 1 km unit length; and average value of linear misclosure of the traverses, 1.5 cm per 1 km unit length.

PRIMARY VERTICAL GROUND-CONTROL NETWORK

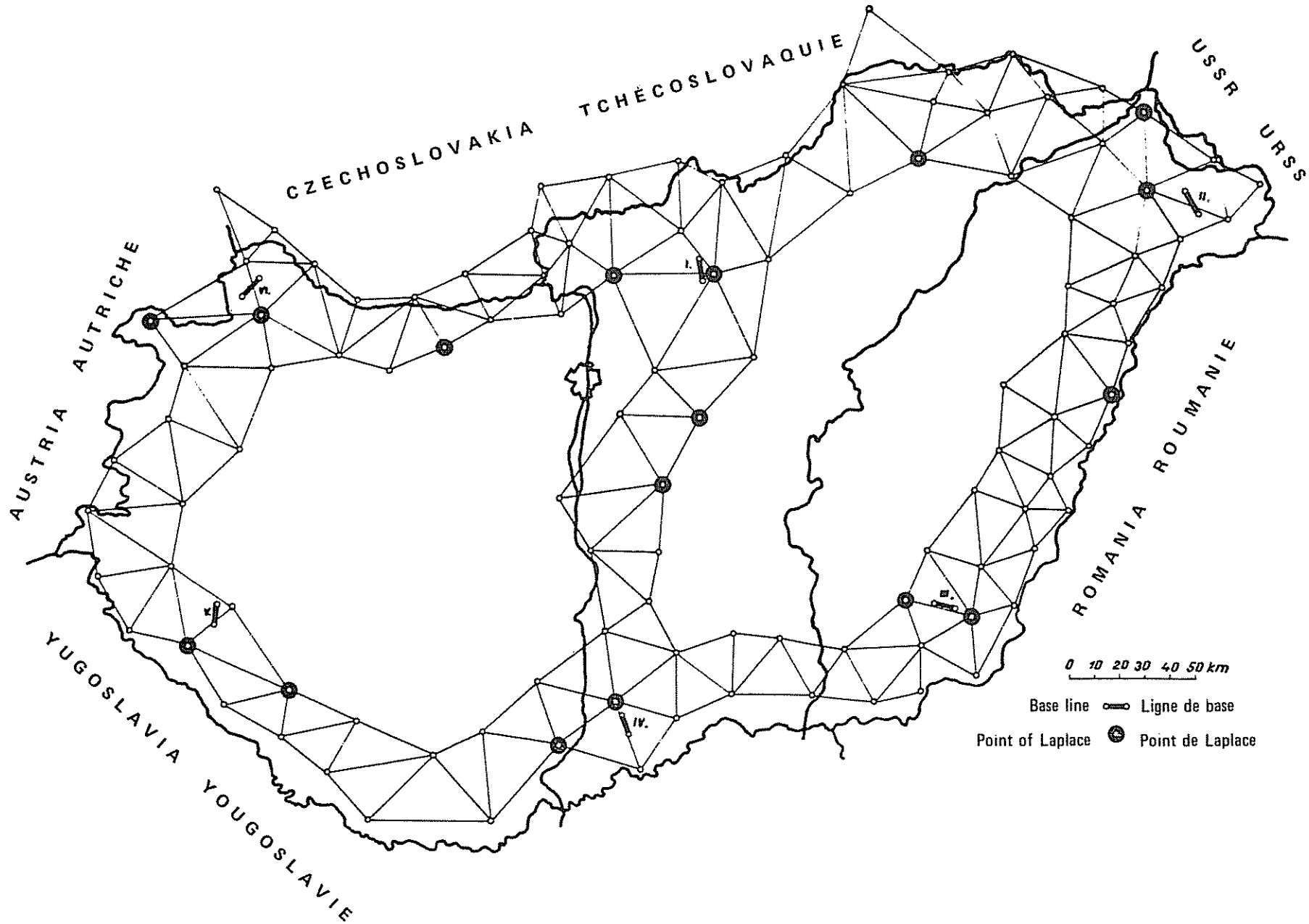
An entirely new primary levelling net was established in Hungary during the period 1958–1964. Figure III shows the first-order levelling net consisting of thirty-three closed traverses. The total length of the first-order lines is about 6,000 km.

The differences in levelling carried out in opposite directions should not exceed the following values: First-order levelling $d_{\text{I}} = 1.2\sqrt{L}$; second-order levelling $d_{\text{II}} = 2.4\sqrt{L}$; and third-order levelling $d_{\text{III}} = 3.6\sqrt{L}$, where L is the length of the levelling section in km and d is the difference in mm.

The mean square errors/km calculated on the basis of the adjustment of the levelling network are $m_{\text{I}} = \pm 0.79$ mm; $m_{\text{II}} = \pm 0.97$ mm; and $m_{\text{III}} = \pm 1.50$ mm.

The measuring and calculation work for the first-, second- and third-order levelling networks were fully completed in 1964, and since then only complementary measurements have been necessary. Recently we developed a plan for a high-precision levelling network with special tracing and fixing to investigate vertical movements of the Earth's crust. The total length of the network, which comprises eleven traverses, is about 3,300 km. Seventy per cent of the network and fixing of the benchmarks has already been completed. During construction of the network thirty-five deep and 600 intermediary benchmarks should be established.

The first measurements of the network should be carried



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Figure I. Hungary: First-order chain of triangulation

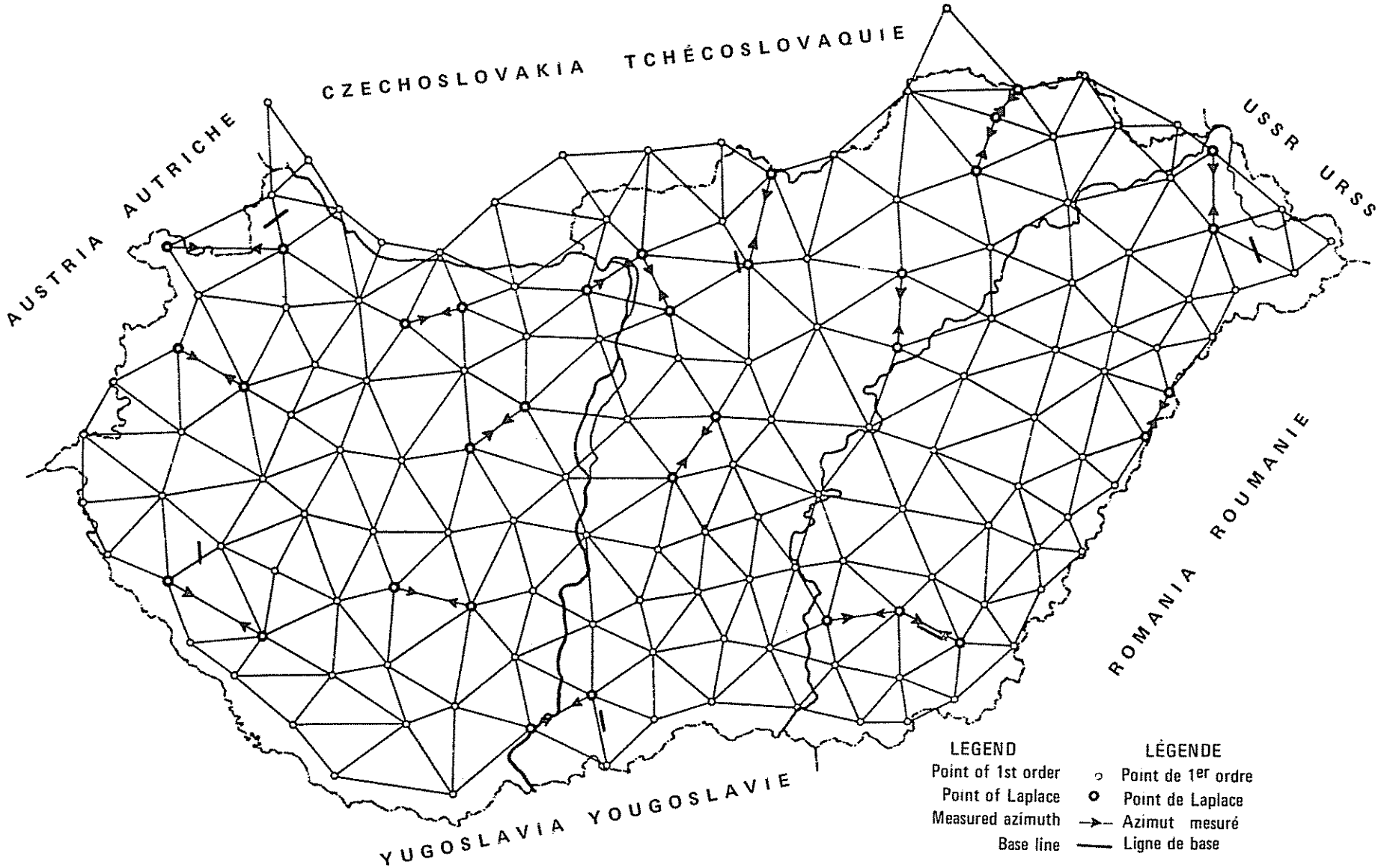


Figure II. Hungary: First-order astrogeodetic network

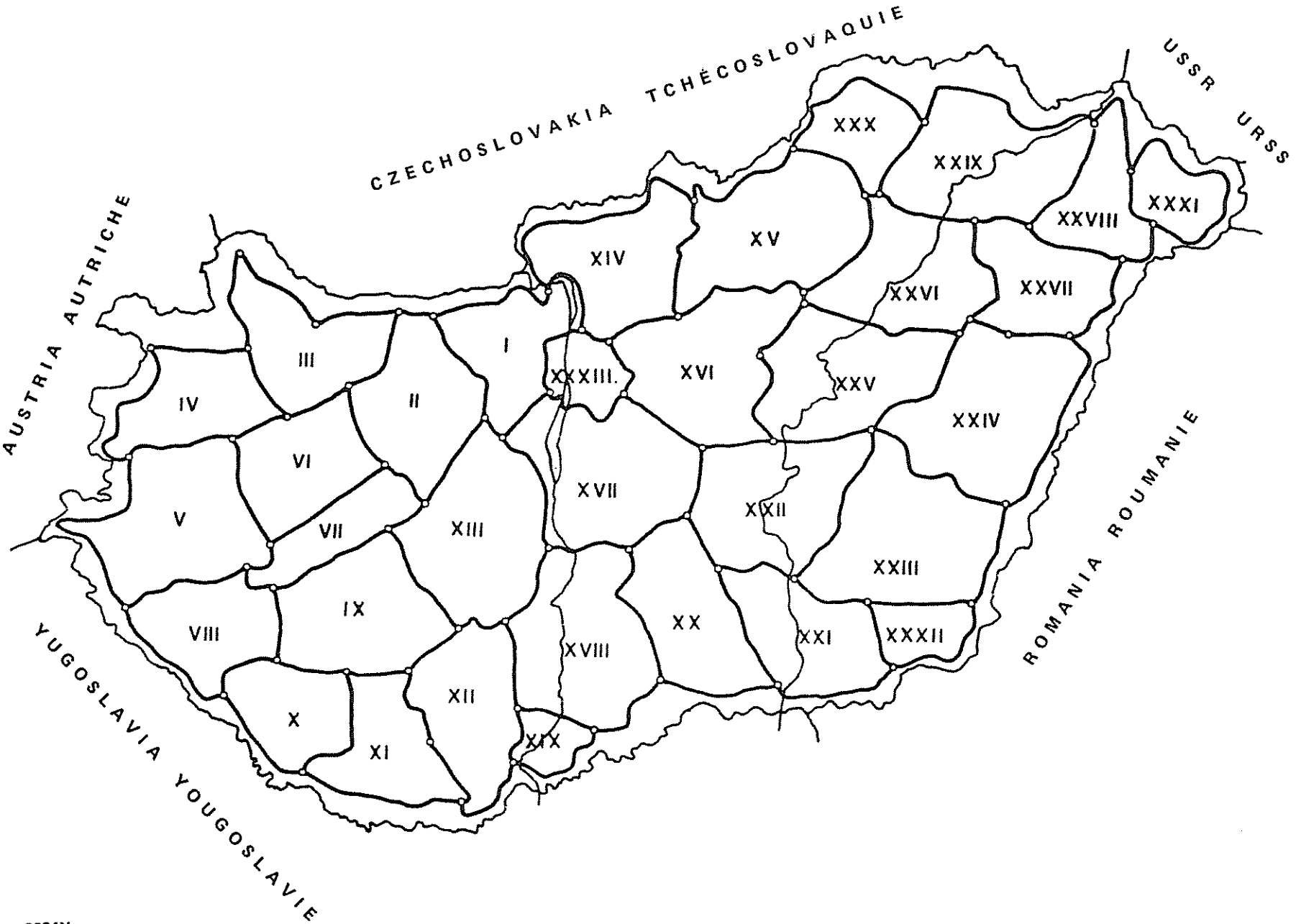


Figure III. Hungary: First-order levelling net

out in 1973–1974, by which time construction of the lines must be completed and linking to the networks of neighbouring countries must be carried out. Moreover, on the basis of the experimental measurements and other investigations carried out in the meantime the most suitable measuring methods must be developed.

HUNGARIAN GEODETIC INSTRUMENTS USED IN SURVEYING

Paper presented by Hungary[1]

The production of Hungarian geodetic instruments is long-established. The first factory—the predecessor of the Hungarian Optical Works (MOM)—was founded in 1876. The industry partook of the general progress and developed especially after the Second World War. As a result Hungarian geodetic instruments are well known throughout the world today; they have made a significant contribution to ground-survey progress in many countries. The importance of this work is highlighted by the fact that only 2 to 3 per cent of the Earth's surface is mapped at 1:25,000 or in greater detail; however, the expansion of population centres, industrial plants and modern agriculture require increased mapping and surveying, including surveying of the sea bed.

The MOM factory is located in Budapest. The various geodetic instruments (and corresponding abbreviations) are as follows:

Te = theodolite;
Ta = tacheometer;
Ma = plane table;
Ni = level;
Gi = gyroscopic theodolite.

The degree of accuracy of each instrument is indicated by means of letters, where "A" denotes the most accurate and "E" the least accurate. The numbers following the letters denote the most developed types of instruments within each category.

The following are the best-known instruments produced by the MOM factory. Their most characteristic parameters will be described later.

Type of instrument	*Designation*
Theodolites	Te-B1, Te-C1, Te-D1, Te-E5, Te-E6
Tacheometers	Ta-D1, Ta-D4
Levels	Ni-A1, Ni-A3, Ni-B1, Ni-B3, Ni-B5, Ni-D1
Gyroscopic theodolites	Gi-B1, Gi-B2, Gi-C1, Gi-D1

Theodolites

The Te-B1 theodolite measures angles in seconds. On its optical micrometer, 1″ can be read directly. The accuracy is $\pm 3^{cc}$ or $\pm 1''$. Its main areas of application are the establishment and densification of triangulation control networks, precise traversing above and below the surface and astrogeodesy. The smooth functioning of the vertical axis is guaranteed by a new system of axes; accurate surveying can be carried out even under unfavourable climatic conditions, as demonstrated in Yemen and other tropical countries. The theodolite has an automatically fixed, accurate guided centring base plate, which makes it possible to achieve 0.02 mm centring accuracy. The central fixing screws and the tangential screws are coaxial, which makes for more practical handling.

By special request, the firm can also deliver additional measuring instruments, such as complete traversing equipment for the Te-B1 theodolite. More advanced types are the Te-B2, for tropical climates, and the Te-B3, which has a compensating height index.

The universal Te-C1 theodolite can be used for angle measurements above or under ground, where the accuracy of the observation in two telescope positions is characterized by a mean square error of $\pm 2.5''$ (fifth-order triangulation, traversing, etc.). The estimated reading limit is 1″. Both horizontal and vertical circles can be read at the same time without any adjustment.

The Te-D1 is a repeat tacheometer-theodolite, with an accuracy of $\pm 5''$. Its main areas of application are traversing, minor triangulation, tacheometry, pegging and measurements for large-scale mapping. Its special features are coaxial central fixing screws and micrometer screws, accurate axle system, easy reading of glass circles and guided centring base plate; it is therefore a favourite instrument among surveyors. In 1957 it won a gold medal at the Brussels World Fair. The Te-D3 has an automatic height index. The Te-E5 and Te-E6 are modern, light, small-size theodolites used by architects; the former is equipped with a compass, while the latter is not. The Te-E6 is very popular because it is easy to use and up to date; it is equipped with all the accessories required for use in mines and above ground when reduced accuracy is sufficient. Its height index is automatic, and its reading accuracy is 0.5′ to 1°.

Tacheometers

The MOM Ta-D1 tacheometer with circle diagrams is used for detailed polar measuring as well as for surveying and pegging work. The estimated reading limit of its scale microscope is 6″. Its construction is similar to that of the Te-D1 theodolite. The distance reduced to the horizontal and the height difference can be read directly in centimetres from the vertical staff placed on the point aimed at. The circle-diagram system characteristic of this type of instrument is an advantage because it increases the accuracy of the automatic reduction. The Ta-D4 tacheometer is a variant featuring an automatic height index.

Surveyors' levels

The Ni-A1 and Ni-A3 instruments are used for precise levelling. The Ni-A1 is one of the most accurate, characterized by high light intensity; 65 mm diameter lens; coincidable and sensitive level indicator projected into the telescope's field of vision; two-stage levelling screw and horizontal slow-motion screw; 5 mm optical micrometer range; and 0.05 mm reading accuracy (but 0.005 mm can

[1] The original text of this paper, prepeared by F. L. Raum, Technical Director, Hungarian Geodetic Mapping Company, appeared as document E/CONF.57/L.89

also be estimated). Exchangeable magnifying lenses (magnification factors 25, 32 and 40) are available and an accuracy of ±0.4 mm/km is possible.

The Ni-A3 is the most modern and most successful MOM levelling instrument. It is equipped with a compensator, the accuracy of which exceeds that of all instruments with compensator and level indicator manufactured to date, since the mean square error is ±0.2 mm/km (for measurements in two opposite directions). As a result, this instrument may be used even when extreme accuracy is required, e.g. for measurements of the national or continental network to check vertical crustal movements or other movements and deformations, machine-shaft setting and development of national levelling networks. Moreover, it is light (3 kg), small, and easy to handle. In recognition of its special structural features, it was awarded a gold medal at the Hanover International Fair in 1970.

The MOM Ni-B1 levelling instrument also has an international reputation; it won first prize at the Brussels World Fair. This instrument can achieve a mean square error of ±2.0 mm/km for levelling in two opposite directions and is suitable for fairly accurate technical levelling. The Ni-B3 and Ni-B5 levelling instruments equipped with compensator are the most sought-after for export purposes. The telescope and structure are both excellent. The setting accuracy of the compensator is ±0.2″. These instruments are suitable for city surveying, building above and below the ground constructions, for topographic surveys, construction of power plants and bridges, as well as water regulation. New variants are the Ni-B5 and Ni-B6, which are equipped with a horizontal-scale glass circle and also have the advantage that the image of the circular bubble is projected into the telescope's field of vision. The mean square error of these instruments is ±2 mm/km, but the error can be reduced with the help of an optical micrometer to ±0.7 mm/km. The Ni-D1 levelling instrument with compensator is used for building and shipyard surveys and is preferred because of its small size and weight; it has a vertical cylindrical shape, and its mean square error is 3 to 4 mm/km.

Gyroscopic theodolites

In 1962 the Hungarian geodetic instrument industry first appeared on world markets with a gyroscopic theodolite. Other instruments of this type have since been developed and all have acquired a world-wide reputation.

The Gi-B1 gyroscopic theodolite was the first to be developed by the MOM Company. Its merits were immediately recognized, as evidenced by the number of orders placed for it; and the new Gi-B2 type served to highlight its advantages. The main difference between the two types is that the Gi-B2 automatically follows the oscillations of the sensing system with the help of a servomotor controlled by a photo-resistor. By separating the theodolite from the sensing system, the measuring time was decreased. The characteristics of the Gi-B2 are mean square error of azimuth determination, ±12″, the weight of the instrument (without case), 32.5 kg; measuring time including setting and observation of four oscillations, 25 to 30 minutes; and energy needed for one measurement, 1.2 ampere-hour.

The Gi-C1 and the Gi-D1 gyroscopic theodolites are used for less accurate measurements. The first can be combined with the MOM Te-B1 theodolite, and the second with the Te-B6 theodolite. The mean square error of one azimuth measurement is ±25″ to ±40″ in 14 to 18 minutes' measuring time. The weight of these instruments is 16.5 to 18.5 kg (including the theodolite, superposed gyroscope, tripod and generator).

The above-mentioned instruments, with the exception of the gyroscopic theodolites, belong to the traditional group of geodetic instruments. However, the Hungarian geodetic industry has also developed new and more specialized instruments, such as the Get-B1 microwave range-finder, manufactured by the Precision Mechanical Enterprise (Budapest), the laser marker, the laser range-finder, the co-ordinate theodolite and the code theodolite. The industry produces instruments for mapping, as well as instruments used in the field. The most common are the polar planimeter, the precision pantograph, glass scales and orthogonal and polar plotting devices.

STELLAR TRIANGULATION AND ITS APPLICATION IN FINLAND

Paper presented by Finland[1]

In 1946 Professor Yrjö Väisälä proposed at the Finnish Academy of Sciences a new method of triangulation, namely, stellar triangulation, which makes use of separate directions instead of the angle measurement of classical triangulation. A flash or a continuous light is produced high in the air using appropriate devices, such as balloons, rockets or artificial satellites, as Professor Väisälä had already suggested long before the space age.

Optical tracking in satellite geodesy is based on the principles of stellar triangulation. When the satellites are moving at altitudes of thousands of kilometres the distances between the observation stations can also reach thousands of kilometres; observations can therefore be used for linking the geodetic networks of different countries. The accuracy of the co-ordinates achieved so far is a few metres.

If the targets are moving at an elevation of dozens of kilometres, as balloons do, the observation stations can be located at distances of some hundreds of kilometres. Since the distances are shorter, the accuracy of the co-ordinates is a few decimetres. Observations of this kind are suitable for checking national networks and establishing a base network in an area where no geodetic base network exists.

Experiments with stellar triangulation in which balloons are used go back to 1946, but the first systematic attempts began in 1959. Among the several variations proposed by Väisälä, the Finnish Geodetic Institute selected the following method. The observations are carried out as follows:

The flash device is carried by a meteorological sounding

[1] The original text of this paper, prepared by T. J. Kukkamäki, Geodetic Institute, Helsinki, appeared as document E/CONF. 57/L.104.

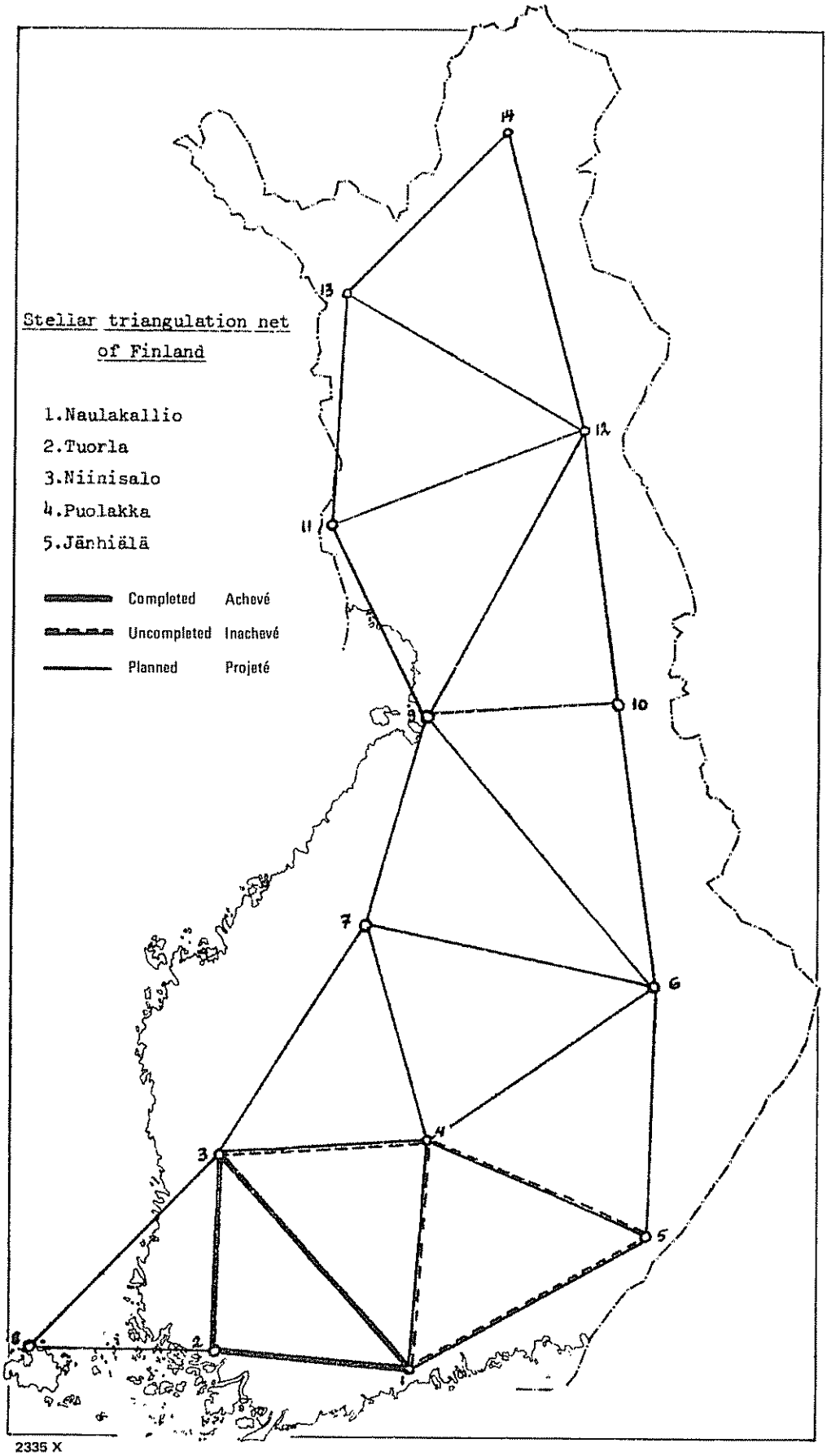


Figure I. Finland, stellar triangulation net

balloon to an altitude of 35 or 40 km. The flashes are triggered from the ground with a radio transmitter. The timing of each flash is determined by a quartz clock. The flashes are photographed against the starry sky with two telescopes that are 150 to 250 km apart. The position of the flash relative to the stars is determined with a comparator on the photographic plate. From these co-ordinates and the right ascension and declination of the fix stars, the right ascension and declination of the flashes are computed. When the sidereal time is used, the right ascension is transformed to an hour angle and so the direction from the telescope to the flash is determined in a rectangular co-ordinate system fixed with the Earth. One flash gives one plane, going through both the telescopes and the flash. Another flash gives another plane. The intersection line of these two planes gives the direction from one telescope to the other. This direction constitutes the fundamental observation in this method. This direction has nearly the same accuracy in the horizontal and vertical planes. The direction of each of the three sides is determined from the three observation stations, and when these are combined, a closure error shows up in the vertical plane but not in the horizontal plane. When the direction of all sides of a network formed by several observation stations has been corrected by adjustment computations and the scale of this network has been derived from an independent geodetic measurement of the length of one or more sides, the co-ordinates of observation stations in the rectangular co-ordinate system and the three components of their errors can be obtained.

The following are the main characteristics of the equipment and installations used in stellar triangulation in Finland.

The light-signal device comprises a receiver (153 MHz) with dipole antenna, a xenon flash tube (100 W, 2.5 ms) with reflector, a condenser, a trigger circuit and batteries in an insulating case with parachute. The total weight, including the case and parachute, is 2.8 kg. It is lifted by a Kaysam 120 G or 130 G weather-observation balloon. The flashes are triggered from the ground with a radio transmitter (153 MHz, 50 W) equipped with a Yagi antenna. The transmitter transmits impulses every second from a Hewlett-Packard quartz clock; the accuracy thus obtained is better than 1 ms. Three Schmidt–Väisälä telescopes with a focal length of 1,031 mm, an aperture of 340 mm and an angle of view of 5° are used for photography.

On each plate seven flashes and about thirty stars of magnitude 8–9 are measured with a UIM-1 comparator, and a co-ordinates accuracy of ± 1.5 μm is obtained. The co-ordinates of flashes are derived with a variation of Turner's method. A programme is prepared for an IBM 360/50 computer that automatically reads the star co-ordinates from the magnetic tape star catalogue of the Smithsonian Astrophysical Observatory. For refraction correction, observations of ambient atmosphere with weather balloons are used.

A stellar triangulation net comprising fourteen stations, with an average side length of 200 km, is planned for the entire territory of Finland. The first triangle, Tuorla–Naulakallio–Niinisalo, has been completed. Eleven balloons were launched, with the following results:

	Successful plates	*Exposed flashes*
Tuorla	25	118
Naulakallio	24	116
Niinisalo	11	63
TOTAL	60	297

The mathematical treatment of measurement results is now in progress. As a first result, the intrinsic accuracies obtained for the Tuorla–Naulakallio side may be mentioned here, namely, $\pm 0.32''$ for the hour angle and $\pm 0.49''$ for the declination; these values correspond to a relative accuracy of about 1:500,000.

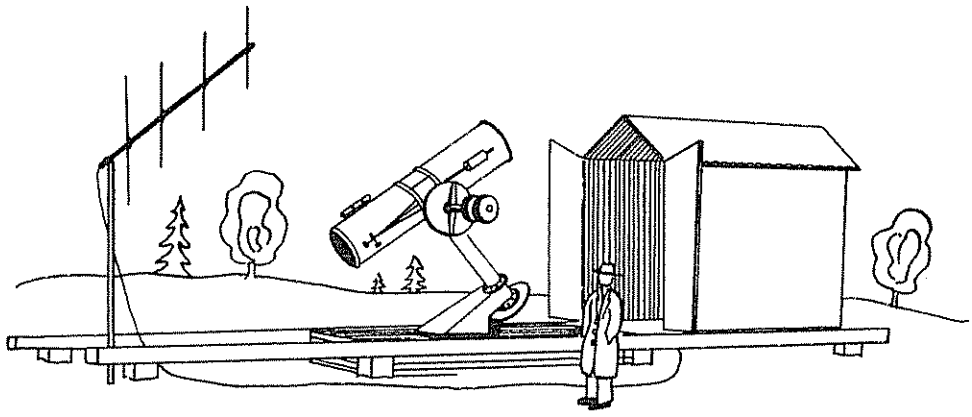


Figure II. Schmidt–Väisälä telescope with shelter and antenna

THE SOVIET "QUARTZ" OPTICAL DISTANCE-MEASURING INSTRUMENT AND ITS USE

Paper presented by the Union of Soviet Socialist Republics[1]

The basic improvements realized during recent years in the field of phase optical distance-measuring instruments intended for geodetic work are, in the main, connected with using optical quantum light generators (lasers) for the source of radiation. The application of lasers as the source of radiation in optical range-finders made it possible to eliminate one of the most serious defects peculiar to previous models of these instruments. This defect meant that measurement of long lines was not possible in daytime conditions. This considerably reduced the efficiency of electro-optical range-finders, and practically prevented their use in trans-polar regions.

Recently, considerable progress was also achieved in elaboration of electronic schemes for electro-optical distance-measuring instruments, so that it became possible to reduce both the size and weight of the instruments and to cut down the power consumption.

The characteristic features of the "Quartz" are a gaseous laser that is used as the source of radiation and the electronic circuitry being based on the principle of frequency transformation thus permitting phase measurements to be made on a low frequency.

The application of the principle of frequency transformation made it possible to take phase measurements with the aid of a high-precision induction type phase resolver. This led to considerable simplification of the problem of phase measurements.

Besides solving the problem of day-time measurements, the application of a gaseous laser created the possibility of using a more compact optical scheme.

A characteristic feature of the gaseous laser is its highly monochromatic radiation. This peculiar feature of the source of radiation makes it possible to eliminate errors of measurements due to errors in determination of the effective wave length.

The "Quartz" optical distance-measuring unit in which all these improvements were introduced, has the following technical features:

1. Daylight range . . . . . up to 30 km;
2. Mean square error M of a measurement of a line is characterized by the formula:

$$M = \pm(1\text{ cm} + 2 \cdot 10^{-6} \cdot D)$$

where D is the distance being measured, in cm;
3. Weight of the instrument is about 25 kg;
4. Power consumption is about 140 W.

The power supply is provided by a benzo-electrical unit (power output 500 W, frequency 400 Hz, weight 23 kg). A complete "Quartz" unit also includes prism reflectors, meteorological devices and short-range radio sets. Test measurements both with the experimental and production instruments corroborated the good operational properties of the "Quartz".

At present, these instruments are used for measuring triangulation base lines and legs of traverses with lengths up to 30 km. Measurements may be carried out both in daylight and in the dark. One set of measurements is taken in about 40 minutes.

When measuring short distances (up to 10 km) with the "Quartz", it is possible to obtain a higher accuracy than that defined by the above formula. As an illustration, some results of measurements of short lines with the "Quartz" are given in the table.

Date 1970	*Distance measured (m)*	*Reference measure (m)*	*Difference (mm)*
20 August	5,320.297	5,320.297	0
24 August	5,320.295	5,320.297	−2
	5,320.292	5,320.297	−5
25 August	5,320.297	5,320.297	0
	5,320.298	5,320.297	+1
	5,320.298	5,320.297	+1
26 August	5,320.303	5,320.297	+6
	5,320.298	5,320.297	+1
	5,320.298	5,320.297	+1
27 August	1,523.167	1,523.169	−2
	1,523.169	1,523.169	0
28 August	1,523.173	1,523.169	+4
	1,379.188	1,379.186	+2
27 August	575.641	575.641	0
	575.643	575.641	+2
28 August	575.641	575.641	0

The mean square error of a measurement obtained from one set of measurement is $m = +2.5$ mm.

In the table, each value of the distance measured was obtained as a result of one set of measurements. The values of the reference distance are known within an error of about 1:1,000,000. Short-line measurements have shown that the "Quartz" distance-measuring instrument can also be used with success for geodetic engineering of different kinds.

[1] The original text of this paper, prepared by the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography, Moscow, appeared as document E/CONF.57/L.105.

STANDARD THEODOLITES IN THE UNION OF SOVIET SOCIALIST REPUBLICS

Paper presented by the Union of Soviet Socialist Republics[1]

Surveying instruments in the USSR are produced according to the national standards valid for the particular types. The national standards are revised every 5 to 10 years to bring them into line with altering requirements of geodesy and surveying and world scientific and technological standards.

Eight types of theodolite are produced in the USSR at the present time according to the valid standards (GOST-10529-63). They are: T05, T1, T2, T5, T10, T20 and T30.

[1] The original text of this paper, prepared by the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography, Moscow, appeared as document E/CONF.57/L.106.

In these abbreviations, numbers show the extreme permissible mean square error of one-set angular measurement, which characterizes the accuracy of the instrument.

The high-precision optical theodolite T05 is designed and used for triangulation and first-order traversing as well

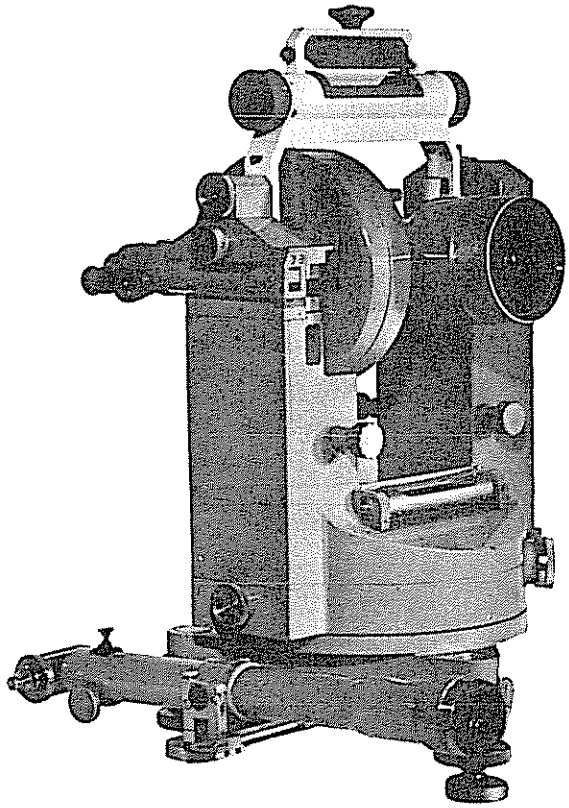


Figure I. The T05 theodolite

as in traversing for base lines of space triangulation with the error of horizontal angles not exceeding 0.5 seconds. The high accuracy of the angular measurements of this theodolite is guaranteed by the following features: horizontal circle with 180 mm diameter, graduated to within 10 minutes with a high degree of accuracy; a wedge optical micrometer which enables taking confident readings up to a tenth of a second; a high-quality telescope with apochromatic correction and three replaceable eyepieces providing magnifications: $\times 62$, $\times 50$ and $\times 37$. An eyepiece optical micrometer is installed to reduce the pointing error of the instrument. A number of pointings at the observed objects can be done without shifting the alidade. A tubular level is provided, which is laid on the horizontal rotation axle of the telescope, the value of graduation of the level if 4 seconds per 2 mm, thus corrections can be made for minor inclinations of the axle. Other improvements have been made to increase the accuracy of angular measurements. For smooth lighting of both horizontal and vertical circles, the theodolite is designed for work only with electric lighting. The upper part of the theodolite, consisting of the telescope and vertical circle, is easily removed from the lower part, which includes the support, horizontal circle and the alidade. Because of this design, the theodolite can be put into two separate metal boxes. This is important in raising the instrument up high geodetical towers and for easier transportation under difficult field conditions.

The high-precision theodolite T1 is designed for angular measurements in triangulation and traversing of second order and for other accurate geodetic operations. The angular measurement error does not exceed 1 second. The instrument is portable and of little weight. The

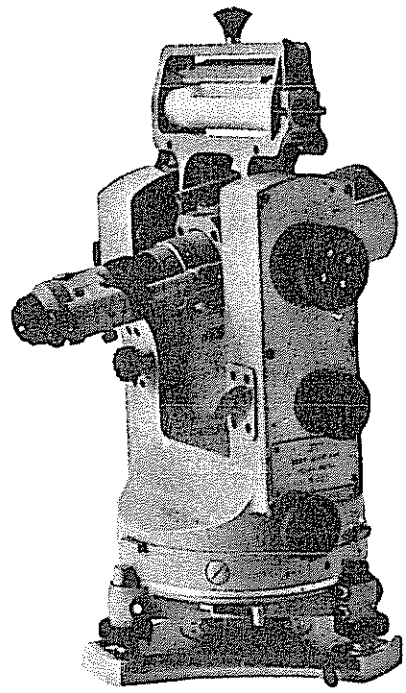


Figure II. The T1 theodolite

telescope is provided with an apochromatic objective and replaceable eyepieces with magnification of $\times 30$ and $\times 40$. The telescope is designed with an optical eyepiece micrometer for the reduction of pointing error. Bearings with zenith distances from 20° to 140° can be measured by this theodolite. It is supplied with knee-type eyepiece sets for telescopes and eyepiece micrometers to make work at small zenith distances more convenient. Lighting of both horizontal and vertical circles is either artificial or natural at the discretion of an observer. The instrument is supplied with a level which is placed on the horizontal axle of the telescope. A replaceable astronomic crosshair is also supplied with the instrument. An optical plummet is designed in the alidade part of the instrument for precise alignment of the theodolite. Alignment by this optical plummet is possible at distances ranging from the levelling screws to infinity. This theodolite is supplied with a special plate for setting on the tables of geodetic towers. This plate serves as a joint when the instrument is set on a tripod.

The optical theodolite T2 is designed for angular measurements in triangulation and traversing of third and fourth orders. It can also be used for civil engineering on construction sites, as well as for astronomical observations of latitude, longitude and azimuth. Conventional dual-vision range-finders and light range-finder measuring units can be fixed to the T2. Additional accessories are provided for compulsory alignment of the instrument. Precise alignment is possible within a range from 300 mm

to infinity. Geometrical levelling can be done by T2 with a cylindrical level placed on the top of the telescope, supplied at the request of customers. The telescope can be traversed through zenith with both ends. Thus observations of objects with small zenith distances are possible. Knee-type eyepieces for the telescope and the reading microscope are supplied for this purpose. Khorrebov's tubular level is supplied with the theodolite for astronomical observations of latitude and longitude. This level is set on the telescope. A tubular level is provided for astronomic azimuth observations; this level is more precise than that on the alidade. The error of an astronomic azimuth obtained by T2 is not more than 5 seconds observed by four to six sets of sun observations and not more than 3 seconds by pole-star observations. Geodetic azimuth can be observed by the method of eight stars in the meridian and prime vertical with an error not exceeding 3 seconds.

The optical theodolite T5 is designed for angular measurements of first- and second-order traversing and micro-triangulation. Its difference from the first three types of theodolite is that readings are not taken from both sides of the horizontal circle by optical micrometer, but by scale microscope from one side of the horizontal circle. A particular feature of the T5 is a built-in optical compensator instead of the tubular level on the alidade of the vertical circle. This ensures automatic setting of the zero point, even with the support inclined up to 3°; thus the T5 can be used as a technical levelling instrument. The theodolite is provided with a high-quality telescope with an orthoscopic eyepiece. An optical plummet is built into the alidade of the horizontal circle. The theodolite is built for work with an auxiliary range-finder unit as well as for compulsory alignment.

The optical theodolite T10 is designed for angular measurements in traversings of first and second order and

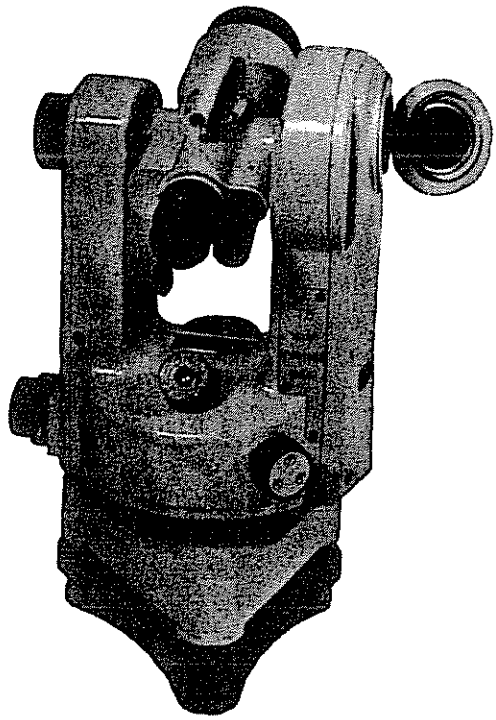


Figure IV. The T5 theodolite

in micro-triangulation of first and second order. This theodolite is provided with a vertical axle of repetition system. An auxiliary range-finder unit can be fixed on the telescope of the instrument. Technical levelling can be carried out by the T10 if a cylindrical tubular level is

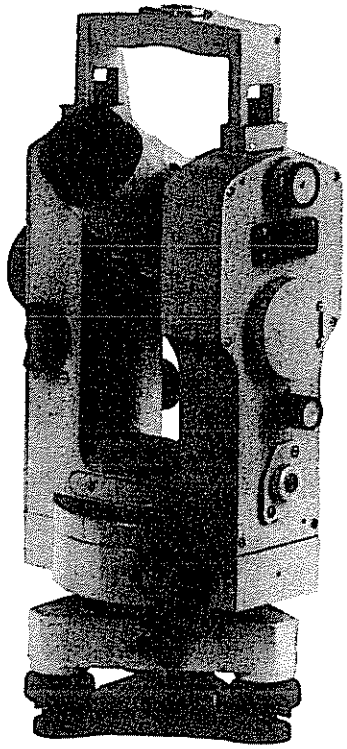


Figure III. The T2 theodolite

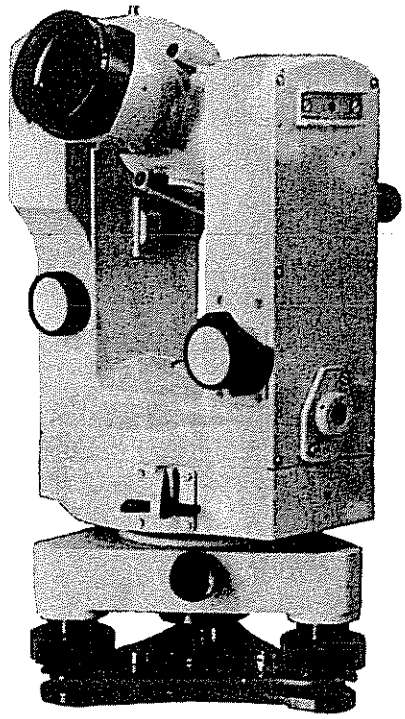


Figure V. The T10 theodolite

installed on the telescope. The optical plummet is built into the alidade part of the instrument. The readings are taken from one side of the horizontal circle by a scale microscope. The instrument is designed for work with compulsory alignment. There is a difference from the T5 type theodolite—a contact cylindrical tubular level with a prism system is installed on the alidade of the vertical circle.

The T15 theodolite is designed for theodolite traversing. There is a vertical axle of the repetition system. A distinctive feature of this theodolite is electrical lighting of the field of vision of the reading microscope, which is explosion shock-proof; thus the instrument is suitable for mining work. The readings of the horizontal and vertical circles are taken from one side only with a scale microscope. It is possible to use the instrument for technical levelling as it has a fixed cylindrical tubular level on the telescope. A compulsory alignment system is provided as in all the other instruments described. A dual vision range-finder auxiliary unit can be fixed on the telescope of the T15.

The T20 theodolite is designed for angular measurements of traverses laid out in mines. The theodolite is provided with a vertical axle of the repetition system type and there is an electrical lighting system. The T20 is explosion shock-proof. A distinctive feature of this theodolite is that it can be set not only on a tripod, but on a console in a mine in both a normal position and upside-down for which the instrument is provided with a reversible tubular level.

The T30 theodolite is designed for angular measurements in traverses run on the surface. Portable size and small weight make the theodolite very convenient and it can be used for field surveying work in remote areas as well as for civil engineering on construction sites, cadastral survey and for general prospecting purposes. Readings up to 1 minute of both the horizontal and vertical circles of this theodolite are taken by estimation with a microscope. The theodolite has no optical plummet, so rough alignment is done by an ordinary plummet, and exact alignment by the telescope of the instrument being turned down, through the hollow vertical axle (this axle is used for repetitions).

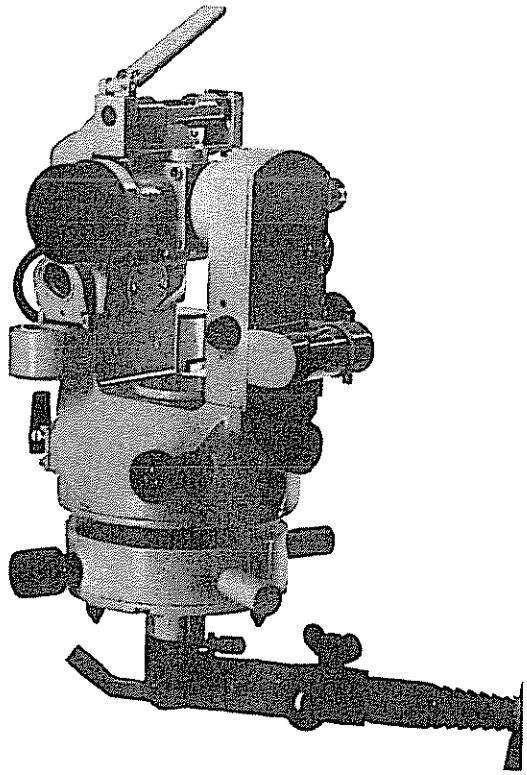


Figure VI. The T20 theodolite

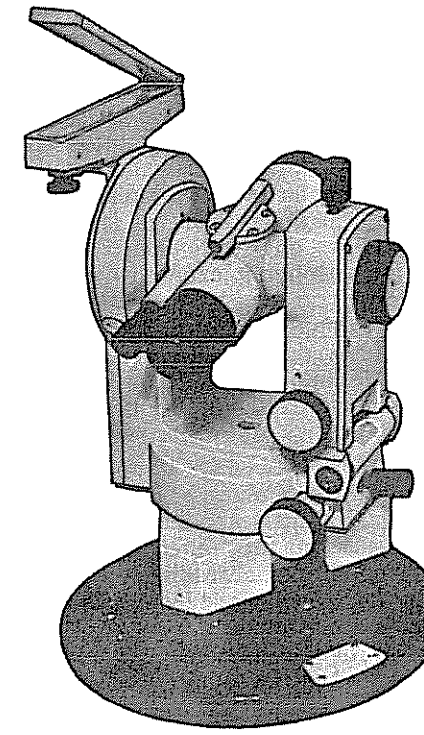


Figure VII. The T30 theodolite

These eight theodolites are to be produced in the USSR until the end of 1971. Beginning in January 1972 a new standard will be valid, namely, GOST 10529-70, according to which production in the USSR will be restricted to only six types of theodolites: T05, T1, T2, T5, T15 and T30. Theodolites T5, T15 and T30 will be produced in two variants.

The first and main variant of the T5 theodolite will be an optical theodolite with a tubular level on the alidade of the vertical circle. The second variant will be the T5K with an optical mechanical compensator instead of a tubular level on the alidade of the vertical circle. The T5K model will have a vertical axle of the repetition system, which will make laying out of engineering projects easier.

T15 and T30 theodolites will be made in surveying (main) and mining variants. Mining variants of the theodolites will be named T15M and T30M, and they will differ from the surveying variants of T15 and T30 by the special design of the vertical axles, which will enable the instruments to be hung upside-down on consoles. They will have resersible tubular levels and electrical lighting. The instruments will be explosion shock-proof.

These alterations will make it possible to unify details and so the cost of production of the theodolites will considerably decrease.

ANNEX

Brief specifications of the theodolites produced in the USSR according to GOST 10529-63

Parameters	Theodolites							
	T05	*T1*	*T2*	*T5*	*T10*	*T15*	*T20*	*T30*
1. Telescope magnification	62, 52, 37	40, 30	25	27	25	25	20	20
2. Objective focal length	500	350	250	218	250	250	160	160
3. Diameter of free aperture of the objective (mm)	64	55	35	35	35	35	30	30
4. Angle of field of vision	0° 40′	1° 30′	1° 30′	1° 30′	1° 30′	1° 30′	2°	2°
5. Value of graduation of scale of reading microscope or micrometer	1″	1″	1″	1′	1′	1′	2′	—
6. Limit of distinction (second)	2.2	2.5	4	4	4	4	4.8	4.8
7. Value of graduation of drum or scale of eyepiece micrometer (second)	1	1	—	—	—	—	—	—
8. Diameter of the horizontal circle (mm)	180	135	90	95	90	80	64	70
9. Diameter of the vertical circle (mm)	130	90	65	70	70	70	64	70
10. The smallest circle graduation	10′	10′	20′	1°	1°	1°	1°	10′
11. The shortest distance (m)	5	5	1.5	2.0	1.5	1.5	0.9	1.2
12. Value of graduation of:								
The laid-on tubular level (second)	4	4	10	—	—	—	—	—
The tubular level of the alidade of the horizontal circle (second)	6	6	15	30	30	45	30	30
13. Weight (kg) of:								
Theodolite	19	7	5.2	3.6	3.5	3.6	2.2	2.0
Theodolite packed in box	36	10	9.7	7.4	7.5	8.6	5.7	4.0
14. Height of the horizontal axle of rotation (mm)	340	255	245	220	235	—	184	180

GEODETIC METHODS OF STUDYING CONTEMPORARY MOVEMENTS OF THE EARTH'S CRUST

Paper presented by the Union of Soviet Socialist Republics[1]

Movements of the Earth's crust are caused by its deformation revealing itself as a continuous change in time t of the position data $(x\ y\ z)$ of the Earth's surface, related to a unified system of co-ordinates.

The changes in the lengths of the measured lines $S_2 - S_1$ and elevations $h_2 - h_1$ may be calculated immediately. If the measurements are obtained in a period of time of t years then the speed of crust movement is characterized by the corresponding ratios of the differences of the measured values:

Horizontal movements $\quad \frac{ds}{dt} = V_s$

Vertical movements $\quad \frac{dh}{dt} = V_h$

Evaluation of the horizontal and vertical speed components of recent movements is of great scientific and practical importance.

Compared to geology, which studies the life of our planet and provides us mainly with a general description of the tectonic phenomena, geodesy can give a quantitative characteristic of the speeds of the movements as well. Here the direction of the movement, whether expansion or compression, rising or lowering, may be shown by means of vectors or by signs (+) or (−).

Knowledge of contemporary deformations of the Earth's crust helps us to evaluate the strength of an earthquake and assuming that every earthquake is preceded by some "preparation" and accompanied by changes in the tensions of the crust, we may hope that geodetic methods may help us discover the deformations preceding this formidable natural phenomenon.

Without over-estimating the role of geodetic methods in studying the movements of the Earth's crust we are in a position to say that this complicated problem can only be solved in co-operation with such sciences about the Earth as geology, geophysics, seismology and geomorphology.

If geodesy could make its contribution to a theory of prediction of earthquakes, all mankind would be greatly indebted to it. The earthquakes of recent years that have taken place in many countries impose on scientists the necessity of making measurements in an attempt to detect the forerunners of others.

Surveying for detection of crust movements is conducted in the USSR by two main methods. These are the establishing of a geodetic relevelling control of high precision over a considerable area and of special geophysical (geodynamic) polygons in some areas in the seismic zone. These polygons are an element of the general system of surveying construction in the country.

In a typical case the geodetic component of geophysical polygons will consist of three types of interrelated geodetic constructions:

(*a*) Minor constructions covering local areas and

[1] The original text of this paper, prepared by the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography, Moscow, appeared as document E/CONF.57/L.107.

crossing geological breaks or covering urban areas and serving for their seismic micro-classification;

(*b*) Medium-scale constructions covering areas of possible epicentres of devastating earthquakes;

(*c*) Major constructions covering considerable areas and including existing astrogeodetic networks and geodetic levelling networks of high precision.

Operations performed on the polygons should be: levelling, linear and angular measurements, gravimetrical determinations and astronomical determination of the azimuth.

One of the polygons of type (*a*) was erected in Tashkent where an earthquake took place (N ± 5.3) on 26 April 1966. The seismic origin, the depth of which was about 10 km, was situated under the central part of the town.

From the date of the many repeated relevellings, the first of which had been made in 1894, the following speeds of the relative vertical crust movements were calculated: before the earthquake, from −0.9 mm/year to +1.2 mm/year; just after earthquake from −16 mm/year to +18 mm/year. In the period of maximum seismic activity the deformations reached +40 mm.

After the earthquake the geodetic measurements in the region of Tashkent were conducted according to a definite programme. As a result the zones of breaking destruction were established by geodetic methods, which form a complicated network of blocks of 0.5 to 15 km^2. This has helped to improve the map of seismic micro-classification required in building the city. This is an example of the practical importance and the necessity of investigating seismic phenomena by geodetic methods.

The density of surveying measurements and the frequency of their repetition is variable. A greater density and frequency of measurements is planned for regions of high seismic activity and in urban areas. Multiple level lines and linear measurements should normally cross the geological breaks and characteristic relief elements.

There is a definite correlation between the conformation and the accumulation of elevation differences in the first levelling and later ones. This correlation enables the directions of crust movements to be more accurately revealed.

A problem to be solved is how to process all the data from the polygons by using computers for the necessary logical operations.

International co-operation in the field of study of the crust movements, realized under the auspices of the International Union of Geodesy and Geophysics (IUGG), will in future allow the drawing of maps of these movements for various regions of the planet and enable an explanation to be given of many phenomena of the latest tectonics. It will also help improve the methods of seismic micro-classification in urban construction.

RECOMPUTATION OF GEODETIC DATA FOR FIRST- AND SECOND-ORDER NETWORK SYSTEMS IN IRAQ

Paper presented by Iraq[1]

The work of establishing GTS bench-marks and a geodetic network of triangulations in Iraq was completed in a short period of time.

The first-order triangulation consisting of a long chain of quadrilaterals aligned due south–north to cover the southern, central and part of the northern areas of Iraq was built mainly on three base-line measurements. One base is in the Basra region, the second is near Baghdad and the third is in the Kirkuk area. Their general lengths are 3 to 5 km. Two or three base extensions were added to coincide with the length of the sides of the quadrilaterals. The measurements of their bays and mean heights over MSL were made by the classical invar-wire and precise levelling methods and have since been adjusted and computed by least-square processes.

Astronomic determination for longitude and latitude and forward azimuth has been verified by sun and polar observations. Only in the case of the southern base were the results consistent with the required accuracy.

The accuracy obtained for measurements of base lines was 1:250,000 and 1:200,000, which was quite sufficient for major survey work. Yet because the general length of chains was too long for international specifications to connect the bases, the general accuracy of geodetic data obtained by geodetic stations was lowered beyond 1:100,000 and 1:75,000, respectively.

The method of figure adjustment considered most suitable for adjustment of observed angles was found wanting in many important respects regarding small error factors.

All measurements, whether obtained by various instruments or observations during different kinds of weather and at all periods, were reviewed in the construction of the necessary correlative normal equations for adjustment and computation of geodetic data. It seemed this was the only suitable method to minimize the effect of some of the large triangular errors which were accepted at that time as the mean of the eight zero readings determined by theodolites of the T3 type.

After adjustment of horizontal angles, the spherical formulae which had been used to compute sides, latitude and longitude and azimuth were "puissants" for short and medium lines for the Clarke spheroid determination of 1866. These spherical rectangular co-ordinates of TM (true mean) and Lambert conformal have been used for plotting and mapping.

In general a closing error in a single triangle of 3.5 seconds and a little more was accepted, and small systematic errors were disregarded and omitted from the adjustment process, such as the Laplace station determination for longitude and latitude. This was done in the southern area only, because the average length of sides was between 15 and 25 km. Since this is rather short, no attempt was made to correct sides for ET, chord-to-curve corrections. Almost all spheroidal excess corrections were neglected in adjusting the figures.

Later a successive figure computation manner was adopted, and no attempt at a base-to-base adjustment

[1] The original text of this paper appeared as document E/CONF. 57/L.127.

process was made to adjust the angles properly. Consequently, owing to a lack of understanding, many weak and inferior observations were introduced into the problem of strength of figure. Such error factors create many difficulties in computation and adjustment of second-order networks which are connected to two or more first-order sides.

More than 12 seconds of triangular closing error was accepted in secondary triangles, and a method of simple, equal shift adjustment of single figures was used to carry on the work. The horizon correction was dropped in adjusting polygons. An accuracy of side measurement of 1:50,000 was considered sufficient.

A shift of more than ±5 seconds in the azimuth of an intermediate base (adjacent base) was countered with one of ±3.5 seconds and ±5.60 seconds in latitude and longitude of the co-ordinates of that base. This was accepted and adjusted graphically or by a trial method of distribution to coincide with geodetic data for the adjacent areas.

By carefully studying the first- and second-order chains as well as the important sources of errors by readjusting the figures, the Survey Department of Iraq was able to determine the real factors affecting the refinement of accuracy. By starting from the beginning and considering all the observations, the Department could obtain better results for its geodetic data and eliminate many earlier mistakes.

The transformation of geographical co-ordinates to one unified projection of spherical–rectangular co-ordinates was adopted and UTM projection was selected with a factor scale reduction of −0.06 per cent on central meridians.

For computing the length of sides of triangles and their azimuths and the longitude and latitude of different stations, Clarke formulae for short and medium lines were used, and a Clarke spheroid of 1880 was considered.

In addition to what was mentioned in our national report, the new geodetic work in Iraq will have more than 200 quadrilaterals, more than 400 geodetic stations, 14 base-line measurements, 14 Laplace station determinations and mean heights of MSL for all such data. All GTS bench-marks and secondary ones are to be connected to our geodetic stations. Our MSL is to be recomputed accurately by the refined least-squares method from the results of more than thirty years of observations of the tide gauges.

The Department of Survey in Iraq is going to break the two very large first-order loops into not less than seven precise levelling loops to be observed properly by applying the most refined method of adjustments to fulfil the requirement of international specifications. An error not exceeding $\pm 4\sqrt{\text{km}}$ will be accepted.

THE ANALYSIS OF GEODETIC MEASUREMENTS

*Paper presented by the United Arab Republic** [1]*

The field circumstances under which geodetic measurements are made create a multiplicity of opportunities for errors to occur. The analysis of these errors is usually done in the classical style by the theory of errors, breaking the total error into an accidental component and a systematic component and quoting the "probable error" or "mean square error" of these components as indicators of quality.

The theory of errors is based on the (one-parameter) normal distribution function

$$f(x; 0, \sigma^2) = \frac{1}{\sigma\sqrt{2\pi}}\varepsilon - \frac{x^2}{2\sigma^2} \qquad (1)$$

derived by Gauss in 1809 from considerations of the errors of observations, setting out with the assumptions (*a*) that when several independent measures of an unknown quantity, all equally good, are given, the most probable value is their "arithmetic mean", and (*b*) that the best value sought has maximum probability density.

It follows directly from this that for a large number of observed values of a quantity M, the most probable value of the unknown would be obtained by making $\Sigma h_i x_i^2$ a minimum, h_i ($\propto 1/\sigma_i^2$) being the measure of precision of the observation M_i, and x_i the corresponding error. This principle, known as the "least-squares principle", was first applied by Gauss for the adjustment of the triangulation network of Hanover in 1823.

Since then geodesists followed Gauss in using the method of least squares for the adjustment of geodetic measurements and the normal distribution as representative of the errors of these observations. In geodetic literature errors are still classified as systematic and accidental. The probable error is still quoted to indicate the precision, and the result of any geodetic operation is still given in the form "estimated value ± three times the probable error or twice the standard error".

For n independent equally good measurements M_i of a single quantity $\bar{M}$, the estimated value is usually taken as the arithmetic mean $\bar{M} = (\sum M_i)/n$ and the standard error s is calculated according to the formula

$$s^2 = \frac{1}{n-1}\sum (M_i - \bar{M})^2$$

Assuming that the errors x_i of the corresponding measurements M_i are drawn from a normal population having the distribution function (*1*), the mean M of the measurement is normally distributed with mean M and standard deviation $\sigma/\sqrt{n}$. If σ^2 is unknown but can be estimated by s^2, then the quantity $(\bar{M}-M)/(s/\sqrt{n})$ is not normally distributed but has the t distribution.

As the number n in the sample increases, the t distribution tends to become of the normal type. In this case it is usual to supply an estimate of the precision of the quantity M by appending to its computed value twice the standard error, and this is sometimes said to imply a probability 0.95 that the true value lies in the range "computed value ± 1.96 × the standard error".

* Now Egypt.

[1] The original text of this paper, prepared by F. Z. A. Messih, Survey Department, Cairo, appeared as document E/CONF.57/L.131.

When the number in sample n is small, the sampling distribution is not normal, and the standard error is an insufficient indication of the interval within which the true value may lie. It is necessary in such cases to consult the t distribution tables for the adequate "confidence interval".

A closely related problem which often recurs in geodetic work is that of "outlying observations". In a set of n measurements values may occur which are far removed from the remaining values and a decision has to be taken whether to reject or accept such values. The usual procedure is to reject those values which are different from the mean by five times the probable error (or six times to be on the safe side). This, however, may lead to biased results, i.e. a rejected value may be valid or an accepted value may be invalid. It is possible in this case to use the "*chi*-square" test

$$\chi^2 = \frac{1}{\sigma^2} \sum (M_i - \bar{M})^2$$

as a criterion for rejecting a value or values which are far away from the mean, as such a test will give an indication of a large dispersion due to the extreme values. We may also use one of the "order statistics" tests

$$B_1 = \frac{M_{(n)} - \bar{M}}{\sigma},$$

$$B_2 = \frac{M_{(n)} - M_{(n-1)}}{\sigma} \text{ or } \frac{M_{(2)} - M_{(1)}}{\sigma}$$

where $M_{(1)}, M_{(2)}, \ldots, M_{(n)}$ $(M_r \leqslant M_{(s)}, r < s)$ is the same set of measurements when rearranged in order of magnitude. Such tests may give better results since particular attention is paid to the end item.

The same argument goes for one of the tests

$$C_1 = \frac{W}{\sigma}, \qquad C_2 = \frac{W}{S}$$

where $W = M_{(n)} - M_{(1)}$ is the range of the set of measurements.

AGENDA ITEM 9

Medium-scale and large-scale surveying and mapping

POSSIBILITIES OF HALF-TONE REPRODUCTION FOR PHOTOMAPS BY SILK-SCREEN PRINTING

Paper presented by the Federal Republic of Germany[1]

During the past several years, the silk-screen printing method, because of its economy, has been increasingly used for map preparation. According to the studies made by Schleicher[2] the costs of printing-forme production for four-colour offset, letterpress and silk-screen printing are in the proportion of 100:90:60. Only by increasing print runs does this ratio become less favourable for silk-screen printing, especially when an edition exceeds 3,000 copies.

Silk-screen printing has the following advantages:

(*a*) The expenses for the basic equipment are low in comparison with those for other processes;

(*b*) The preparation of printing formes is easy and economical;

(*c*) by the silk-screen procedure, colours can be printed very bright and opaque.

In topographic map production silk-screen printing has especially been applied to the reproduction of linear elements, although its application to the reproduction of half-tones has also increased. In this case silk-screen printing has been used for:

(*a*) Half-tone representation, as relief shading and photomaps;

(*b*) Representations of areas by uniform half-tone value: flat tones, in particular for elements of thematic maps;

(*c*) Reproduction of multicoloured continuous-tone originals by multicolour half-tone screening.

In comparison with conventional printing procedures, there is only limited experience in half-tone reproduction using silk-screen printing especially with regard to the ruling distances for screens applicable to the major part of topographic map printing, i.e. more than 30 lines per centimetre. As a result the reproduction research division of the Institut für Angewandte Geodäsie has been studying the possibilities of using half-tone silk-screen printing in topographic map production.

Silk-screen printing differs from the other printing processes by the following characteristics.

(*a*) The printing forme consists of a fabric covered by a stencil (fabric and stencil are tightly mounted on the screen frame);

(*b*) This printing forme has a space of about 5 mm above the paper to be printed on and only while actually printing is the printing forme pressed upon the print carrier by means of a squeegee;

(*c*) The actual printing procedure is done by a squeegee which squeezes the ink through the openings of the stencil on to the print carrier placed underneath. Thus the principle of silk-screen printing is mainly based on the following three uses of the squeegee: squeezing the ink through the openings of the stencil, removing the ink from the stencil and pressing the stencil on to the printing base and print carrier.

Outlined below are the factors of silk-screen printing which influence the quality of half-tone reproduction.

The squeegee

(*a*) Kind and hardness of the squeegee material, form and size of the sharpened edges;

(*b*) Kind of squeegee holder, the kind of force for impressing and the angle of the squeegee blade;

(*c*) Kind of movement of the squeegee across the stencil and its uniformity, as well as speed of the squeegee;

(*d*) Ratio of squeegee size and lift and shift to the fabric surface.

The fabric and the stencil

(*a*) Number of meshes and threads diameter of the fabric;

(*b*) Kind of stencil and thickness of coating;

(*c*) Parallel, rectangular or diagonal positioning of the stencil with respect to the fabric;

(*d*) Kind of screen-printing frame and stretching device for the fabric as well as the way of fastening the screen-printing frame to the printing machine.

Ink (especially the thickness of the ink coat applied)

(*a*) Composition (ingredients) of ink and its specific weight;

(*b*) Viscosity of screen printing ink and its rheological characteristics.

Print carrier

(*a*) Differences in quality of paper and other print carriers, e.g. as to surface finish, absorbing property, etc.;

(*b*) Dimensional stability of the print carrier during the printing process;

(*c*) Flatness properties of the stock to be printed on.

[1] The original text of this paper, prepared by H. Mühle, Institut für Angewandte Geodäsie, Frankfurt, appeared as document E/CONF. 57/L.4.

[2] K. Schleicher, *Der Siebdruck im Buch—und Offsetbetrieb*, Polygraph, 1952, No. 2, p. 25.

Skill of the printer

(*a*) Gaining exact parallel between screen, print carrier and printing base;

(*b*) Observation of the torsion tolerance of holding the printing frame, the squeegee, the printing base and the machine elements connected therewith, regulating the squeegee operations;

(*c*) Perfect lay of the print carrier on the printing base, observation of the accurate register between printing forme and stock to be printed on;

(*d*) Variation of the printing process by using additional ink and other printing mediums for different purposes (e.g. reducer), as well as of the working speed of squeezing.

The preparation of the screen-printing stencil, i.e. the printing forme, is most important and the following requirements must be met in its preparation:

(*a*) The openings of the stencil must have even borders in order to obtain a print with sharp-line elements;

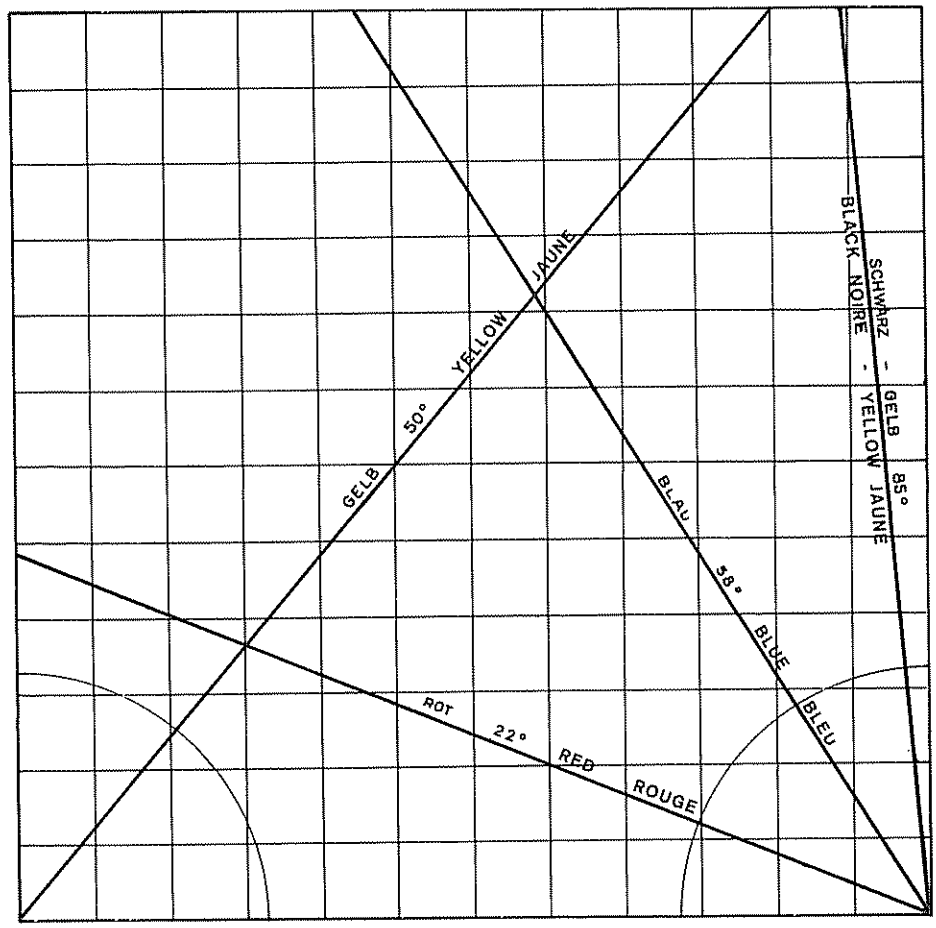
(*b*) The half-tone copy should be placed in an exact register (moiré-free) with the fabric;

(*c*) Preparation of a non-reversible half-tone transparency of a continuous-tone negative (this transparency already having the range of tonal values, which can be reproduced in half-tone screen printing with a particular ruling distance between screen lines).

Direct printing, i.e. the direct printing-down method, light exposing through the copy on to the fabric with the sensitized stencil coating, has proved unsuitable, whereas the indirect printing method (where the copy is first printed down on to a stencil coat-film of a pigment film, Ulano Poly X, which after development is impressed on to the fabric) shows better results for the required quality of sharp-lined half-tone dots in half-tone printing.

Nowadays a pigment film is available the stencil coat of which is already applied on to the screen fabric before exposure and contact printing is made directly on to the fabric with the stencil coat, so that dimensional instabilities are avoided in printing. For this procedure two preparations are used: the D-cote process of McGraw Colograph, United States of America, and the Comaline direct film of Messrs. Frankenthal, Federal Republic of Germany. A special problem in half-tone screen printing is the phenomenon of "moiré" which is feared in silk-screen printing very much since here two similar systems overlap, namely the half-tone screen and the fabric meshes, both producing the so-called "silk-screen moiré".

In order to avoid this moiré phenomenon, the use of a so-called "moiré tester" has proved advantageous in practice. This is an auxiliary tool developed by the "Schweiser Seidengazefabrik AG" in St. Gallen, Switzerland. By turning a circular fabric pattern on the screened printing copy, one determines the screen angle which shows no moiré. With the angle determined in this way, the transparency is later printed down on to the fabric of the screen-printing frame.



Screen angles for silk-screen printing

With multi-coloured half-tone printing one has to determine the appropriate screen angle for each colour separately, which avoids the colour moiré with the next colour, as well as the screen-printing moiré with the fabric of the screen-printing stencil.

While three-colour offset printing requires a standard angle of 0° for yellow, 30° for red and 60° for blue, silk-screen printing often requires other screen angles for the different colours with respect to each other.

Tests in three-colour silk-screen printing with the hand squeegee process have shown that the best printing results have been obtained with the following screen angles (starting from the bottom line of the picture): red, 22°; blue, 58°; yellow, 85°. With four-colour printings, however, the angle of 85° left for yellow, has been used for black, and for yellow we have applied an angle in the opposite direction of 50° to the right (see the figure).

In practice, however, one has to work mostly with already screened copies resulting from offset printing. Therefore we have also made tests with half-tones copies having offset screen angles for printing of air photographs.

For silk-screen printing we have used a colour air photograph, measuring 18 × 24 cm, to prepare screen-printing stencils by the indirect method on nylon fabric (180 threads per centimetre) by means of colour separation for blue, red and yellow. In this case we have applied the following angles: blue, 75° left; red, 75° right; yellow, 90° centre. With the small picture size no moiré has appeared.

The reproduction of tonal values in half-tone silk-screen printing is of optimal quality, when art (coated) paper is used, as the test results show in the table. With this printing test a screen half-tone step wedge with nine increasing gradation steps of tonal values (the difference of density between the steps being 10 per cent) has been printed with different ruling distances between screen lines. Then the reflection density value has been measured on the print, in order to show the difference in tone values with respect to the original.

Based upon the values resulting from the evaluation of our tests the following are the most significant details:

1. The squeegees, in combination with the counter-pressure exerted by the base plate of a silk-screen flat-bed press, is the most important requisite, for the squeegee performs the actual printing process by squeezing the ink through the fabric and the stencil. For this reason the squeegee must never to be too hard, since the irregularities of the material to be printed or those of the base plate have to be compensated. A "make-ready" as performed in letterpress or offset printing is almost impossible with silk-screen printing procedures. On the other hand a hard squeegee would be advantageous for obtaining a sharp print as required to reproduce the screen dots exactly. To obtain the best printing results the blade of the squeegee should be made of relatively soft resilient plastic material and have absolutely straight sharp edges without any burrs. In addition, the flexibility of the squeegee blade is influenced by the width of the blade, which is clamped more or less deeply in the holder so that the working part of the blade is free and flexible. Our experience has shown that the best suited material is polyurethane plastic, but it nevertheless has one disadvantage since nicks on the edges of the blade may easily occur.

Range of tonal values in half-tone silk-screen printing. Comparison of density reproduction at different distances between screen lines using art paper (100 g)

Values of screen stepped wedge quoin (per cent)	*Ruling distances between screen lines Density values in percentages*					
	13	*20*	*30*	*40*	*48*	*54*
90	81	84	87	89	93	92
80	73	74	79	80	88	87
70	60	64	68	75	80	80
60	52	54	58	62	73	73
50	44	45	48	41	46	49
40	33	34	34	32	36	45
30	23	24	24	23	29	33
20	10	12	9	11	14	14
10	4	3	—	—	—	—

In order to achieve the best results of the silk-screen process applied to the printing of continuous-tone photomaps by screen elements, the various stages of the printing operations must be performed with optimal experience in the process. Only in this way is it possible to obtain exact and uniform results, especially a "perfect register". These interactions not only refer to the "one-man squeegee" and to the "printing base" but also to the fine adjustment of the pressure on the squeegee. An insufficient pressure will cause a defective print and will make the ink on the screen stencil dry too quickly, while too great a pressure will spread the ink and spoil the stencil.

2. In the silk-screen printing of photomaps the fabric and the stencil are of essential importance for the quality of the density range of screened half-tone elements. The various fabrics to be used for the printing of screened elements of aerial photomaps must be produced with the greatest weaving accuracy possible and with utmost dimensional stability. In order to accomplish a perfect reproduction of the continuous-tone values for screen elements of the photomap, the fabrics must have four times as many threads per centimetre than the number of lines shown by the screen system. In order to obtain a reasonable contrast range on the photomap for visual perception by the map reader, we have to use at least a screen showing 48 to 54 lines per centimetre. With these considerations we have reached the crux of the problem of using silk-screen printing for photomap reproduction with screen elements. The only materials which possess sufficient dimensional stability to be used as fabrics for the large-sized photomaps are polyester and steel. The fabrics made from these materials contain only a maximum of 140 threads per centimetre, which does not allow silk-screen printing with screens having 48 to 54 lines per centimetre. On the other hand, nylon is the material which can be woven with 180 threads per centimetre to print the 48 screen but nylon does not have the required dimensional stability for photomap sizes ranging from 40 to 60 or 60 to 80 cm. Nylon keeps a good register only up to a maximum size of approximately 20 × 20 cm. Our experience has proved that there are more difficulties in working with steel than in working with polyester fabrics for silk-screen printing. The possibilities of printing finer screens by the silk-screen process for topographic map sizes could be improved when fabric producers succeed in creating polyester fabrics containing 180 threads per centimetre. This progress in fabric production would then match the requirements for screen-printing with ruling distances between screen lines ranging from 48 to 54 lines per centimetre to be used in photomap half-tone reproduction. At present it will only be possible to print

single-colour screens as a continuous-tone photomap element in normal map size, when the screen colour is printed as first "colour run", and when the register of the following stencils (with the line elements in the other colours) is adjusted to the register marks of the first screen colour print. Screen stencil for three or four colours should only be used in small-size printing, as given by single air photographs (18 × 24 cm).

ORTHOPHOTOGRAPHY AND MAP REVISION

Paper presented by the Federal Republic of Germany[1]

The rapid transformation of the landscape has again created considerable pressure for map revision and thus on topography and cartography. The situation has been considerably aggravated by the fact that the use of maps and the requirement for constant revision can hardly accept compromises. In areas where considerable development is taking place, out-of-date maps are an obstacle to all forms of planning. The demands caused by the old map situation and the new map requirements have led to experimentation with new technical procedures. Amongst these, orthophotography promises the greatest success. The production of orthophotographs with suitable equipment can be mechanized to a great extent and even automated. On each orthophoto the planimetry of four features (hydrography, vegetation, settlement and communication system) are included, and these are the features which are generally most affected by revision. Not only can plotting be carried out extremely rationally but optimum solutions are also offered for revision. On the one hand, the orthophotographs can be reproduced in any required working scale in which revision could best be carried out and, on the other hand, their rapid and inexpensive reproduction makes it possible to produce as many copies as are required for each revision project. It is then possible to engage several people at the same time in the revision of a map and to divide up the work both vertically and horizontally by splitting up the orthophoto by means of enlargements. The orthophoto offers considerable advantages for topographical projects as well as for cartographic work. The planimetric fidelity of the picture gives not only a reliable view of the whole revision necessary and an exact idea of the details to be revised but it is also possible to use the orthophoto directly as a basis for plotting supplementary topographic surveys. The orthophoto is therefore an ideal basis for revision which, with the intention of making the important features of transformation of the landscape visible on the map, is designed to be orientated according to topographic and cartographic needs. Gradual revision related to such needs can hardly be avoided any longer since it is required that map series be corrected two to four times as often as before, especially since the topographic importance of the individual groups of features has changed considerably in relation to previous requirements from the point of view of map use and is concentrated in areas with considerable development. In whatever way revision is carried out, its success depends primarily on the quality of the photographic material, on the picture and on the contrast sharpness of the orthophotos. The quality of the orthophotos is generally limited by the scale of the photo or the altitude. The larger the scale the better the interpretation results. On the other hand, time for the production of orthophotos will be reduced where fewer models have to be evaluated, that is to say, smaller scale photography. Corresponding tests were carried out in the spring of 1968 to determine this correlation, as well as suitable photographic qualities.

Producing orthophotos

A photographic flight for six sheets (6 ft × 12 ft) of the 1:25,000 topographic map of the Stuttgart area was prepared. A scale of 1:10,000 was laid down for the orthophotos and each orthophoto covered one quarter of a sheet of the 1:25,000 topographic map. The scale was large enough to permit the recognition of sufficient detail in the orthophoto whilst the estimated time required for evaluation of eight models for one sheet of the 1:25,000 topographic map was acceptable. Taking into account the parameters of the equipment of the RMK 15/23 wide-angle chamber and of the GZ 1 orthoprojector, 1:34,000 was found to be a suitable image scale. The control points necessary for planimetric and altimetric adjustment were taken from the 1:2,500 topographic basic map series without beaconing or other external operations. Although survey work of the area in question was carried out about seventy years ago and is thus one of the oldest in the country, it is still possible to find in the aerial photograph sufficient identifiable unchanged points, particularly road crossings and road forks. The orthophotos were made with a Zeiss GZ 1 orthoprojector set up in June 1968 which was coupled direct to a C8 stereo planigraph. A transparency was inserted in the frame of the orthoprojector which produced orthoprojection and thus a negative on Cronar Commercial S film. The model scale in the stereo planigraph was 1:20,000, the unrolling speed in the orthoprojector was 5 mm per second and the diaphragm width four metres. Profile hachuring was not carried out as the contours of the six map sheets were accurate enough and could hardly be revised.

Revision project drawings for the 1:25,000 topographic map

Othophotos can assist in the revision of a map in various ways. The simplest solution technically, but cartographically the most thorough, would be to remove altered areas from the linear layout and to replace them with corresponding sections from the orthophoto. This procedure is questionable, even though expedient, because of the almost insurmountable divergence between images and the impossibility of compiling continuous tone photographs. Because of orthophoto's unsuitability for linear and planimetric plotting of various types, the lack of commentary extending to all features and groups of features equally and the small possibility for compiling the photographic image by manipulating graphic emphasis and by varying by means of extracts from groups of features, any hopes of considering it as any sort of substitute for traditional maps must be abandoned in those fields where map utilization has already crossed the line

[1] The original text of this paper prepared by W. Beck and E. Strobel, Land Survey Office of Baden-Württemberg, Federal Republic of Germany, appeared as document E/CONF.57/L.5.

between initial demand with predominantly quantitative emphasis and modern primarily qualitative requirements. Accordingly, the transformation of the continuous tone photo into a linear image or linear extraction of the portions of the feature image to be revised from the orthophoto is unavoidable. It can only be examined to determine whether these modifications can be carried out manually or mechanically. Whatever success is obtained from experiments in mechanical solutions, the prospects are nevertheless slight for obtaining approximately uniform and satisfactory results under varying conditions. Thus the manual method was selected using a procedure where the transparent orthophoto was placed on the light table under a transparent blueprint of the corresponding map to be revised. Features to be corrected in the map are traced in black on the transparency of the map at the same time as compilation and local adjustment. The results of this cartographic transcription depends on the degree of interpretation. Many opportunities seem to exist which favour these cartographic drawing operations, such as provisional linear marking of the features to be revised on the transparency or another copy of the orthophoto, colour copying of the map on to it, or operations carried out on both the orthophotographic and cartographic original connected with suitable reproductive connexion. The attempt to print the map directly on to the orthophoto has not contributed to simplifying the revision of the various features nor to speeding up the procedure. Particular importance is attached to the scale on which the revision project drawings are prepared on the basis of the orthophoto. It has been found that even a scale of 1:10,000 was too small for the operation in question. After the revised originals have been drawn for one sheet of the 1:25,000 topographic map on the basis of orthophoto enlargements on a scale of 1:5,000, an orthophoto enlargement (transparency) is made on a scale of 1:7,500 and an enlarged blueprint on the same scale of the old issue map is made on Pokalon. The two sheets are superimposed and aligned on a light table and then the alterations are traced on to the blueprint. Where necessary, compilations are carried out, substituting other symbols and making connexions to the unaltered features. Alterations which cannot be established with sufficient certainty are noted on prints of the orthophoto for reconnaissance, these are as follows:

(*a*) Alterations to the annotations which an orthophoto cannot contain, e.g. names or places, frontiers, numbers of arterial roads, information for certain legends;

(*b*) Alterations of the planimetry of areas hidden by adjoining features as a result of the central perspective properties of the aerial photograph, those features which are overshadowed by adjoining features and cannot be recognized and those features which are visible in the orthophoto but cannot be distinguished with sufficient certainty or are prone to false interpretation.

The alterations in the first group can as a rule be taken from existing documents. The alterations in the second group will necessitate reconnaissance in the field. In the case of the sheet in question, 263 alterations of widely varying scope were noted. Examination showed that 3 per cent were attributable to obscured areas, 12 per cent to shadows (the height of the sun at the time of the photographic flight was approximately 42°) and 85 per cent to visible features which could not be interpreted with a sufficient degree of certainty. The difficulties in interpretation are therefore predominantly responsible for field reconnaissance. Large obscured areas should always be field checked otherwise important alterations may go undetected. For example, various buildings, road and hydrographic alterations were not visible in a narrow valley with wooded slopes and railways. New industrial lines could not be determined from the orthophoto. The removal of a length of railway line whose bed is now used as a road was also not recognizable in the orthophoto. Documents for field reconnaissance will consist primarily of prints from the orthophotos in which the features to be photographed are marked in crayon, as well as photocopies of the revision originals and prints of the old maps. During the field checking, measurement is only rarely necessary because as a rule the contours are present on the orthophoto and it is only the contents of the photo that have to be clarified. The results of the field reconnaissance are then entered on to the revision originals.

Conclusions

Considerable difficulties in the preparation of revision originals for the 1:25,000 topographic map based on orthophotos are caused by interpretation, i.e. by the recognition and the correct interpretation of the topographic changes in the orthophoto. Under the conditions in question the working scale of 1:10,000 had been found too small so that enlargements of the orthophotos to a scale of 1:7,500 are necessary.

On the basis of this experience the Baden-Württemberg Survey Office had two photographic flights carried out on a scale of 1:22,500. From these aerial photos it was possible to make 1:7,500 orthophotos. The number of models here rises from eight to eighteen for each 1:25,000 topographic map. These additional models are acceptable because the improved picture quality of these orthophotos facilitate interpretation and probably reduce the over-all time involved. There are some further correction proposals to be tried, e.g. the use of colour orthophotos which may facilitate interpretations even further. Consideration should be given to having a brief reconnaissance carried out before the preparation of the revision originals. By using a motor vehicle for a period of one to two days for one sheet of the 1:25,000 topographic map at least the classification of the roads could be established. The orthophotos made for map revision are also available for other purposes. As considerable time elapses before using a revised map, the orthophotos can be used as a supplement to the old map.

In conclusion, the Land Survey Office of Baden-Württemberg has been correcting the planimetry of the 1:25,000 topographic map since 1968 with the aid of orthophotos. According to the nature and extent of the alterations, orthophoto transparencies are made on a scale of 1:7,500 or 1:10,000. A reproduction of the content of the old map in blue on a transparent sheet (revision original) is placed on a light table with the orthophoto transparency. New detail to be recorded is traced on to the revision original in black Chinese ink and features to be deleted are painted out in white. Topographic features which cannot be discerned with certainty in the orthophoto are noted on a print of the orthophoto, field reconnaissance is carried out on such features and then they are entered on the revision original. The advantage of this procedure is that it permits considerable time saving in photogrammetric plotting.

THE PRODUCTION OF PHOTOMAPS

Paper presented by the Federal Republic of Germany[1]

There are significant differences between an aerial photograph and a conventional map, even though an aerial photograph taken at a low elevation from the ground nadir may be similar to a map covering the same area. The aerial photograph is obtained according to the laws of optics on a central projection. It depicts all the ground details visible from the camera station at the moment of exposure: significant and insignificant ground features, permanent and temporary objects. On a conventional line map, however, unimportant details are suppressed and important features enhanced. Normally, maps represent permanent features only. Depiction of ground detail on aerial photographs is restricted to the tonal range of grey shades. To date, colour aerial photography has not succeeded in making headway. The conventional map consists of sets of symbols, dots, lines, areas and colours and is therefore much more explicit and selective in content than the aerial photograph. Owing to the photographic central projection of aerial photographs, points and ground objects depicted are unavoidably displaced from their true positions. These image displacements will increase with the amount of relief, with greater distances from the principal point and with decreasing focal length. The image displacements due to tilt and relief do not permit other map details, such as contour lines, to be properly plotted on the various image portions over the whole area of the photograph.

THE ORTHOPHOTO TECHNIQUE

In recent years many attempts have been made to eliminate image displacements due to differences in ground elevation. The "zone-by-zone" rectification method where the terrain is divided into small band-shaped zones along given contour lines, the polyhedron method using most contiguous, irregular polyhedrons replacing the terrain and the facet method have been used. All these methods were difficult to employ and time consuming and gave only approximations. There was no satisfactory solution to the problem of eliminating the displacement due to relief until the advent of the modern differential rectification methods providing the aerial photograph with the geometrical properties of a map.[2] Differential rectification is done by scanning a stereoscopic model in a meandering pattern on the stereoplotter. The floating mark is required to scan the model in a continuous fashion. With some orthophotosystems, motion of the floating mark is controlled by the operator of the instrument by means of a handwheel. With other instruments it is controlled fully automatically by electronic correlation. All motions of the floating mark, to include the Z, or elevation, motion are transmitted to another instrument called the "differential rectifier". The differential rectifier may either be directly connected to the stereoplotter or may be combined with a storage and display unit, the latter method offering both technical and economical advantages. In both methods the distance between the photograph to be rectified and the projection plane (projection distance) is automatically so adjusted to a small image area that no parallactic displacements will occur. At the same time the image information within the minute area elements is successively projected on the recording film on which the "orthophoto" providing continuity of imagery and scale is produced. By this method one of the most significant disadvantages of conventional aerial photographs has been overcome. Today, aerial photography has found completely new applications for given scale groups because the abundance of detail depicted on aerial photographs is now supported by the geometrical properties inherent in conventional maps. This quality permits the aerial photograph that is rectified by the methods described above to be used for a much wider variety of purposes than ever before.

RECTIFICATION BY STANDARD METHODS AND ORTHOPHOTO COMPILATION

It is evident that there are no image displacements due to relief when level terrain is depicted on aerial photographs. When the maximum permissible image displacements due to relief that are acceptable for the final scale at the margins of photographs are predetermined, e.g. 1 mm, it will be most simple to determine the amount of relief allowable to perform rectification by standard methods and the amount of relief requiring differential rectification in order to ensure that relief displacements occurring at the margins will not exceed the predetermined value. This value, however, is not only dependent upon the differences in elevation of the terrain photographed, but also upon the size of the photograph and the focal length of the lens system in the aerial camera used. When using photographs at the common size of 23×23 cm, the horizontal displacement of features from their true position will not exceed 1 mm at the final scale of 1:10,000, if the amount of relief in the sheet area and in the easily plotable portion of the photographic image does not exceed 24 m and if a 30 cm focal length lens is used. Therefore, the ground area to be photographed will be divided wherever possible into areas of nearly flat terrain, for which the photos will be taken with an aerial camera provided with a long focal-length lens system and rectified individually as a whole by standard methods and areas for which the photos will have to be taken with a wide-angle lens camera and rectified by the differential methods to produce orthophotos. If these aspects are considered in dividing the terrain and in taking and rectifying the photographs, it will no longer be necessary to distinguish between photos rectified by standard methods and orthophotos, because both of them exhibit the same geometrical properties as provided by a conventional map. Photographs rectified in this way, to which cartographic symbolization, names and marginal information comparable to that of conventional maps are added, should inclusively be referred to as "photomaps", regardless of the method employed in producing them. This would eliminate the terms "photographs rectified by standard methods" (*Einzelentzerrung*) and "orthophotographs", which refer to the production technique employed. The common user of these "photomaps" will be little interested in the method

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[1] The original text of this paper, prepared by Georg Krauss, Federal Institute for Topography and Topographic Research, Bad Godesberg, appeared as document E/CONF.57/L.7.

[2] K. Schwidefsky, *Die Orthophotokarte und die Entzerrungsverfahren für unebenes Gelände*, Bildmessung und Luftbildwesen, 1965, pp. 143–156.

of production, particularly as he is not too familiar with these designations. Knowing the properties of the final product is, therefore, of fundamental importance to him. If the term "photomap" is used, the product concerned should however possess the geometrical properties provided by a conventional map on orthogonal projection. In the Federal Land of Nordrhein-Westfalen a photomap on the scale of 1:5,000 will become part of the *Deutsche Grundkartenwerk* (German basic map series) on the same scale.[3] The former 1:5,000 controlled photomosaics compiled from rectified image portions of photographs will continue to be produced in small numbers. About 45 per cent of the area of Nordrhein-Westfalen can be covered by 1:5,000 photomaps produced from only one photograph rectified by standard methods as described above. Since in some of these areas vertical control is intended to be established by photogrammetric methods, additional photographs will be taken of these areas with a wide-angle camera. It is planned to have all gaps in the German 1:5,000 basic map series filled up by the *Luftbildkarte* 1:5,000 (1:5,000 photomap) in the near future. Furthermore, these 1:5,000 photomaps will replace the present 1:5,000 controlled photomosaics which were assembled from portions of rectified aerial photographs. In many cases these photomaps will serve as map supplements like the controlled mosaics did, the main difference being that the photomap retains the wealth of photographic imagery available on the original photograph and, most significantly, has the metric quality of the conventional line map. In order to be able to predetermine aerial surveying and mapping requirements and working procedure the sheets of the basic map of Germany covering Nordrhein-Westfalen have been classified into the following three categories:

(*a*) 3,600 sheets showing differences in elevation of less than 10 m (about 42 per cent);

(*b*) 1,800 sheets showing differences in elevation from 10 to not more than 35 m (21 per cent);

(*c*) 3,240 sheets showing differences in elevation of more than 35 m (37 per cent).

The most efficient and economical method of producing the 3,600 sheets of the first category will be to photograph the terrain with a normal-angle lens camera (f:30 cm) and to complete rectification of one photo for one sheet by the standard method. However, this method will not suffice where exact plotting of elevations is required. Production of the 3,240 sheets in the third category will require photographs taken with wide-angle lens cameras (f:15 cm) and processed by orthophoto techniques. These photographs may also be used for precise stereoplotting of vertical control unless presentation of relief is achieved automatically by orthophoto techniques. The decision as to which of the two methods is to be applied in compiling the remaining 1,800 sheets will depend upon the area involved.

The photographic scale

In the introduction to this paper the similarities and differences between an aerial photograph and a conventional line map were pointed out. Normally the value of photo-intelligence characteristics of aerial photographs will deteriorate rapidly as the flight altitude increases, i.e. with the decrease in scale. The scale of the aerial photographs and of the photomaps compiled from them will largely depend upon the landscape involved. For example, aerial photographs on scales 1:50,000 and smaller covering a uniformly natural landscape may be expected to provide adequate information whereas the scale of a photograph of a densely populated built-up landscape must necessarily be larger. The photomaps in current use range in scale from 1:1,000 to 1:100,000 and smaller. Extremely large scales are disadvantageous in that the perspective displacements of elevated features such as buildings, high bridges, forests etc., are clearly recognizable, thus impeding usefulness. Such displacements cannot be removed by orthophotoscopic rectification, but even at a scale as large as 1:5,000 they are hardly recognizable any more. For many purposes photomaps ranging in scale from 1:5,000 to 1:15,000 are superior to conventional line maps because they provide a great amount and variety of information and are readily interpretable. At these scales, cartographic elements other than marginal information, names, contour lines and road classification should be kept to a minimum in order to facilitate reproduction, maintenance and revision. This procedure will permit the photomaps to retain the primary characteristics of aerial photographs. Smaller scales, even on the scale 1:25,000, require that the aerial photographs be interpreted at the office and by special overprints the most essential map detail such as roads, buildings or forests could be made distinguishable and more clearly identifiable. Thus, with decreasing scale the photomaps become more and more similar in appearance to the standard topographic maps. In countries not yet or only partially covered by topographic maps the use of small-scale photomaps may prove successful because they can be produced more rapidly than the standard line-drawn maps.[4] Large-scale photomaps will certainly be increasingly produced, both in countries not yet covered by large-scale line maps and in countries already mapped at these scales. The photomap will eventually be the substitute for the controlled mosaic in current use. It is quite conceivable that photomaps of a given scale group (e.g. 1:5,000 to 1:25,000) may be required and used in addition to standard topographic maps. They are apt to substantiate the line maps with regard to special information such as type of forests, land use etc. and would facilitate map maintenance and revision activities.

Photographic flight planning

In planning photographic flight missions for mapping purposes the photographic requirements shall be adapted whenever possible to the map scale and sheet size in such a manner that the number of models required for orthophotoscopic processing or the number of single photographs required for rectification by standard methods is kept to a minimum.

Figure I shows an optimal flight design. The line of flight should follow the centre line of the individual map sheets (generally east–west direction or north–south direction). Exposures should be made in consecutive sequence so that successive pictures are obtained, each of which overlaps the photograph preceding it and the photograph

[3] F. Vob, *Die Herstellung von Orthophotokarten in Nordrhein-Westfalen*, Bildessung und Luftbildwesen, 1968, pp. 3–13.

[4] W. Radlinski, *Orthophotomaps v. Conventional Maps*, International Symposium on Photomaps and Orthophotomaps, Ottawa, 1967, pp. 118–122.

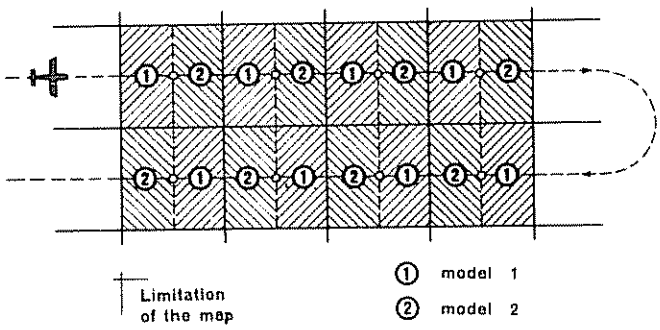


Figure I. Photographic flight design

following it so that an unbroken coverage of the area is obtained. The amount of overlap should preferably be 90 per cent. This permits the photographs to be selected to suit the sheet size. If orthophotoscopic methods are employed, three photos forming two models are required for each sheet, while in conventional rectification a single photograph is needed. In either case, the two models or the single photograph provide full coverage of the area represented by the map sheet. This flight design will for instance meet the requirements for coverage of areas mapped on sheets at a size of 40×40 cm or 50×50 cm and for map scales of 1:5,000 and 1:10,000. For other map scales and sheet sizes it may be necessary to take three flight runs to cover two adjacent map sheets.

The table illustrates photographic flight requirements for photographs suitable for scales of 1:5,000 and 1:10,000. The enlargement ratio selected for scale changes is between 1:2.6 to 1:4.1, as is required for the Gigas-Zeiss orthoprojector. As optimum conditions cannot always be achieved, photographic scale and flight design also depend upon the operating ceiling of the aircraft available and upon prevailing weather conditions.

Control points and their determination

Compilation of photomaps requires the existence of control points (pass-points) whose horizontal and vertical positions are defined by space co-ordinates in the national co-ordinate system, in order to ensure that the conventionally rectified photographs and/or the photogrammetric models may be adjusted to the geodetic system in use and, consequently, to the given sheet lines. These control points may either be points marked on the ground by survey signals or natural features clearly identifiable on the aerial photograph or even "construed points" formed by a small disc cut from the photographic emulsion on the transparency. The number of photogrammetric control points to be established and the degree of accuracy to be obtained will vary with the flight design and, in a large measure, with subsequent work proceedings. As a general principle, the control points should preferably be located in the corners of the photographs or models. This requirement will not only ensure sufficient accuracy, but also reduce the number of points required, as control points selected in this way may be used for adjacent photographs or models because of the forward and side laps. The accuracy to be obtained in determining the horizontal co-ordinates of these control points is not required to be

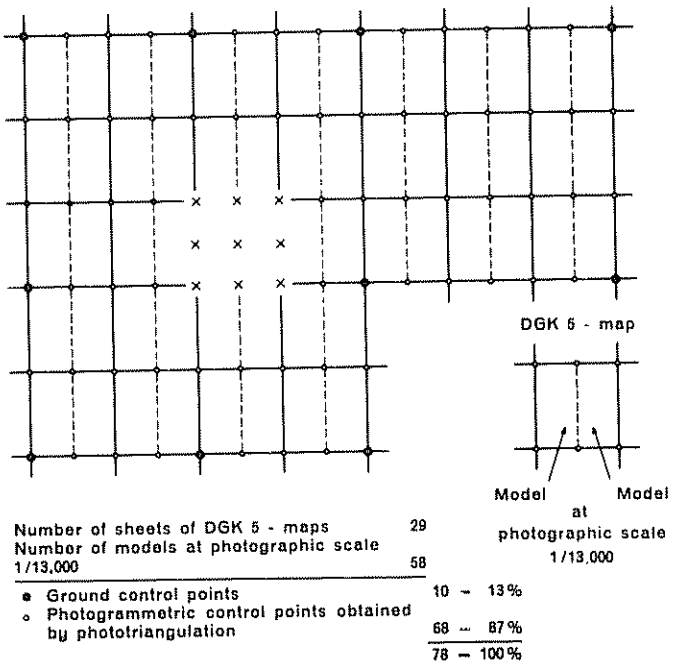


Figure II. Determination of control points in the production of the basic map of Germany (photomap) 1:5,000 by phototriangulation and block adjustment

Photographic flight data

Exposure data	*Map scale m_K = 1/5,000*		*Map scale m_K = 1/10,000*		
				Conventional rectification of single photographs	
	Ortho-projection	*Conventional rectification of single photographs*	*Ortho-projection*	*1 run = 1 map strip*	*3 runs = 2 map strips*
Focal length	15 cm	30 cm	15 cm	30 cm	30 cm
Size of photograph	23×23 cm	23×23 cm	23×23 cm	23×23 cm	23×23 cm
Photographic scale m_B	1/13,000	1/12,000	1/26,000	1/22,000	1/15,000
Width of flight run	2.95 km	2.76 km	6.0 km	5.6 km	3.45 km
Width of map strip	2.0 km	2.0 km	4.0 km	4.0 km	2.67 km
Side lap	32%	27%	33%	21%	23%
Flight altitude	1,950 m	3,600 m	3,900 m	6,600 m	4,500 m
$m_B:m_K$	1:2.6	—	1:2.6	—	—

better than the planimetric accuracy of the map at comparative scale, i.e. for the scale of 1:5,000 a planimetric accuracy of 0.50 to 1.0 m will be acceptable. To rectify a single photograph by standard methods, i.e. for one map sheet, the horizontal co-ordinates of at least three, or better, four control points will be required. In producing orthophotographs, i.e. orthophoto maps of undulating terrain, vertical co-ordinates are required in addition to the horizontal co-ordinates, in order to permit spatial orientation of the various models. This orientation requires at least three properly selected vertical control points. In general, a surplus of two or three photogrammetric control points will be established in order to ensure maximum accuracy in bridging. If only orthophoto maps are to be produced, relief accuracy is generally not required to be any better than that provided by line-drawn maps at comparative scales. However, production of orthophoto maps usually entails plotting of elevations and contours. This may nowadays be achieved by modern instruments without a tremendous amount of extra work. The automatic contouring device[5] developed by the Zeiss Company at Oberkochen as an accessory unit to the Gigas-Zeiss orthoprojector appears to be particularly well suited for this purpose. Where a relatively high degree of vertical accuracy is desired, vertical control is to be established at least to the accuracy attainable by the plotting instrument, i.e. to the utmost vertical accuracy to which the instrument can be adjusted for the model scale concerned. In compiling the 1:5,000 photomap of Germany, aerial photographs are being taken at the scale of 1:13,000. The stereoscopic model will be prepared at the scale of 1:10,000 for transfer of image information to the orthophoto. In this case the standard deviation from their true positions of vertical control points that are clearly identifiable, i.e. to which the instrument can be accurately adjusted, will be m h: ±0.18 m. The vertical control points used for plotting elevations at the scale of 1:5,000 should therefore be determined to a somewhat higher accuracy of 0.10 to 0.15 m. It is not necessary to determine positions and elevations of control points by ground surveys. In many cases the co-ordinates may be obtained from existing documents. The use of phototriangulation combined with block adjustment has proved to be a great aid in the establishment of control. The pattern of, and the method employed in establishing control for the compilation of the German 1:5,000 photomaps is illustrated for a small block in figure II.

[5] K. Fölle and W. Rösel, *Automatische Erzeugung von Höhenschichtlinien bei der Herstellung von Orthophotos*, Bildmessung and Luftbildwesen, 1969, pp. 227–234

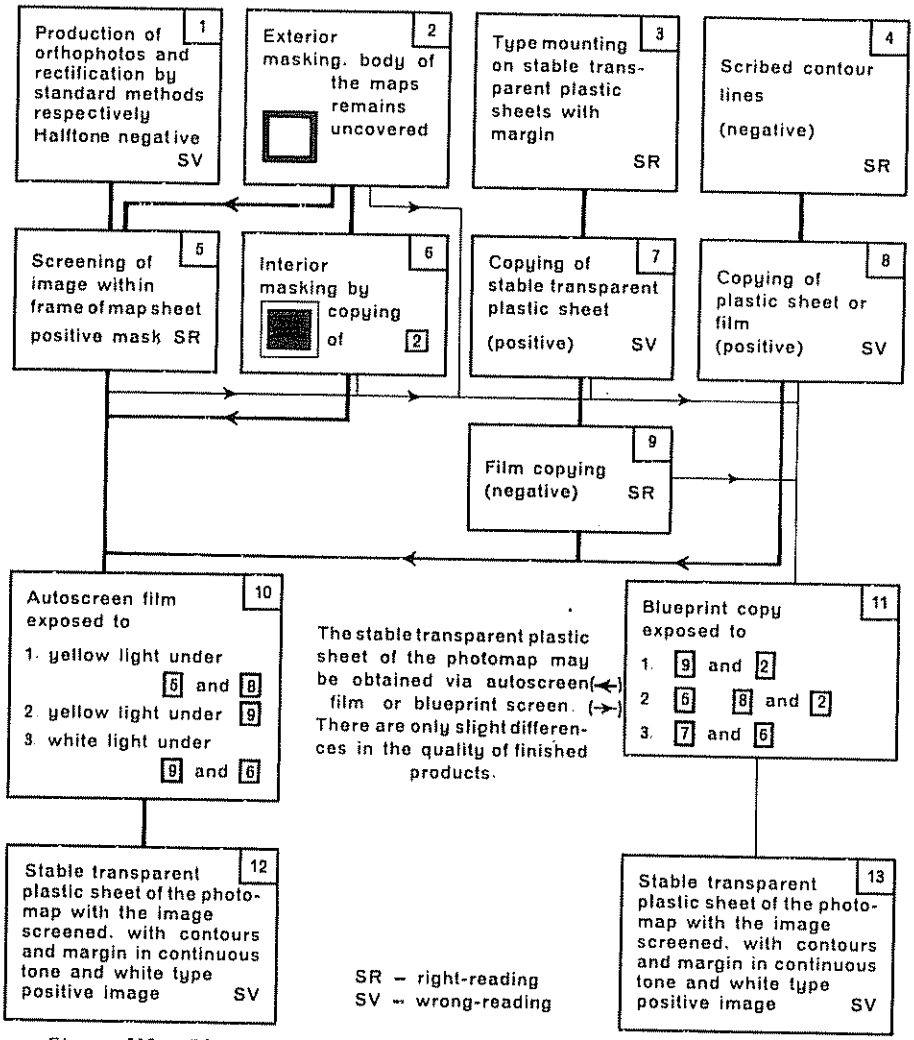


Figure III. Photomechanical steps for producing large-scale photomaps



Figure IV.
Conventional line map at 1:5,000



Figure V. Photomap at 1 : 5,000

It is intended to determine the vertical position of control points by ground surveys, because the contour lines to be obtained are required to be most accurate. Where a lesser degree of accuracy will be acceptable, extension of vertical control may be completed by phototriangulation.

Reproduction of photomaps

The photomap is composed of a half-tone image, marginal information, names and—depending upon the result desired—additional colour separation plates.

It was recommended that the photographic characteristics should preferably be retained for large scales and cartographic assistance, including additional colour separation drafting, should only be rendered to the extent required.

Figure III is a flow diagram showing the photomechanical steps for a 1:5,000 photomap with the contour lines superimposed. The result of this process is a wrong-reading stable transparent plastic sheet from which "blueprint" copies may readily be drawn, because so large a scale usually does not justify printing. Blueprints are hardly inferior in quality to photographic prints, especially when using contrast paper. If ground changes have occurred in the area represented on the photomap and the photomap is required to be revised, the stable transparent plastic sheet containing the image is replaced. Work process involved may be essentially facilitated if the profile scanning process of the first orthophotoscopic rectification is stored. These terrain profiles may be used again when the new flights are designed. While exposing the new orthophotographs[6] the orthoprojector is automatically steered by a display unit in accordance with the previous scan pattern. The second transparent sheet containing marginal data, names and contour lines usually does not need to be revised so that there will be little drawing to be done in maintaining and revising photomaps. Figures IV and V illustrate the comparison of a conventional 1:5,000 line map with a 1:5,000 photomap of an identical area. In the very near future, colour films and colour photographs will be specially employed in the production of photomaps, despite several initial complications. Colour photography will certainly enhance the photo-intelligence characteristics of the photomap. The colour prints will be produced not only by photomechanical copying methods but also by copying processes not based on halides. The use of colour films appears to be especially promising for medium scales, e.g. 1:25,000 and 1:50,000. To date, no experience has been obtained in the Federal Republic of Germany in the compilation of photomaps at these or even smaller scales. The orthophoto will continue to provide the basis from which to compile photomaps even at these scales, the only difference being that some of the photographic imagery will have to be enhanced while some other is removed. Additional colour separation plates will have to be drawn. These photomaps will have to be reproduced by lithographic printing methods. In the United States the pictochrome process has been widely employed to produce photomaps.[7] Using the Klimsch-Variomat ("*Strichstärkenwandler*") an accessory devised for line variation and elimination of moiré, Koeman and Schweissthal[8] have tried to convert the continuous-tone (black–white) photographic imagery to minute random dot patterns suitable for lithographic printing and to obtain the most significant outlines on a separate printing base. Experiments are being made for the same purpose with the "equal-density" film (*Aquidensitenfilm*) developed by the Agfa-Gevaert Company. Though results of latest developmental work along these lines have not been completely satisfactory so far, procedures and techniques will be improved within the next few years and colour films will increasingly be used in the future. As a result, the time-consuming colour separation drafting will be reduced and the final products improved.

Photomaps and conventional line maps

The photomap will be further developed in the future. In many parts of the world it will be produced at various scales because at present the photomap is most promising in serving as a reliable base for planning purposes, as a product that is rapidly available and is relatively inexpensive. Costs involved in producing a 1:5,000 photomap as compared to that of a line map at the same scale will be in the ratio of 1:4. In other areas the photomap will supplement existing line maps or fill up gaps in the range of scales. Orthophotos will aid in revising existing maps more rapidly and in greater detail. In some countries the so-called "controlled photomosaics" were somewhat disappointing when used for planning purposes, because it was not realized that the mosaics were lacking the geometrical properties of conventional line maps. Photomaps, however, will soon disperse some of the objections against the use of aerial photographs and will find new applications in the field of photogrammetry. On the other hand, orthophotos will also serve as a basis for digitizing and subsequent storing of the various topographic features represented. This will lead to a further development in the field of automatic mapping permitting line maps to be produced more rapidly and economically.

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[6] H. K. Meier, *Gigas-Zeiss Orthoprojektor Design Features and Practical Results*, International Symposium Photomaps and Orthophoto Maps, Ottawa 1967, pp. 54–64.

[7] Ch. W. Schlager, *Die Orthophotographie im kartographischen Werfahren*, Bildmessun und Luftbildwesen, 1966, pp. 15–22.

[8] R. Schweissthal, *Grundlagen, Bearbeitung und Herstellung grossmasstäbiger Luftbildkarten*, Technische Hochschule (Hanover, 1967).

AIM[1] IN PRODUCTION

Paper presented by the United Kingdom[2]

At the Fourth United Nations Regional Cartographic Conference for Asia and the Far East, V. A. Williams and H. H. Brazier presented a paper (E/CONF.50/L.60) entitled, "Aerotriangulation by the Observation of Independent Models (AIM)". In it they described a method of aerotriangulation which could be performed on the Wild A8 to produce, through punched-tape facilities and a Ferranti Pegasus computer, co-ordinates for plotting.

Since that date the independent model method has become universally recognized and widely used. The Directorate of Overseas Surveys (DOS) alone has observed by AIM some 2,000 overlaps on a Wild A8, 1,200 overlaps on an A9 and about 500 overlaps on a B8. The photoscales have ranged from 1:6,000 to 1:67,000 for mapping at 1:1,200 to 1:50,000.

This may be an appropriate time to consider what changes have been made both in outlook and production methods, what we have learned as a result of our experiences and to consider the results we have achieved.

Undoubtedly, the greatest change has been in outlook. In 1964 it was envisaged that AIM would be used only for large-scale mapping since the development of auxiliary aids such as the Airborne Profile Recorder (APR), Horizon Camera etc. promised to provide suitable data required for mapping at medium topographic scales without having to resort to aerotriangulation. Experiments carried out at DOS led us to the conclusion that auxiliary equipment was not, in fact, supplying a truly economic answer to our problems. We therefore carried out experiments in aerotriangulation for topographic mapping using 1:40,000 photography on the A8. The answer achieved was compared with that achieved from Slotted Template Assembly (STA) and bridging for height on Multiplex which, up to that time, was our standard procedure. As expected, the accuracy achieved by AIM was better than the STA/Multiplex result despite the fact that only a fraction of the available control was used in the former method. Equally, and possibly more important was the fact that there was some gain in time using AIM. This gain was due to the fact that AIM requires only one preparatory process which leads up to the combined observation for plan and height as opposed to the two quite separate processes required for STA and an independent heightening programme.

Clearly, if we could show a gain using 1:40,000 photography, an even greater gain could be expected from smaller scales of photography—scales too small to be suitable for STA at 1:50,000. We figured that the optimum photoscale for 1:50,000 mapping was 1:70,000 and that this scale could be easily achieved by available commercial aircraft if a super-wide angle (SWA) camera was used.

These facts were taken into consideration when a re-equipping programme was started in the middle 1960s. During the past five years the DOS has built up its SWA stereoplotting equipment so that its total holding is now one Wild A9 (fitted with EK5), three B8s (one fitted with EK8) and 17 Kern PG2s. For more than a year now we have been carrying out AIM for 1:50,000 mapping on the A9 and more recently we have used the B8, both with excellent results. We are able to observe ten overlaps per seven-hour working day on either of these instruments.

Changes in our methods have been quite minor. Fundamentally the principle of using perspective centres and three pass-points in each supralap to define each model and to effect a mathematical connexion between successive overlaps has not changed. We have experimented a good deal with the presentation of the pass-points and have now rejected the hand-drawn cross. In its place we have supplied artificial pass-points on negatives, using different types of point-marking devices. All the devices produced marks much more quickly than we could draw crosses by hand. When a device is used care must be taken to ensure that the encircling mark does not impair the operator's choice and reading of a good height point within about a millimetre of the plan position.

Until early 1970 the observing procedure remained unchanged as all our work continued to be processed on a Pegasus computer. We now have access to an ICL 1902A computer which has enabled us to modify our procedure to the extent of observing points within an overlap in any order provided those points are appropriately tagged.

When writing new programmes for the ICL 1902A computer, it has been possible to refine the computations so that no tedious editing of results is required, while at the same time printing-out corrections and discrepancies both for photogrammetry and on control points so that errors or blunders can be isolated and appropriate action taken. Only very rarely is re-observation in the plotting instrument required.

When AIM was first introduced it was claimed that one of its advantages was that observations could commence before control co-ordinates became available. This is still a valid claim but we have found in practice that, if there is a large element of roll in the photography, the adjustment is aided if the first overlap of a strip is approximately levelled in the omega direction and the omega carried forward from overlap to overlap. This has been particularly noticeable when using SWA photography. This additional operation adds virtually no time to the aerotriangulation.

For large scale work, which we usually observe on an A8, we have found that the best results are obtained if the operator is allowed to identify his own control and tie points, the former from the surveyor's descriptions. However, at topographical scales the control and tie points are often marked on the diapositive with a point marking device. This latter method saves a good deal of instrument time but can be used only if the control is supplied on locally flat ground. One less acceptable feature arising from such marking of the control and tie points is that some of the interesting part of the job is taken away from the operator and there is a danger that he will become bored and thus make mistakes. It has been necessary to strike the right balance between a long spell of AIM at topographical scales which might lead to boredom and too short a spell which does not allow the operator to get into the swing of the job. We have found that six to eight weeks is about the right length of time. This is about the

[1] Aerotriangulation by the Observation of Independent Models.

[2] The original text of this paper, prepared by H. H. Brazier and D. Reid, Directorate of Overseas Surveys, London, appeared as document E/CONF.57/L.9.

time taken to observe a typical AIM "block". We therefore normally use the block as a unit of operating time, thus giving the operator a personal interest in his own block.

The adjustment of AIM has shown that quite small errors in control can be detected. Ideally therefore, control for all scales of mapping should be pre-marked on the ground. Our experience has shown that the use of pre-marked control reduces the amount of preparatory work necessary before aerotriangulation and leads to faster and more accurate observations which can be used with increased confidence at the computing stages. These advantages combine to make a very strong case for all control to be pre-marked even at the cost of some extra effort in the field. When conditions are such that pre-marking is not a practical proposition an additional responsibility is placed on the surveyor, who is then required to supply the photogrammetrist with a precise identification of each control point. Points which are most suitable for triangulation or traversing in the field are frequently not positively identifiable on the photography. Our surveyors are therefore encouraged to choose a group of good photogrammetric points close to each basic control point.

The independent model method of aerotriangulation is primarily designed for the economic production of maps and the DOS has never failed to achieve sufficient accuracy for the scale of map required. In absolutely ideal conditions of excellent photography with easy selection of firm detail points and with good pre-marked survey control, the mean square residual in control should be less than 25 microns at plate-scale. Theoretically such accuracy might be used to control mapping at say, eight to ten times the photographic scale, but interpretation difficulties normally preclude maps being made at more than five times the scale of photography.

It would be satisfying to be able to conclude this paper with a positive statement about the savings, in terms of over-all production times, which have been achieved by the introduction of AIM for topographical mapping. After about a year, we have found that, up to the point in the production line when plotting of detail and contours can be started, there is a saving of at least 40 per cent by using AIM in place of STA and Multiplex.

We are not prepared to be so positive about plotting times as there are so many variables due to the type of terrain and the need to try out new ideas that we feel we have not yet sufficient evidence to provide a useful comparison. We are satisfied, however, that the saving in over-all production time has justified the DOS decision to invest large sums of money in equipment appropriate to the AIM method.

EXPERIMENTAL PHOTOMAPPING AT THE DIRECTORATE OF OVERSEAS SURVEYS*

Paper presented by the United Kingdom[1]

Before discussing the Directorate of Overseas Surveys' (DOS) photomapping experiments in detail it is necessary to draw the reader's attention to the context in which the experiments were conducted. The Directorate's primary aim is to produce usable maps in quantity as quickly and as cheaply as possible. Given that at the present time orthophotography and, in areas of low relief, rectified mosaics provide the only satisfactory way of automating planimetry the problem was to determine in what ways and in what circumstances it would be possible to take advantage of data presented in these forms for map production as an alternative to the costly method of producing compilations and fair drawings for colour printing. It will be argued later that in some areas of the world the photomap is in fact a better product than the conventional line map, but this fact would weigh less heavily in our evaluation of the experiments if the search for perfection had resulted in a technique which cost more in time and money than the mapping system it was designed to replace.

OBJECT

In many parts of the world there are areas of swamp, desert and forest where topographical features are either too indefinite or too ephemeral to be satisfactorily represented by the standard techniques of conventional topographic mapping. It is in areas such as these where photomosaics may have more impact than conventional line maps. However, photomosaics even when made by differential rectification in the form of orthophotographs, still suffer from an important limitation. They are unselective in the detail they record. The DOS experiments have been made in an attempt to introduce some degree of selection and to change the emphasis in the visual impact made by the various features of the landscape so as to enhance the value of photomosaics as map substitutes. The idea is not new. Photomaps have been produced by mapping agencies with varying degrees of success for over 30 years. In general, however, the methods employed have required a degree of production control of the photographic processes involved which we could not hope to maintain under normal production conditions. Even so, there has been serious loss of the image quality of the original photography. Our experiments have therefore been directed toward developing a production technique suitable for the cartographic enhancement of photomosaics and orthophotographs of certain types of terrain to meet certain specified selection requirements.

SELECTION OF DETAIL FOR ENHANCEMENT

As stated at the beginning of this paper the photomapping technique is, in our opinion, of greatest value in areas where paucity of "hard" detail renders conventional mapping unsatisfactory. It is less appropriate in urban areas where "hard" detail abounds and there is thus no real need to seek elaborate methods of distinguishing buildings from vegetation cover, except as a means of producing a rapid interim map substitute. It is in the resolution of variations within the vegetation pattern that most scope for useful selection exists. We have chosen to base our "photographic" selection on height and texture

* Colour materials will be found in pocket at end of volume.

[1] The original text of this paper, prepared by A. G. Dalgleish and A. B. Whitelegg, Directorate of Overseas Surveys, London, appeared as document E/CONF.57/L.10.

of vegetation and to resolve man-made features and water areas by the more usual cartographic techniques of scribing and masking. The following paragraphs describe the techniques used in the DOS photomap system. It must be understood, however, that variations in film quality, equipment employed, cartographic enhancement etc., dictate variations in procedure and the explanations given, therefore, should be accepted for general guidance only. The work flow is illustrated in the diagram overleaf.

The photographic components

The photomosaics

To prepare the mosaic the first requirement is a complete set of carefully matched prints which have been rectified on the Wild E4 rectifier/enlarger to control positions determined by aerotriangulation. If any final adjustment to reproduction scale is required it can be made when the assembled mosaic is photographed in the process camera. The ground control is plotted on an enamel coated zinc plate upon which is inscribed a grid of appropriate size and scale. The prints are then trimmed for trial fit to control, all joins being disguised where possible by cutting along edges of firm detail, centre of roads etc. The edge of the print overlapping the join is feathered by lightly scoring the surface with a sharp knife and peeling away the unwanted parts of the print with a backward peeling movement. In order to fit the prints to the plotted control a V-shaped cut is made in the print with the apex of the V coincident with the identified position of the control point. The resultant "flap" can then be lifted to expose the plotted position on the enamelled plate. When the print is correctly positioned the "flap" is then flattened and stuck down to the plate. The adhesive used is National Adhesive 311/0334 in cream form (i.e. without water added). After being stuck down to the plate any retouching considered necessary is carried out to disguise joins and emphasize weak detail. Fitting marks (i.e. crosses) are added at the four corners, outside the proposed neat line, for use as described later.

Photographing the mosaic

(*a*) The mosaic is placed in the process camera and a continuous-tone negative is made at the prescribed scale (hereafter referred to as CT);

Type of film: Kodak C.F.7;

The negative should have a density reading of 0.6 in the shadow area and 1.7 in the highlight area, giving a density range of 1.1;

(*b*) With the process camera remaining set as in (*a*) above (allowing for the appropriate adjustment if a glass half-tone screen is employed) a half-tone negative (133 dot) is made (hereafter referred to as HT);

Type of film: Kodalith type 3, 0.007".

The negative should have a printing dot value of 90 per cent in the shadow areas and 10 per cent in the highlight areas;

(*c*) CT is placed in a contact frame and a positive (hereafter referred to as P) is made by overexposing to the degree specified below. The exposure times are approximate only as some trial may be necessary in order to reach a situation where the middle tones are presented as a black (solid) or white texture;

Type of film: lith-type emulsion 0.007" (i.e. Kodalith type 3, Formalith Criterion Duralith);

Exposure: 9 secs point source light (15 watt) at 7 ft.

Development: 3.75 minutes Kodalith developer—constant agitation at 70 °F.

(*d*) From P a contact negative is made in a conventional manner (hereafter referred to as N);

Type of film: Lith-type emulsion as above (P);

Exposure: 8 seconds with point source light as above (P);

Development: 3.5 minutes Lith developer as above (P).

The cartographic components

Interpretation

The amount of detail to be portrayed by cartographic means will depend, mainly on the type of terrain covered. Normally, it will include roads, tracks, rivers, buildings and areas of water. Interpretation of such detail is necessary for the guidance of the cartographer responsible for scribing and preparation of masks. It may be carried out concurrently with the preparation of the mosaic using a separate set of prints.

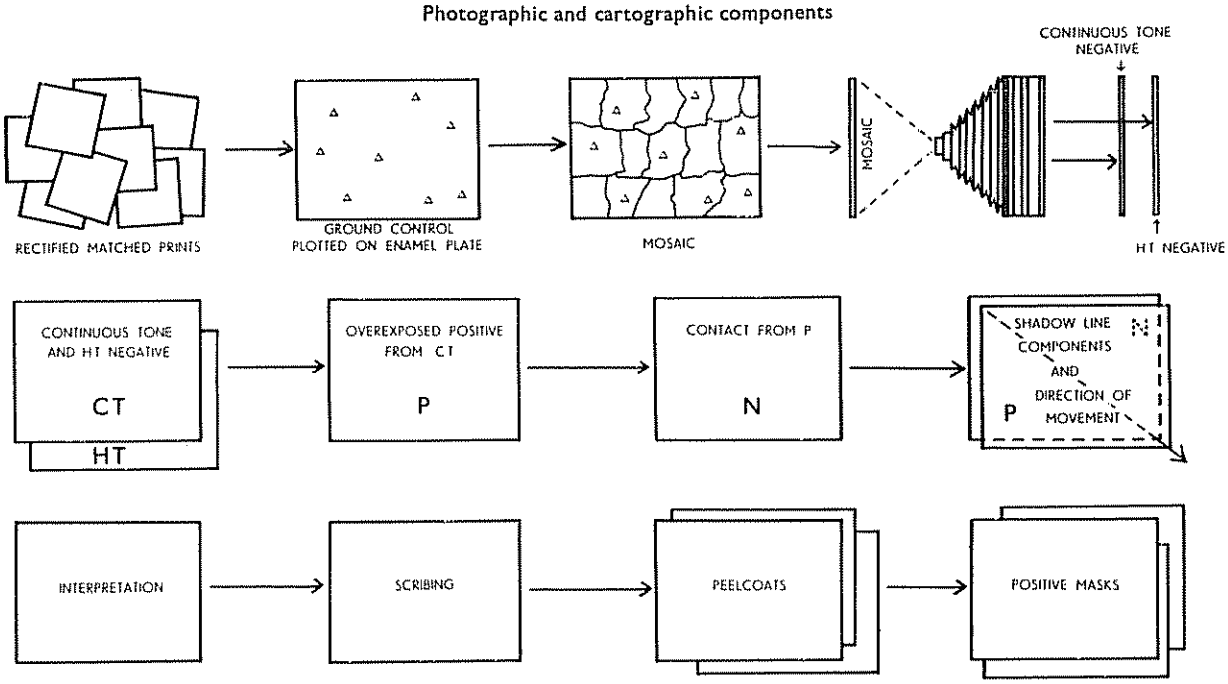
Scribing and preparation of masks

(*a*) To provide a base for scribing a Stabilene sheet is placed on top of CT and fixed by means of stud registration. The detail on CT which can be seen through the Stabilene is then scribed, in accordance with the interpreted prints. Every item to appear on the final map, excluding lettering, e.g. border, neat line, planimetric detail, vegetation guide lines, fitting marks (crosses) etc., is scribed on the one piece of Stabilene. This gives a master base from which peel-coats and positives can be taken, these being made photomechanically, by contact, emulsion to emulsion.

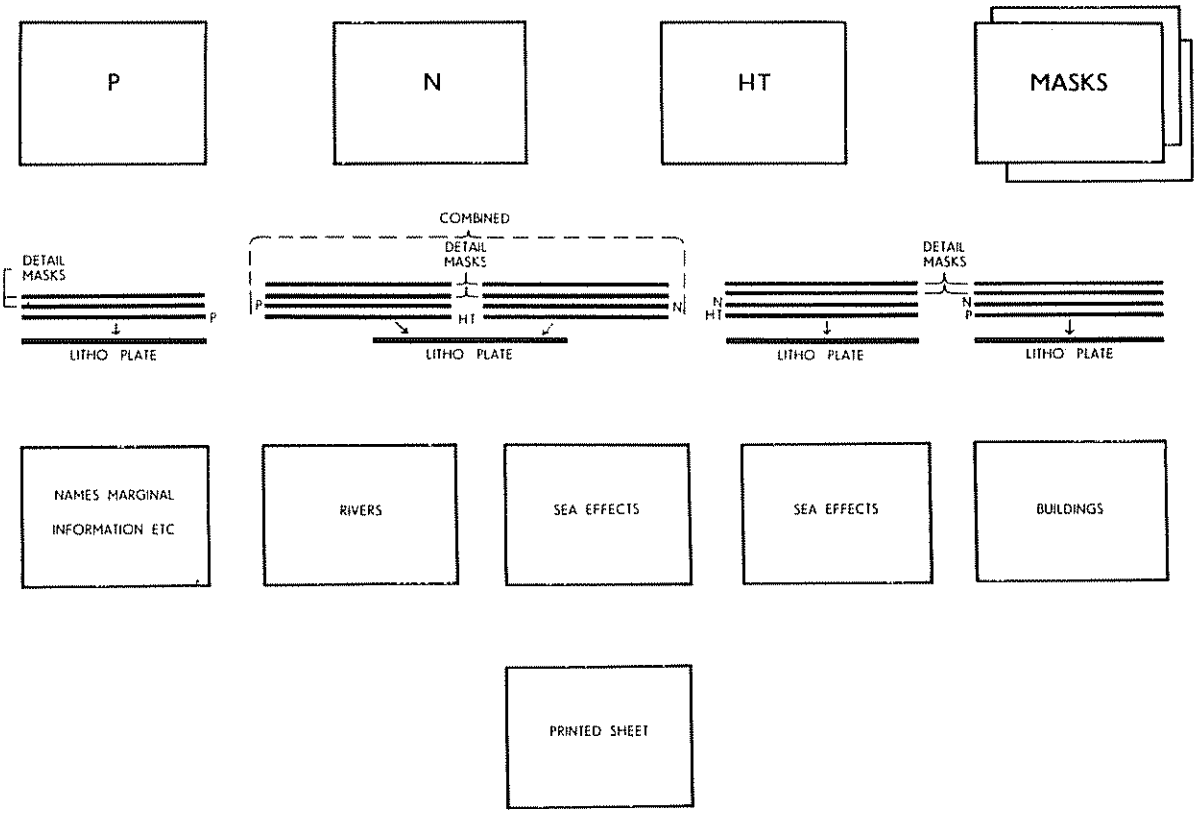
(*b*) *Sensitized peel-coats.* These provide all masks required and can be treated for working purposes as positives, i.e. every area which is not required on the final negative is peeled away leaving a positive image of the final areas required. In most cases, however, an overlap of a scribed line's width is required between the final masks. The linework which defines the areas required on each individual peel-coat including the fitting marks, is painted out with peel-coat retouching fluid. When the unwanted areas are peeled away, the line remains and is therefore included in the required areas. One of the peel-coats is used to obtain the master "stop-out" mask. This is a mask used in conjunction with every combination of P, N and HT at the final printing stages to prevent any detail on the photographic components appearing in areas where another colour is required, or which are to remain white on the final map. Obviously all irrelevant material such as vegetation guidelines and town area guidelines must be deleted from the peel-coat. Since small, flat tropical islands frequently lend themselves to the photomap technique a separate "stop-out" mask is required for areas of water, coral, etc., which may also allow for lettering in this area to appear white if required. The island itself is masked, and the relevant lettering is added in the required position. All the components which form the coral, the sea or any other water features are exposed with this additional mask to ensure that the lettering and the islands are masked out in exactly the same position. When all peel-coats have been completed, contact negatives are made.

(*c*) *Positives.* Only one positive need be made from the master scribed document. This is then contacted to

Photographic and cartographic components



Reproduction
Components and combinations for litho plate making



make the required number of negatives, which, when individually separated, provide the remaining colours necessary to complete the map, i.e. road fillings, rivers, lakes, buildings etc. The positive meanwhile can be used as a base for positioning of lettering on the map face and in the margin. As the positive already incorporates any borders or neat lines required, the resulting contact negative, when separated, forms the negative for the black printing.

(*d*) On completion of these processes the component CT serves no further purpose in the photomap technique.

Components required for plate-making

To summarize, the printing plates will be prepared from the following components: the negative HT, the negative N, the negative P.

x negatives from the master scribed document } the number depends on the detail selected for cartographic portrayal
x masks }

Registration of the components prior to litho plate making

Introduction of the shadow line

The first step in the registration of the components is to determine the displacement required between N and P to give the desired shadow relief effect. This is achieved by placing N on a light table in a fixed position and then placing P directly over it. P is then moved towards the natural light source appearing on the air photography. The amount of movement is very small and should approximate to the width of a shadow cast by a low bush. Conditions at the time of photography obviously influence the amount of offset but it would not be expected normally to exceed 2 mm. When the displacement has been finally determined the positions of N and P are held and the two components are punch registered ensuring that the holes are clear of any border and lettering on other components. P is then removed from N, having first re-positioned the fitting marks on P to coincide with those on N. (*Note.* When a series of adjacent sheets is being prepared by photomap techniques it is necessary to ensure that the amount of displacement between N and P is constant for all sheets.)

Registration of the remaining components

With N still in its fixed position on the light table, HT is placed over in precise register and holes are punched in HT, to conform with those previously punched in N. All the remaining negatives and masks are then similarly registered with N and punched.

All the components for reproduction should now be in correct register when studded together and the holes so punched must be used throughout all subsequent stages.

Choice of colour for printing

The following describes the manner in which the components were combined to produce nine lithographic printing plates for a particular task and indicates the colour selected. This provides for three vegetation textures but if further variants are required, additional half-tone negatives are necessary, in which case special care must be exercised to ensure that screens are angled correctly. The colours indicated are basic and may require to be balanced to be in harmony with the tonal values of the air photography.

Plates prepared from the photographic and cartographic components

Flat land undertone	light yellow P + detail masks	
Flat land half-tone	medium green P + HT + detail masks	double exposure
Flat land high veg.	medium green N + HT + detail masks	double exposure
Swamp, mangrove etc.	blue green N + HT + detail masks	
Shadow line	dark green P + N + detail masks	

Plates prepared from the cartographic components

Names, marginal information etc.	black
Rivers	dark blue
Sea effects	light blue
Sea effects	medium blue
Buildings	red

Economic considerations

This account would not be complete without some mention of the economics of production. As was stated at the beginning of this paper, one of the principal objects of the experiments was to try to develop a production technique by which acceptable maps could be prepared more quickly and at less cost than conventional line maps. At this point in time it would be unwise to claim complete success on either count. Of the new photomaps so far produced only three have been circulated for serious user comments on the acceptability of this method of presentation. Initial user reactions to a 1:40,000 photomap of the island of Tongatapu have been favourable but a complete evaluation is not yet available for detailed study. A two-sheet series at a scale of 1:25,000 of Aldabra Island has also been prepared for evaluation by members of the Royal Society's expedition. Here again we shall have to wait some time before detailed comments are available. Production of this latter series has, however, enabled us to establish two most important points. First, that the technique described in the foregoing paragraphs gives sufficiently consistent results to enable sheets produced independently to be accurately matched and secondly, that the high-lighted vegetation pattern which results from photographic selection of tonal differences combined with the shadow line effect accords reasonably well with the patterns established by detailed photo-interpretation. It appears, therefore, that the photomap may prove superior to conventional methods for the rapid mapping of vegetation distribution. All three of the maps clearly demonstrate the superiority of the technique in the mapping of shallow water submerged detail. With production experience limited to three maps only, it would again be unwise to be dogmatic over comparative production costs. It is well known that map production costs vary widely with the type of terrain being mapped and with the specification adopted. With a complex specification, however, there is no direct linear correlation between production costs and the number of colours used in the final printing. This is an important consideration for it will have been noted that the reproduction material described, which related to the Aldabra experiment, required nine printing colours. The cartographic effort required to produce these plates, however, is considerably less than for conventional mapping but the extent of this saving cannot be fairly established from the limited data so far available. It is in the preparation of the vegetation plate, which in areas best suited to photomapping accounts for some 25 per cent of the total cartographic cost, that savings are most clearly indicated. On the debit side considerably

more cartographic skill is required in the retouching of photomosaics to correct imperfections in the air photography which would otherwise upset the uniformity of the desired tonal separation. It should be noted that uncorrected glare spots will lead to anomalies of interpretation which are not always easy to detect on the finished map but will be very misleading to the map user. On balance, we believe, subject to user-acceptance of our photomap, that it should be possible to achieve savings in the order of 25 to 30 per cent on the cost of equivalent conventional mapping. Whether we can realize this ambition in practice will depend largely on whether the sample areas we have used in our experiments prove to have been truly representative of the conditions we are likely to meet in those areas of the world still unmapped. Whatever the outcome, it appears likely that at least some of the features of the photomap[2] will have an influence on the future development of conventional cartography.

ACKNOWLEDGEMENT

Although we in the Mapping Branch of DOS like to consider the experiments described above as a communal effort, as in many ways they are, we gratefully acknowledge the special contributions made by Mr. Cyril Parfitt, Senior Grade Cartographer in our Experimental Section, for it has been largely due to Mr. Parfitt's enthusiasm for the project and his artistry in handling colours and textures which has enabled us to translate our ideas into an acceptable production technique.

[2] A sample colour photomap was made available to the participants at the Conference. See pocket at end of volume.

POSTSCRIPT

Since the foregoing paragraphs were written, development work has continued and user reactions to new experimental sheets have begun to reach us. We have been greatly encouraged by the favourable user reaction to photomaps in general and of reefs and coral islands in the Pacific area in particular. The latter are especially suitable subjects for the photomapping technique. It has been suggested, for example, that the photomap depiction of the underwater features of lagoons and barrier reefs, supplemented by soundings, could provide one of the best aids to inter-island navigation and local fishing activities yet available. Such an extension of the possible application of photomapping was not envisaged at the outset of the present series of experiments and it would be unwise at this stage to assume that a breakthrough in the charting of coral islands is in sight, but nevertheless results to date are sufficiently encouraging for work to continue.

CURRENT STATUS OF ORTHOPHOTO MAPPING IN THE UNITED STATES GEOLOGICAL SURVEY—1970

Paper presented by the United States of America[1]

Fifteen years have passed since Russell K. Bean first reported the development of the United States Geological Survey (USGS) orthophotoscope, nearly two years after the first workable mock-up model of a scanning device had been used to prepare orthophotographs (Bean, 1955). The design and operational features of the various models of the orthophotoscope have been well documented (Loscher, 1964; Bertram, 1965; and Meier, 1966) and will not be repeated here. It is assumed that everyone is familiar with an orthophotoscope and its product, the orthophotograph.

It is interesting to note that since 1955 at least seven different manufacturers have produced instruments capable of making orthophotographs either as the primary function or as an adjunct to automatic scanning and generation of hypsometric data.

Before considering the present status of equipment for orthophotography in the USGS, let me repeat the definition of an orthophotograph: "A photograph derived from perspective photographs and equivalent to a photograph made by orthographic projection. In a perfect orthophotograph there are no displacements of images because of tilt or relief." (Radlinski, 1967.)

Where the terrain relief is minimal, orthophotographs can be prepared from perspective photographs by ordinary rectification. USGS instrumentation for production of orthophotographs consists of eight rectifiers, four of which are equipped with colour-corrected lens and light sources for production of colour orthophotographs, and four model T-64 orthophotoscopes, the most recent model available, for differential rectification of photographs of terrain where relief is significant. These instruments have proved themselves by producing thousands of orthophotographs since they were placed in operation in 1965.

Recent developments in orthophotography include both instrumentation and products. The original model T-64 orthophotoscope has been modified to include a Kelsh-type projector (Neyland, 1968) as the centre, or exposing, projector. By use of a short-focal-length lens, the projection distance of the Kelsh-type projector matches that of the adjacent ER-55 (Balplex) projectors, so that the nominal scale of the orthophotographs is approximately 2.7 times the original aerial film scale. The major advantages of the modification are the increased resolution resulting from use of 9×9 inch diapositives and the possibility of using the original aerial negative in the centre projector if desired.

The projector modification, which permits the use of contact-size diapositives, makes it possible to produce colour orthophotographs on the model T-64. The well-known anaglyphic projection principle normally used in conjunction with orthochromatic film for recording the differentially rectified images from the centre projector is, of course, totally unworkable for projecting and printing colour orthophotographs. To print a colour orthophotograph, it is necessary to project a perspective colour original, using balanced white light, onto a sensitized colour film base under the exposing projector. To accomplish this, the three projectors on the support bar are

[1] The original text of this paper, prepared by R. R. Mullen, Chief, Branch of Photogrammetry, Topographic Division, United States Geological Survey, Washington D.C., appeared as document E/CONF.57/L.21.

rearranged so that the stereomodel is formed to one side by ER-55 projectors while the exposing and printing takes place at the same time on the other side under the Kelsh projector. The tilt, scale, and swing adjustments of the printing projector are determined by first orienting the Kelsh with one ER-55, then shifting the ER-55 projector along the bar to the far right position and reforming the model to be scanned by inserting the second ER-55 projector. A viewing platen directly connected to the exposing platen is used for following the terrain profiles. Either colour diapositives or Aero-Neg film can be used in the exposing projector. Use of the Aero-Neg film eliminates the high cost of colour diapositives and makes the orthophotograph a first-generation product of the camera original. A trial project using Aero-Neg film for producing colour orthophotographs of an area of geologic interest was moderately successful.

Although operation of the model T-64 orthophotoscopes may be considered semiautomatic to the extent that the exposing platen is driven automatically in x and y, an operator must control the z motion. This requirement involves both advantages and disadvantages. As an advantage, the scanning operation is monitored and controlled by the best real-time correlator yet devised, the human eyes and brain. On the other hand, the operator is committed to a no-break, tedious, two-hour period of constant vigilance.

We have tried for years to relieve the tedium of this operation. The first breakthrough came in conjunction with the development of the automatic line follower (Pilonero, 1967). It is now possible, through the use of the line follower, to control the production of orthophotographs by means of model profiles generated on a special profiling device. Essentially, the profiling device consists of a precision x–y co-ordinatograph equipped with a special tracing table, by which the stereo-operator can produce profiles at selected intervals and what is more important, at whatever speed the terrain detail dictates. Complex terrain can be traversed slowly and, if necessary, traversed again to correct profiling errors. These profiles then become the input for the line follower, which provides servocontrol for automatic operation of the orthophotoscope. Before proceeding with the next obvious modification of the orthophotoscope, let me report briefly on some recent developments in obtaining profiles by automatic means other than electronic.

For several months a series of experiments has been conducted under the leadership of James G. Lewis with the aim of obtaining terrain profiles by photographic means. Profiles have been recorded photographically from an artificial terrain model by means of bread-board equipment. The equipment is designed to record on film the co-planar segments of rays from each of two projectors which have been oriented to form a stereoscopic model. Edge-enhanced transparencies are used in the projectors, one positive and the other negative. The profile appears as a continuous grey line of medium density and stands out against the random black and white imagery or non-corresponding ray segments (Lewis, 1970).

The ability to produce profiles nearly automatically can only enhance the development previously described. Obviously, if the x, y, z motions of the orthophotoscope can be controlled automatically, continuous attention by an operator is no longer required, and the elements for projecting stereomodels become superfluous. All that is needed for exposure of the orthophotograph is a single projector, designed for efficient photographic printing, equipped with adjustments for tilt, scale, and swing with respect to the projection surface. These considerations lead into the next development, the orthophotomat, which is currently undergoing operational tests.

The orthophotomat is a new instrument for the production of orthophotographs, not a modification of the orthophotoscope. It will accommodate both colour and black-and-white aerial photographs of full 9×9 inch format. The nominal scale of the orthophotographs will be 2.8 times that of the original photographs.

Other design specifications for the orthophotomat are as follows:

Scan speed—10 mm/s (variable);
Slot width—$2\frac{1}{2}$, 5, $7\frac{1}{2}$, 10 mm (interchangeable discs);
z range—420 ± 75 mm;
Projection lens—Hypergon f32;
Time needed to scan one entire photograph—less than two hours.

We have now arrived at the stage of development where almost everyone agrees to the general statement, "Let us adopt standards for the preparation of orthophotomaps." However, as soon as we start considering what the standards should be, it becomes evident that the standards adopted for the regular quadrangle topographic maps are not nearly so applicable to orthophotomaps. Just recently a new orthophotomap product has been authorized for production by the USGS. This product, especially designed to substitute for the standard topographic map in the as yet unmapped areas of our western States has been called the "orthophotoquad" and consists of a cartographically unenhanced photo-image in $7\frac{1}{2}$-minute format. Orthophotoquads can be prepared from aerial photographs specially planned so that the principal point of the central photograph of two stereopairs is directly over the centre of the quadrangle. Thus, after orthophotoscope scanning, a single orthophotograph enclosed in a standard border and properly labelled becomes the map substitute product. An orthophotoquad can also be prepared from a mosaic of orthophotographs. The orthophotoquad represents about the minimum of photogrammetric and cartographic effort, yet it is considered to be an entirely suitable product for its intended purpose.

Just one final thought on orthophoto instrumentation. Automatic orthophoto devices incorporating the BAI Corporation Image Correlator will undoubtedly be the next item in the long line of USGS orthophoto instrument developments.

Attention is now drawn to the cartographic developments in orthophotography. Since the report (Pumpelly, 1967), to the 1967 ASP-ACSM annual convention, a new series of photo-image bases has been developed for the lithographic production of orthophotomaps. The image pressplates are prepared from three basic films, the image-tone negative, an accent-tone negative and a surface-tone reverse positive. The details of the preparation of these films are beyond the scope of this discussion and are documented elsewhere (Clark and Pumpelly, 1968).

As would be expected after a long period of experimentation and development in orthophotomapping, we have recently produced two orthophotomaps which we consider outstanding examples of the state of the art. These are

the South Bird Island and the Dallas, Texas, orthophotomaps, both of which are on display at this meeting. Experiments are still in progress with the amount of cartographic enhancement needed to make an orthophotomap a universal map product. Cartographic enhancement includes such techniques as etching road widths, emphasizing drainage patterns by scribing and applying colour to enhance, depict or classify various features.

Orthophotomaps appear to have a wide range of utility at a rather wide range of scales. We have produced several large-scale (1:7,200 and 1:12,000) experimental orthophotomaps of city areas and well over 200 standard scale (1:24,000) orthophotomaps of all types of terrain. Just recently completed is a set of three orthophotomaps of the highly urbanized San Francisco Bay area at the scale of 1:125,000. These small scale maps were produced for the Department of Housing and Urban Development for planning purposes. A series of orthophotomaps at 1:24,000 scale are being produced in the area of the great Alaska oil discoveries.

It would appear that the orthophotomap—brought to this stage of development by the efforts of many in the fields of instrumentation, photographic processing, cartographic processing and lithographic printing—is preferred by many map users, some only partially skilled in interpretation, over the conventional symbolized map.

REFERENCES

Bean, R. K. "Development of the Orthophotoscope", *Photogrammetric Engineering*, vol. 21, No. 4, pp. 529–535, 1955.

Bertram, Dr. Sidney. "The Universal Automatic Map Compilation Equipment", *Photogrammetric Engineering*, vol. 31, No. 2, pp. 244–260, 1965.

Clark, C. A. and Pumpelly, J. W. "Procedures for Processing Image Reproduction Films for Orthophotomaps", United States Geological Survey (unpublished report) 1968.

Lewis, J. G. "Stereoscopic Profiling by Intersection of Ray Trace", paper presented at ASP–ACSM Fall Technical Conference, Denver, Colorado, 1970.

Loscher, W. "The B8 Stereomat", *The Photogrammetric Record*, vol. 4, No. 24, pp. 476–482, 1964.

Meier, Dr. H. K. "Theory and Practice of the Gigas-Zeiss Orthoprojector", translated from *Zeiss-Mitteilungen*, paper presented during the 30th Photogrammetric Weeks at Karlsruhe, 1966, No. 2, 1966.

Neyland, H. M. "Orthophotoscope Modifications", presented at XI International Congress for Photogrammetry, Lausanne, Switzerland, 1968.

Pilonero, J. T. "An Automatic Line Follower", presented at XI International Congress for Photogrammetry, Lausanne, Switzerland, 1967.

Pumpelly, J. "Color Separation and Printing Techniques for Photomaps", *Surveying and Mapping*, vol. XXVII, No. 2, pp. 277–280, 1967.

Radlinski, W. A. "Orthophotomaps v. Conventional Maps", *The Canadian Surveyor*, vol. XXII, No. 1, pp. 118–122, 1967.

AUTOMATED CARTOGRAPHY DEVELOPMENT IN THE DEPARTMENT OF DEFENSE

Paper presented by the United States of America[1]

When automated cartography began in either the middle 1950s, late 1950s, or early 1960s, depending on who is telling the story, its primary purpose was the elimination of the time-consuming, manual, colour separation process. However, during this same time-frame, many proposals were put forth which involved either the automation, or at least substantial change, of all the map production steps of cartographic research, aerial triangulation, photogrammetric and map compilation, colour separation and reproduction. Consequently, in the area of automated cartography we have found it difficult to keep focused on the problem at hand long enough to keep from diluting our objective and consequently our progress toward that objective. However, while we are trying to concentrate on improvements in the colour separation area, we find this map production step continually getting impacted by development in the other map production steps of data acquisition, photogrammetric and cartographic compilation, reproduction and distribution. Changes in how we acquire and process such things as radar imagery, changes in the compilation methods to include, for instance, digitizing, changes in products to such things as pictomaps and changes in distribution to include such things as electronic transmission to remote terminals are all impacting the map production cycle. Thus we find ourselves in an environment that will not stand still long enough for us to apply the technology that we have just developed. The demands of the total process have outraced the solution to a problem in any one area of the operation. This certainly is not unique with automated cartography, but we believe that it has not been recognized to date as the serious problem that it really is. Consequently, ten years after initiation of efforts to improve or eliminate the colour separation process, and at least five years after carefully integrated, phased programming was documented, very little substantial improvement in the colour separation process on a production basis has actually taken place.

The antidote for these changing conditions that hamper improvement is an integrated, across the board, development programme that pays particular attention to successful implementation in a total production environment. Too many times in the past, however, attempts to automate have been individual attacks on stereo compilation instrumentation, colour separation procedures, automating the map library, or data research capability, building a digital mapping capacity, automating type placement, or investigating conventional symbolization, without giving enough emphasis to total production problems.

PRESENT PROGRAMME

The conventional research and development (R&D) process in the Department of Defense (DoD) is divided into four categories. These categories are basic research, exploratory development, advanced development and engineering development. Most of the automated cartography effort has progressed to the latter two stages. Thus, concurrent thinking must be given to the solution of production problems that must be faced in a production environment while the R&D is being brought to a successful conclusion. This planning is especially needed in developments related to map production in the automated

[1] The original text of this paper, prepared by R. A. Penney, Cartographer, Advanced Systems Office, Mapping, Charting and Geodesy, Department of Defense, Washington D.C., appeared as document E/CONF.57/L.28.

cartography area because past history has shown too much diversion between setting a goal initially and then finally achieving it. Too many times we have ended up with the tail wagging the dog as, for instance, in the case of digital mapping. What started out as an improved model-carving process ended up with a by-product (digital data) that turned out to be far more important than the solution to the original problem. Peripheral by-products again are clouding the objectives of automating the compilation and colour separation processes. Such things as the use of the digital and/or analogue by-products types of photographic or computer storage and implementation of a data bank concept must be integrated carefully with automated cartography and care taken to keep these things from diverting it in its final stages.

The current Army programme for an automated cartographic system is oriented completely toward a digital approach. The new procedures for stereo and manual compilation are aimed at digitizing both pictorial and cartographic map data. All of this data is then to be input to a computer for the required manipulation and storage. Output will be accomplished through a digital plotter which will produce the final reproduction quality, colour separation material. The completed system is expected to include the following types of equipment.

(*a*) *Stereo compilation digitizers*. In addition to the digital output of the UNAMACE and similar equipment, conventional stereo instrumentation will be equipped with digital encoders;

(*b*) *Cartographic compilation digitizers*. In this area, the Army has developed the automatic contour digitizer and is proposing the planimetric compiler which will permit digitization from photographic products and existing maps. Also related is a colour separation scanner that will provide a capability for scanning and digitizing a multi-coloured map manuscript;

(*c*) *Digital input–output display devices*. These will provide the capability for recall of the stored data from the computer in graphic form for editing purposes;

(*d*) *Advanced plotters*. These give the capability to provide reproduction quality colour separations by photographically exposing images from digital data records;

(*e*) *Peripheral items*. These would include the computer software required to implement the system and peripheral improvements such as the automatic type placement system.

The Air Force programme for the development of an automated cartography system has been mainly predicated on the use of an automatic colour scanner to separate colour coded compilation manuscripts. A two-phased programme is expected that will initially provide a production capability to accomplish this with a later objective of developing a digital and analogue cartographic data bank. The following basic instrumentation is anticipated.

(*a*) *Automated colour separation device*. This device consists of a drum scanner, a special purpose processor and a tape storage unit. Output in digital form would record the feature colour, line centre, beginning and end of areas and the determination of half-tone areas;

(*b*) *Raster plotter*. Edited and proofed linear features and outlines can be plotted in final map form from digital input;

(*c*) *Semi-automatic digitizer*. This would provide the ability to digitize cartographic data over and above the digitizing capability currently at the Aeronautical Chart and Information Centre;

(*d*) *Computer software packages*. These include all computer programmes necessary to implement the total automated cartography system.

All of the automated cartography planning by DoD is oriented toward a data bank concept. The data bank input may be in graphic or analogue, as well as digital, format. This then permits the solution of the additional problem of planning and making a format for a data bank concept that will be amenable to all DoD needs, including the diversity of map scales all users may require.

Future considerations

Until now, the main difficulties that have been encountered while trying to construct a workable, cost-effective, automated cartography system have not been the lack of semi-automatic and automatic state-of-the-art equipment. Rather, these difficulties have been due to the tendency to consider this as mainly an R&D problem without giving proper emphasis to the production problems that must be solved before a workable system is possible. For example, the big problem in automating type placement is not related to the feasibility of placing the name in computer memory to be played back at some future date, but rather the merit of placing every name in the world in memory and retrieving them selectively according to the desired scale of the final product and name density which depends on the type of map or pictorial product on which they will be placed. As another example, state-of-the-art equipment exists that can digitize a road and play it back on command. The real problem is putting this road in a data bank from which it can be retrieved in proper symbolization according to scale and type of product, and in proper relationship with all adjacent symbolization. Our concern is that the procedure that predominates today in automated cartography of developing state-of-the-art equipment, then testing it for feasibility, next integrating it into a workable system, then adapting the equipment to all kinds of input data and finally attacking the production problems is not resulting in a workable system in a reasonable time frame. Neither does the answer lie in solving all of the problems related to production and appearance of the final products before we release a workable system for production. The answer lies between the two extremes in an area in which we have only scratched the surface to date. This would be a major cartographic testing element that combines R&D and production in an environment that faces all of the production challenges that must be met by a successful system. Along with the equipment feasibility problems, this testing element must also test the validity of retaining such things as existing symbolization and cartographic license, as well as giving clues to the best balance of personnel and automated equipment needed in an actual production environment. The Air Force currently has several production personnel working in its R&D area, but the main effort is being directed at the testing of various mixes of equipment for feasibility and utility. The Army also has a continuing programme for phasing R&D equipment into their production facility. However, to investigate the production problems properly, it is imperative that the automated cartography programme comprehensively cover, on an expanded basis, the following areas.

(*a*) Either be compatible with or adaptable to all mapping acquisition systems and include provision for inputs from existing maps, digital data, orthophotography and photogrammetric instruments;

(*b*) Provide a phased programme from current manual to eventual completely automated production which will cover near-time improvements and be amenable to continual changes in technology and instrument capability;

(*c*) Address the relationship to a data bank concept, including type and format of interim product outputs;

(*d*) Address the problem of making current map and chart symbolization compatible with an automated system or vice versa;

(*e*) Address the problem of editing at appropriate times to ensure satisfaction with the interim data bank products as well as the final map, chart or related product;

(*f*) Address the compatibility of the various types of photogrammetric and revision instrumentation that are anticipated in the system;

(*g*) Be responsive to anticipated changes in final product requirements.

Conclusion

Automation will inevitably result in the reduction or elimination of the colour separation step in map production. A considerable amount of R&D progress has already been made by DoD. However, the time has come to shift the emphasis from R&D solutions to equipment problems to the facing of the critical related production problems in a total production environment.

ALL-WEATHER MAPPING SYSTEM

Paper presented by the United States of America[1]

The United States mapping community has looked forward for many years to some form of an airborne sensor that will provide, at any time of the day or night, despite clouds or fog, terrain imagery that is suitable for topographic mapping. Investigations of the possible use of radar as an airborne sensor for mapping was initiated in the late 1940s and early 1950s when plan-position indicator (PPI) radar imagery was first developed. As development of more advanced radar sensors gained momentum, additional study programmes were initiated to determine not only the possibility of developing an airborne radar sensor that would satisfy the unique data requirements for topography, but also the possibility of developing the associated ground-based reduction equipment to provide a total all-weather topographic mapping system.

As a result of these studies and follow-on research and development test programmes, a breakthrough in radar mapping systems development was achieved in 1967 when radar imagery of Panama and north-west Colombia was successfully obtained, utilizing a modified APQ-97 radar that was mounted and flown in a modified YEA-3A test aircraft. This radar coverage was accomplished in an area of continuous cloud cover which, for a period of 20 years, consistently precluded obtaining mapping by use of optical photographic systems. As a result of this demonstration of side-looking radar techniques, the United States initiated an advanced research and development programme to produce a prototype airborne radar acquisition system with the required positioning capability and associated ground-based data reduction system. This research programme is intended initially to produce a capability to compile medium-scale maps and eventually to compile large-scale maps.

Before discussing the details of the research and development programme, three basic questions need to be addressed.

[1] The original text of this paper, prepared by C. DiCarlo, General Engineer, Advanced Systems Office, Mapping, Charting and Geodesy, Department of Defense, and F. Treadwell, Physical Scientist, Directorate of Advanced Systems, United States Army Topographic Command, Department of Defense, Washington D.C., appeared as document E/CONF.57/L.30.

The need for an all-weather mapping system

The basic reason for an all-weather mapping system is to obtain quality imagery suitable for production of medium- and large-scale maps of the cloud-covered areas extending about twenty degrees north and south of the equator. In addition to meeting this basic requirement a need is recognized for an all-weather imaging capability that can be used to supplement traditional photography whenever weather or light conditions deny the use of an optical system.

Accuracies needed to produce topographic maps

To provide an objective criteria for the system, it was established that an all-weather mapping system should be capable of collecting radar navigation and other data which will permit production of topographic maps to United States' standard accuracies.

For 1:250,000 medium-scale maps, the horizontal accuracy requirement is: 90 per cent of all well defined features must be plotted within at least 416 ft of their geographical positions, referenced to the map projection. For vertical accuracy, 90 per cent of all contours must be accurate to within the "basic contour" interval. In areas where the slope is less than 10 per cent, the basic contour interval is 50 m; here elevation accuracies must be 50 m with a 90 per cent assurance. In areas where slopes are more than 10 per cent, the basic contour interval is 100 m; here the elevation accuracy must be 100 m with a 90 per cent assurance.

For 1:50,000 large-scale topographic maps, the horizontal accuracy requirement is: 90 per cent of all well defined features must be plotted within 83 ft of their true position. The accuracies of contours in areas of flat terrain must be within 10 m of true elevation 90 per cent of the time. Note that the accuracy requirements of large-scale maps over medium-scale maps are a ratio of 5 to 1 better for both horizontal and vertical accuracies.

A complete all-weather mapping system

A complete all-weather mapping system consists of two basic subsystems: the airborne collection subsystem and a

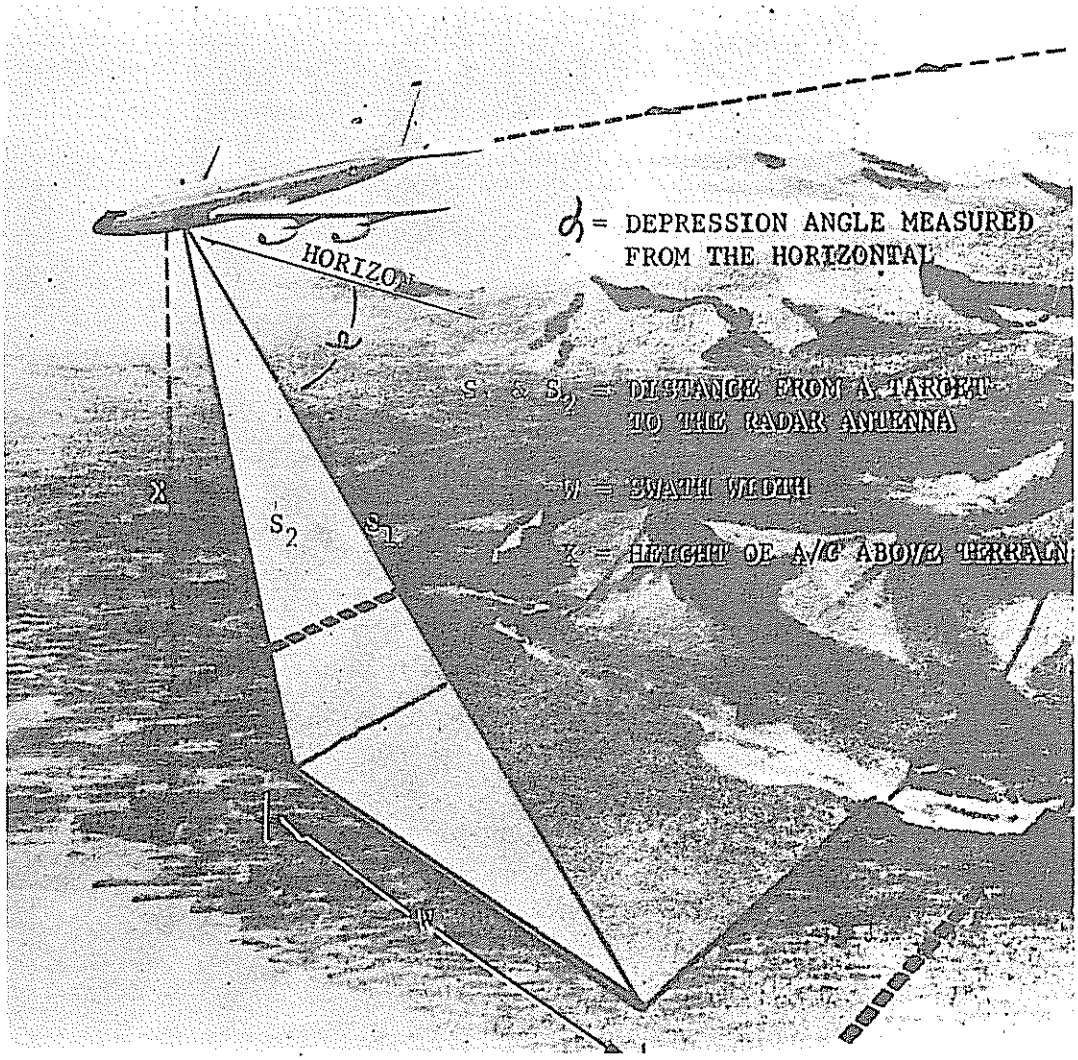


Figure 1. Radar basic parameters

ground-based data reduction subsystem. In the airborne collection subsystem, the primary source of data is the radar sensor. It provides an image of the terrain. It must have high resolution characteristics incorporating a highly directional transmitting–receiving capability; it must operate on an efficient, narrow band of high frequencies; it must transmit precisely controlled radio waves; it must measure time with great accuracy and, finally, it must display or record the information with fidelity such as on continuous strip film. Our all-weather mapping systems scan only to one side to simplify the acquisition system design. Some of the basic parameters associated with the side-looking radar are shown in figure 1.

The height x of the collection platform above the terrain is variable as with aerial photography. The distance from the radar antenna to a terrain feature being recorded is a function of time and is measured in slant range, S-1 and S-2. This term, slant range, is used to differentiate it from ground range, which is the horizontal distance between objects on the ground. Slant ranges of 10 to 50 nautical miles are considered normal. The ground coverage, w, which is obtained in one single pass of the aircraft is referred to as the "swath width". Mathematically the ground range is related to "slant range" by the cosine of that particular depression angle. The depression angle is the angle "alpha" measured from the horizontal for a particular beam and it may vary from 10° to 80° depending upon the shape of the antenna.

The key element of mapping systems is securing accurate data on the elevation of terrain features. This data is obtained by the use of radar imagery flown in a stereo mode, which is accomplished by radar coverage of the same area twice, from opposite sides or same side with 50 per cent minimum overlap. The aircraft maintains the same altitude and depression angle on the radar. Although the feasibility of topographic mapping from stereo radar has been demonstrated, analyses to date have been based on the theoretically ideal situation of exactly parallel flight lines, equal altitudes, perfect antenna stabilization and precise synchronization of film and ground speed. Of course, such ideal situations never exist in real life. To test this theoretical analysis, the Army collected radar stereo imagery which was analysed and the results indicate that elevations accurate enough for medium scale maps are feasible. The actual radar imagery (figure II) was obtained in our Panama operations.

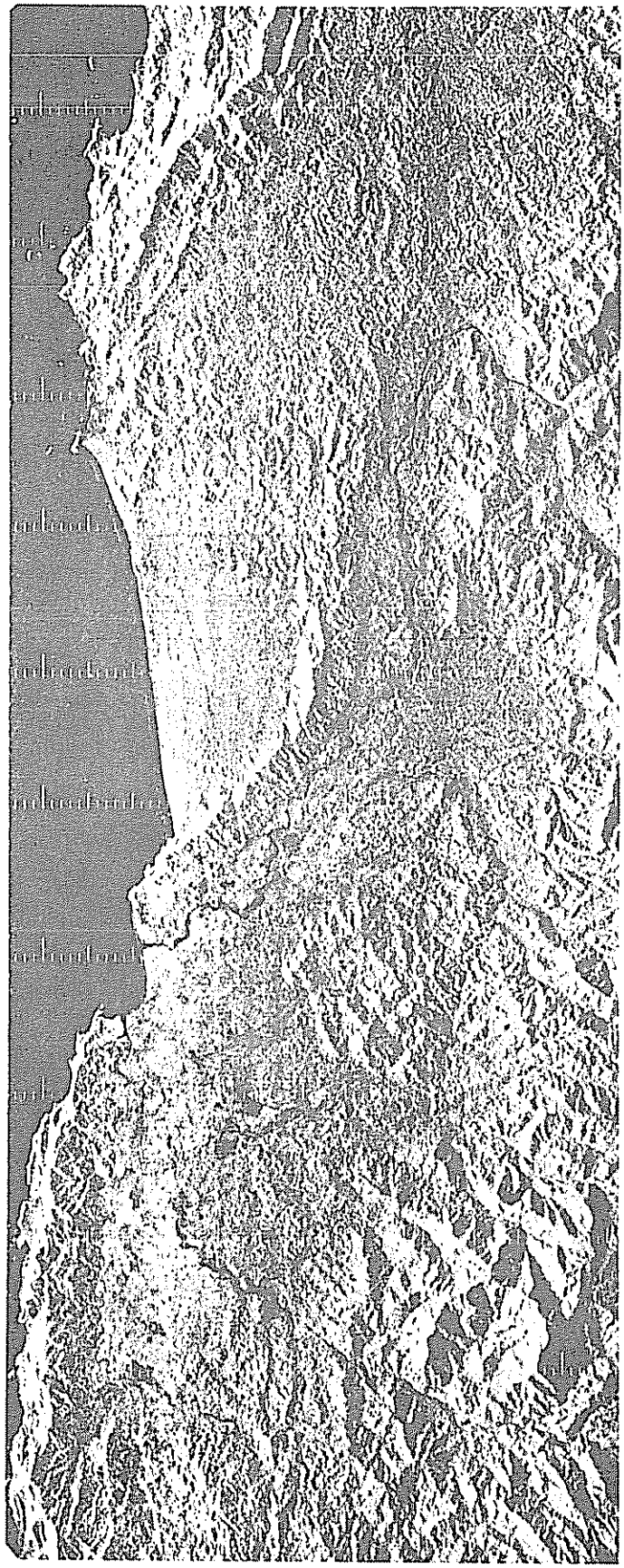


Figure II. Radar imagery of Panama

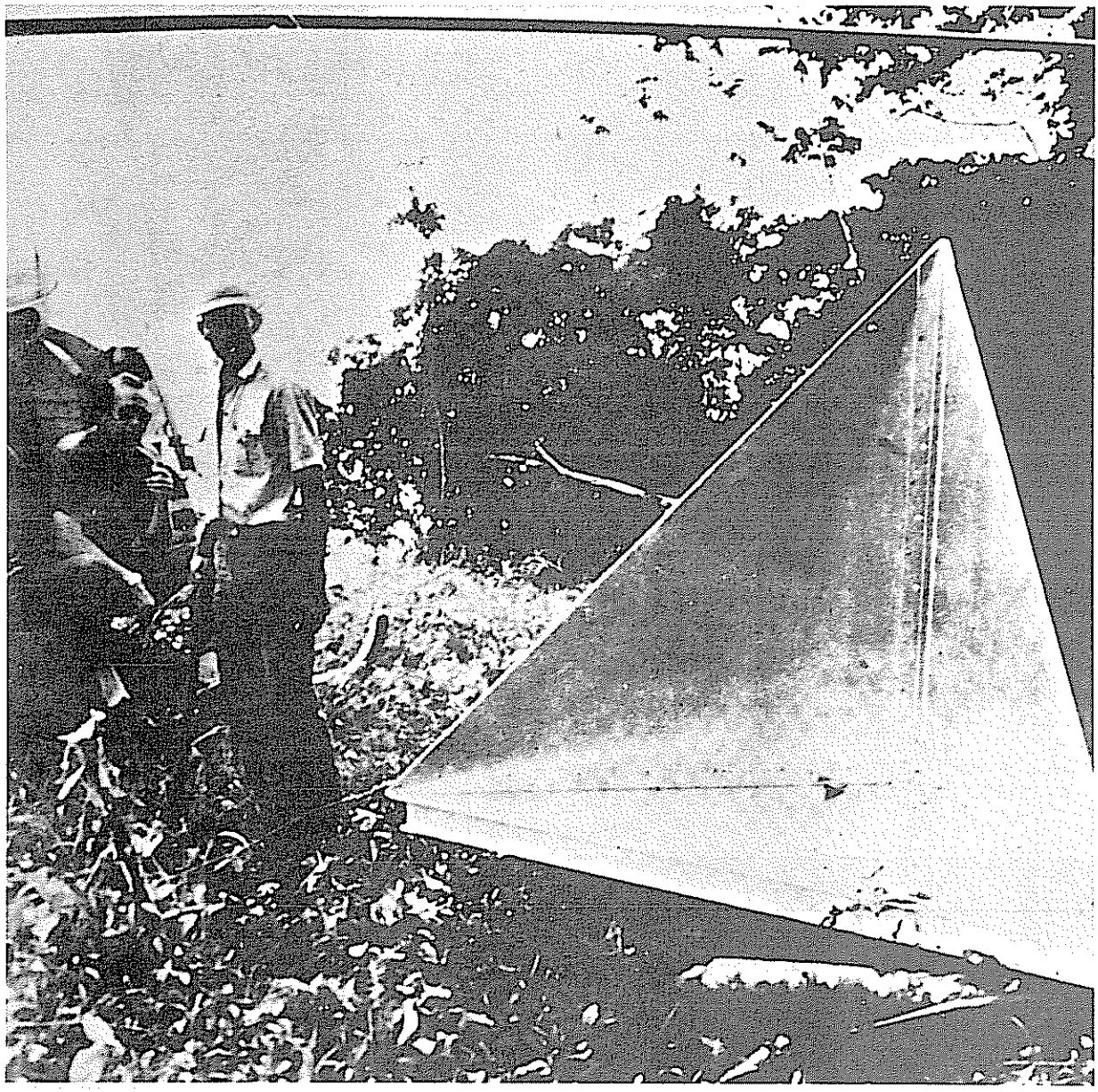


Figure III. Radar reflector

To complete the airborne collection system, navigation equipment must be provided to record accurate positional data of the acquisition aircraft in synchronization with the collection of radar imagery. If the navigation system cannot provide positional data accurate enough to meet the requirements for topographic maps, then a sufficient number of accurately located ground control points, marked to show on radar, must be deployed. The ground control points may be any identifiable natural or cultural features whose x, y and z positions are accurately known. On these control points, special radar reflectors are placed. The reflectors (figure III) clearly mark the pre-selected control points on the radar imagery. The number of ground-control points required is determined by the inherent accuracy of the over-all airborne mapping system. A more accurate navigation system in the acquisition aircraft would lessen the necessity for ground control point identification. Field verification of the mapping system's positional data and radar imagery is made as soon as the aircraft lands, to assure that all systems have performed properly. The data is then sent to a central data reduction centre. Here, the output of the computation process is twofold: corrected planimetric positions of terrain features which become the base for transferring other detail to the base map and contour information to generate the required elevation (topographic) data. Radar imagery interpreters transfer the pertinent detail to the map base and also the elevation information to form the completed topographic map.

First operational all-weather mapping system

With this basic understanding of an all-weather mapping system, it is hoped that a better understanding of the United

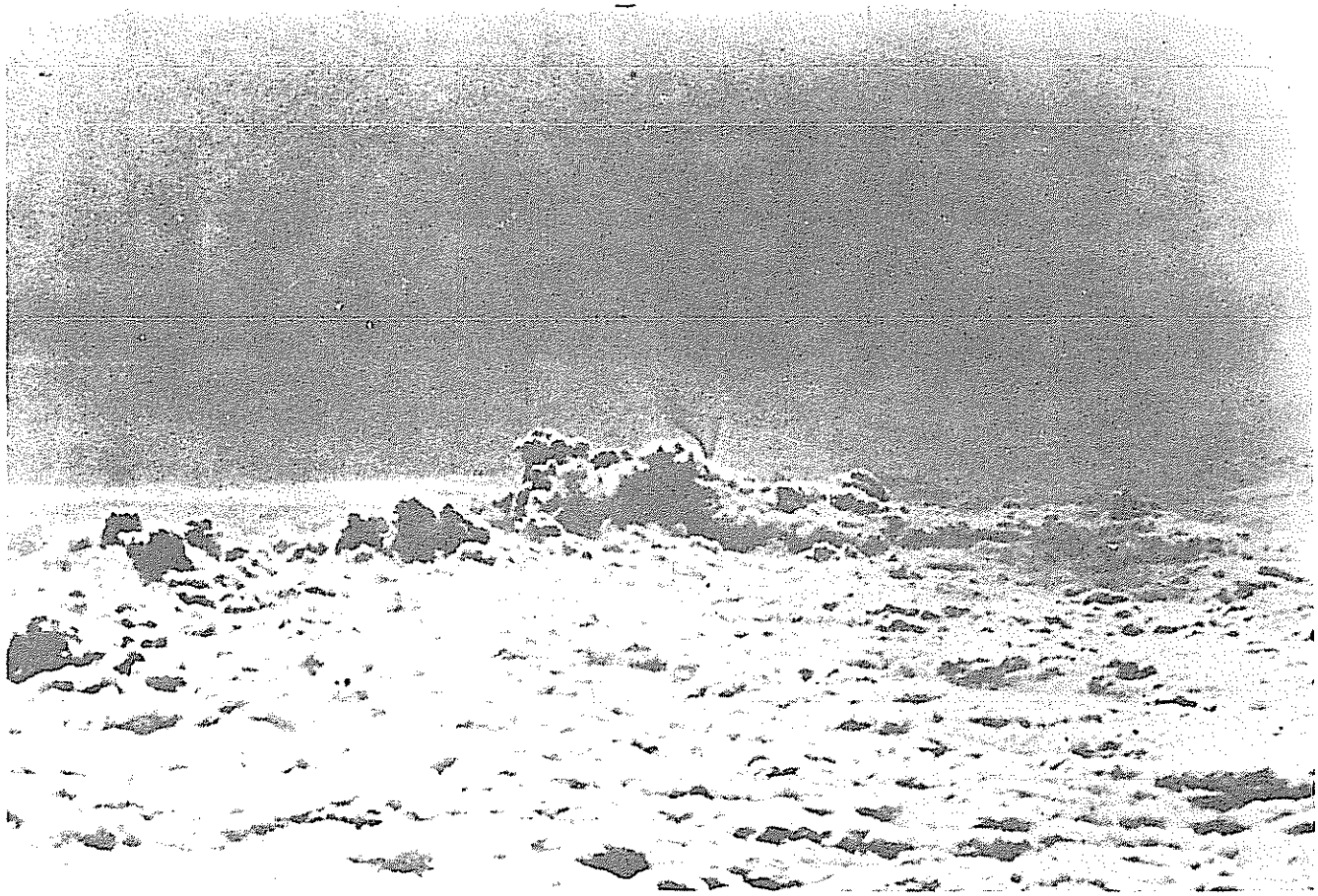


Figure IV. Darien Province: Heavy cloud cover

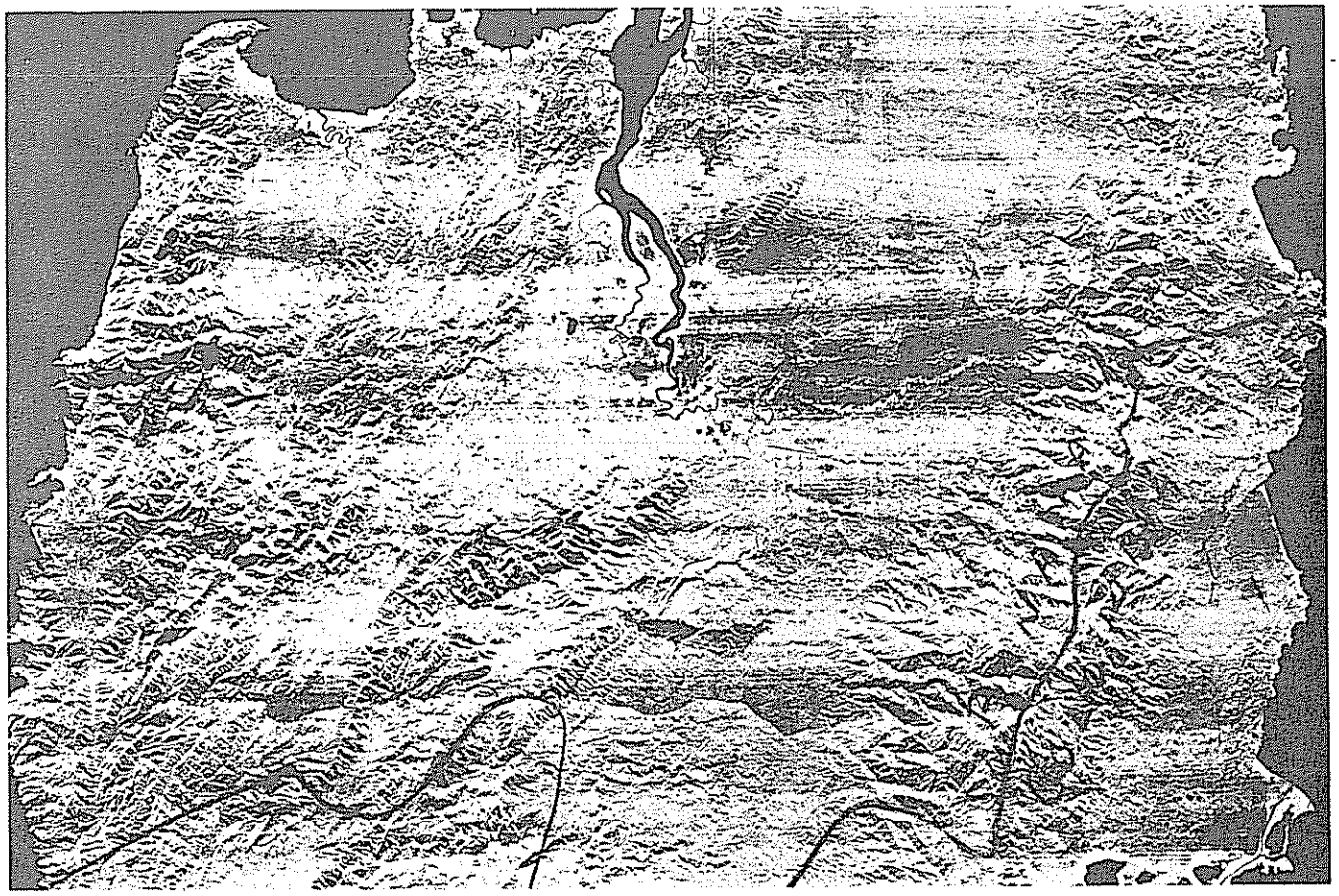


Figure V. Darien Province, Republic of Panama and North-western Colombia

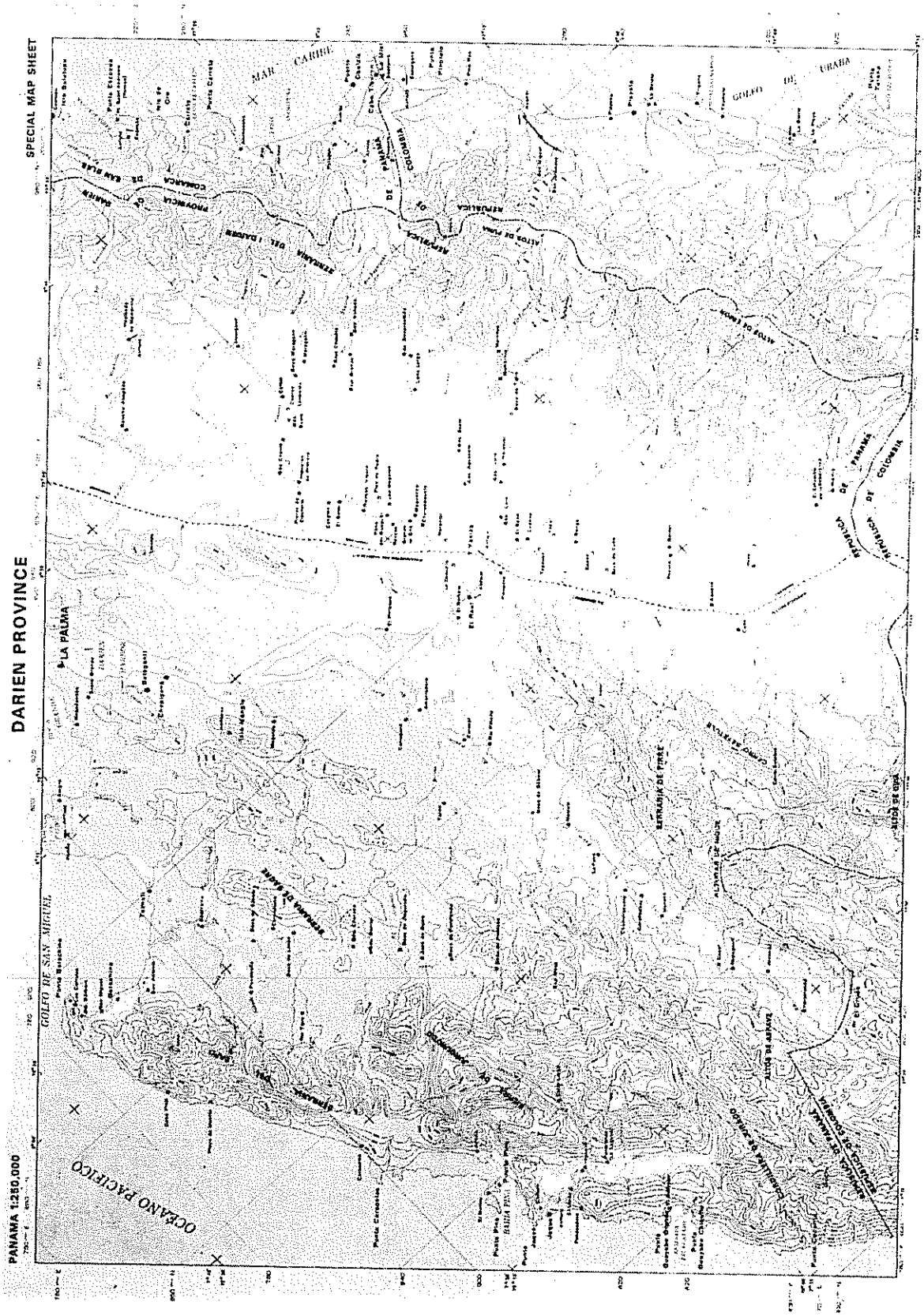


Figure VI. Darien Province: Topographic map

States Research and Development Program will result. As has been indicated, attempts to develop an all-weather mapping system date back to the late 1940s and not until the mid-1960s was there a degree of success in utilizing radar. In 1967, the prototype radar mapping system was installed in a jet-type YEA-3A aircraft and was used to acquire radar imagery over Darien Province in Panama. An example of the usual cloud cover in that area can be seen in figure IV. The cloud cover consistently averaged 83 per cent, making mapping from traditional imagery impossible. On this project, radar imagery suitable for mapping purposes was obtained and assembled into this uncontrolled radar mosaic (figure V). Subsequently, the radar mosaic was used to demonstrate its potential by extraction of data for overlays that portray surface drainage, surface vegetation and suitability for road, helicopter and airport construction. A total of thirteen overlays were prepared from the radar imagery. In addition, the positions of mountain ranges shown on previous maps were found to be in error. Because of the excellent definition of features, the mosaic is now being used by pilots of small planes for navigation.

After preparing the mosaic, the data reduction process was completed by identifying image points in the radar imagery, computing the positional and elevation data for those image points and with this data a medium-scale map of the area was produced (figure VI). All this work was completed with research and development funds and its success led to the present operational concept of using a DC-6B aircraft, with refurbished and improved side-looking radar and Doppler radar navigation equipment installed (figure VII).

The radar sensor in the DC-6B aircraft at 20,000 ft provides a 10-mile swath width at sea level. The approximate speed is 200 knots and radar flight lines are programmed to achieve a four-mile sidelap. The DC-6B aircraft completed flight tests over a radar test range in the United States in April 1969. The aircraft then deployed to Panama and Colombia to acquire additional radar imagery and associated positional data, permitting compilation of medium-scale maps over 60,000 square miles of hitherto unmapped area. Previous to the deployment of the aircraft, the Army, working with Inter-American Geodetic Survey (IAGS) personnel and Colombian officials, selected locations for all ground control points and positioned radar reflectors in the Panama and Colombia area.

It is significant that the DC-6B all-weather mapping system is largely dependent on development of radar reflectors in order to achieve the desired accuracy. In the radar sensor, stabilization and resolution needed improvement so that the production of maps could be accomplished more efficiently. The data reduction techniques used to process and reduce the collected airborne data was inadequate and production costs and manpower requirements were high. To overcome the above deficiencies, a second research and development programme was implemented to provide advanced all-weather mapping acquisition and data reduction components.

Advanced acquisition subsystem

An advanced type radar sensor will be designed for installation in an RC-130A mapping and charting aircraft (figure VIII). The aircraft utilizes a HIRAN distance measuring system that is capable of positioning the aircraft to within 24 ft relative to the ground stations (figure IX). HIRAN ground stations are located on first-order geodetic control points so that the horizontal accuracy for the aircraft is ± 50 ft. The aircraft navigation system is backed up by a Doppler navigation sensor to provide a continuous recording of ground speed and drift angle. In addition, a stabilized mapping camera is used to obtain photographs of the terrain where holes in the clouds permit. The altitude sensor, and the attitude of the radar antenna sensor are critical. In the RC-130A, a proved terrain profile (radar) provides data on heights above the ground to ± 10 ft, up to an altitude of 35,000 ft. The new radar sensor in the RC-130A has improved antenna stabilization and resolution over the radar now being used in the DC-6B aircraft. With the superior resolution of the radar and greater accuracy of the collected positional data, the need for deployment of radar reflectors for ground



Figure VII. All-weather mapping aircraft

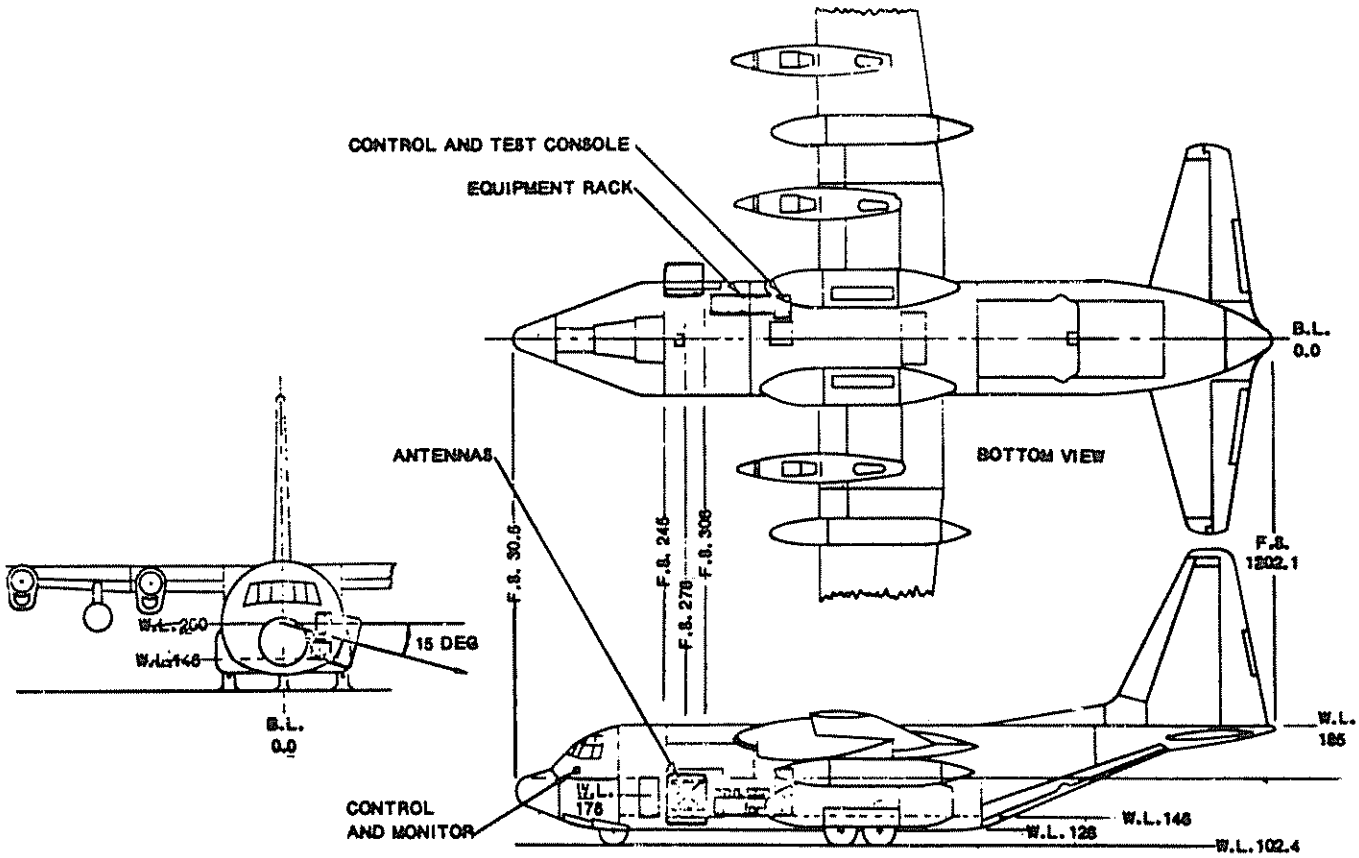


Figure VIII. RC-130A modified for all-weather mapping

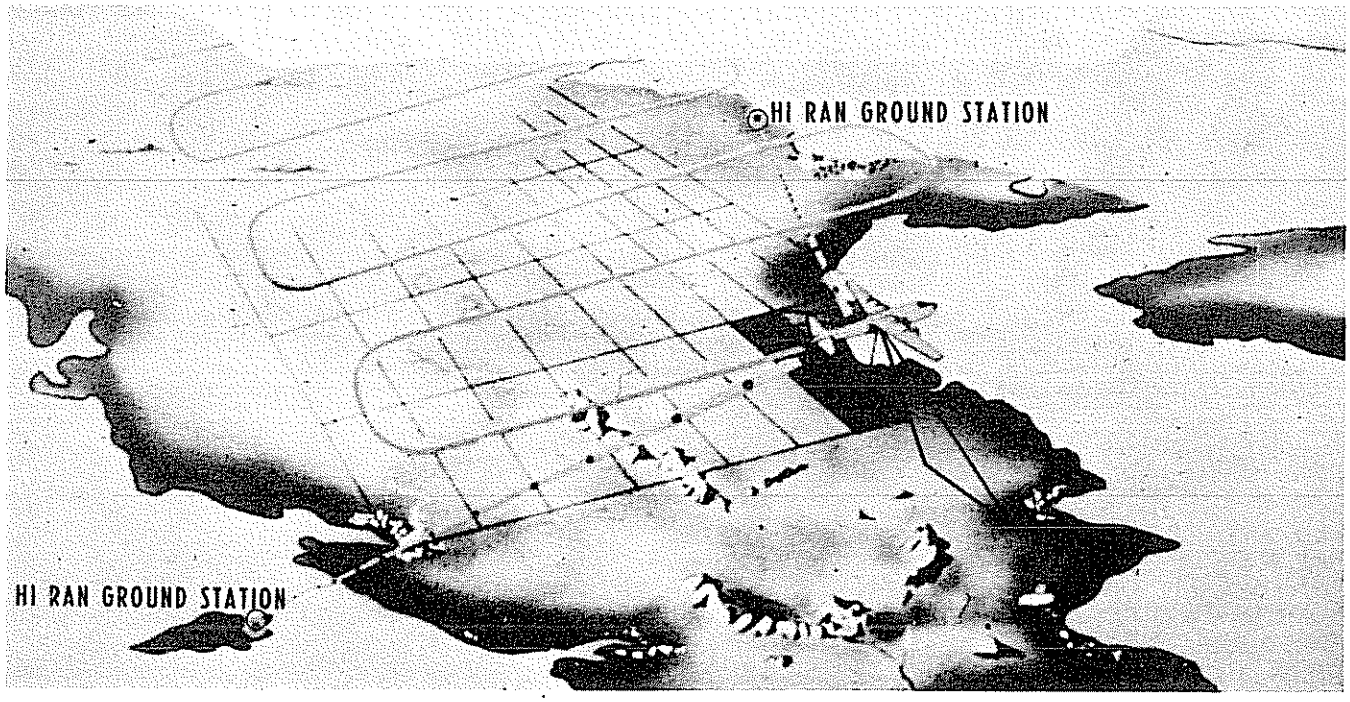


Figure IX. Electronic positioned radar imagery

control is substantially reduced. In addition the data reduction is more efficient and superior detailed medium-scale maps should result.

Advanced data reduction subsystem components

With this understanding of the parameters which directly affect the engineering development of the data reduction subsystem we can review the various components that now make up this subsystem.

The data reduction subsystem is an assembly of equipment integrated into a highly flexible man–machine combination being developed for map production capability. Standard photographic equipment such as dark rooms, LogEtronic Printers, enlargers, continuous roll developers etc., is already available at these DoD facilities. In addition, standard compilation, transcribing and reproduction equipment is required for the production of the final map products. Hence, only the particular radar processing and reduction equipment which must be added to the standard map production facilities will be discussed.

Base plant correlator

The airborne data acquisition subsystem for the RC-130A aircraft is based upon a synthetic aperture radar sensor. This radar sensor produces Doppler histories of the terrain imagery. The base plant correlator equipment is used to correlate the Doppler history film and produce high quality imagery. A prototype model of this universal radar signal processor (figure X) has successfully demonstrated the feasibility of a correlator with the required resolution and geometric accuracy. This universal correlator consists of a variable-power optical system and two film transport systems designed to operate over a range of speed ratios to permit tracking of phase histories. The magnifier telescope subsystem provides magnification

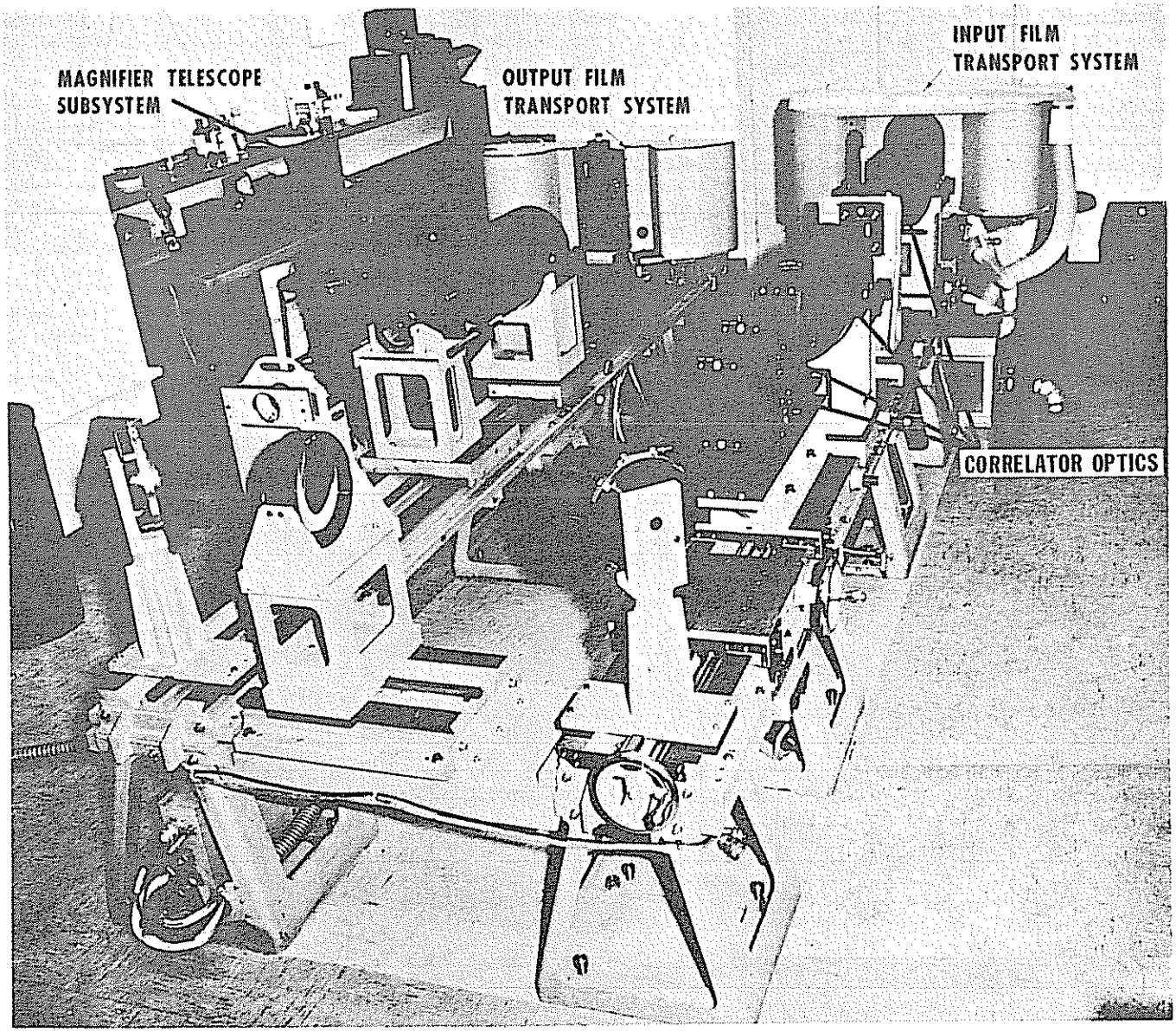


Figure X. Universal radar signal processor (correlator)

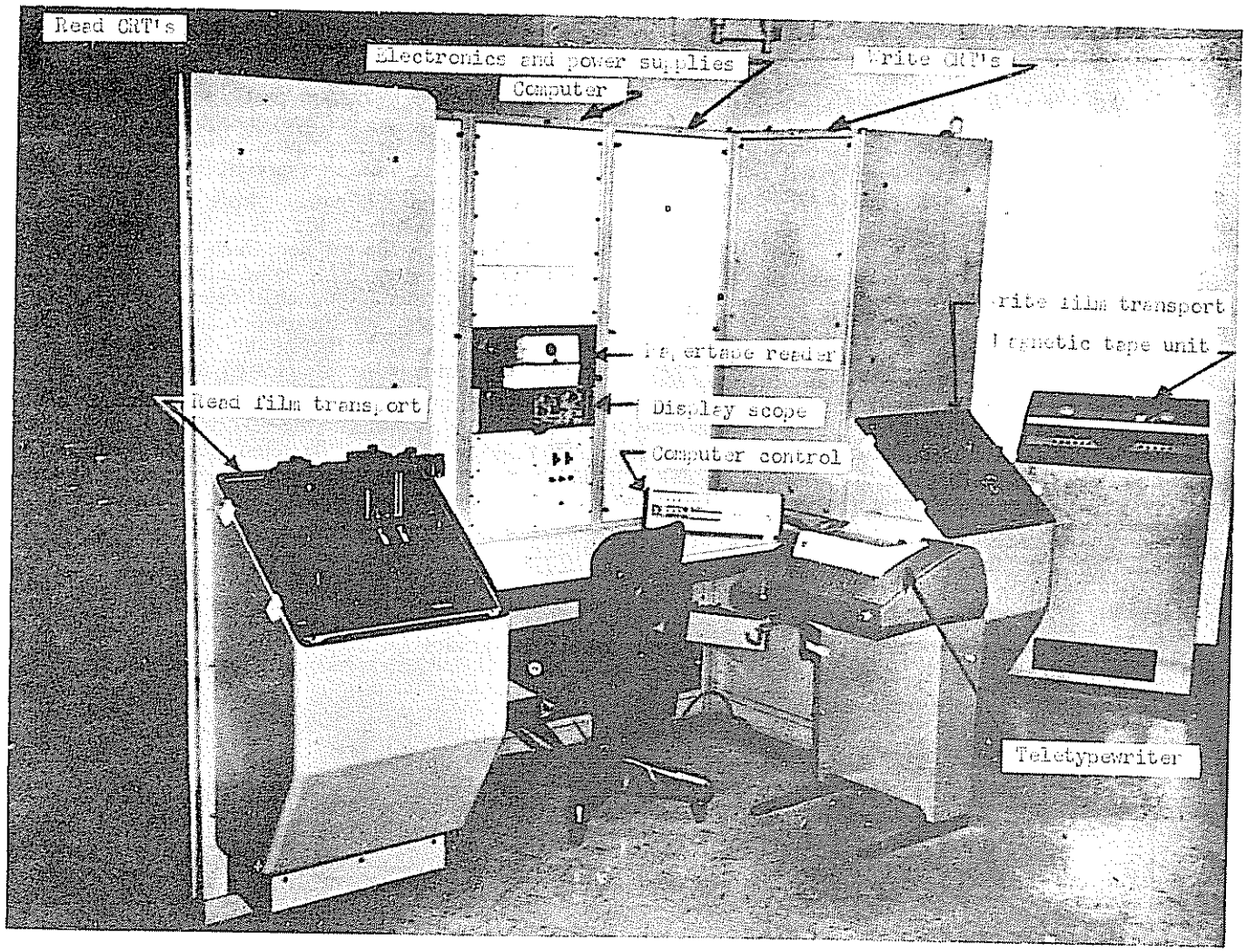


Figure XI. Orthographic radar restitutor

of one half to three times of the image. Auxiliary units permit data block transfer, image film marking and mode stripe sensing.

As recognized, correlators are normally relatively small in size. However, due to the precision and geometric fidelity required for mapping, the present size of this correlator becomes significant. The correlator, less control console, is approximately 8 ft wide by 17 ft long by 4 ft high. The total weight of the optical bench alone is over 4 tons. The control console weighs 0.5 ton.

The correlator will be capable of correlating 35-mm, 70-mm, 5-inch and 9.5-inch nominal data film widths having maximum continuous lengths of 1,500 ft of 3-mm thickness, 850 ft of 4.5-mm thickness or 730 ft of 6-mm thickness. However, correlation is limited to width increments of 4.5 linear inches of phase histories at any one time. An improved correlator incorporating all improvements found in engineering evaluation of the prototype model will be obtained in the near future.

Orthographic radar restitutor

The orthographic radar restitutor (ORR) has been developed to correct distortion inherent in film imagery obtained by airborne side-looking radar (SLR) mapping sensor. Errors involved are those caused by variations in radar look angle during the scanning process. These errors must be removed before accurate topographic maps can be prepared from the film data. The ORR restores radar film imagery to its true appearance as if viewed from directly above.

Physically, the ORR consists of five individual units (figure XI) fastened together to form a single cabinet complex. One two-bay unit contains the read CRTs and film transport. An identical two-bay unit contains the write CRTs and film transport. Two single-bay units contain the electronics and power supplies. The remaining single-bay unit contains the computer with associated electronics. Peripheral units consisting of a teletypewriter, high-speed paper-tape punch and a magnetic tape unit (not shown in figure XI) are located for convenience of operator use and connected to the main cabinet by cabling.

Inputs to the ORR will be the radar imagery produced by the base plant correlator and a tape containing a grid of computed elevation points. The grid will be computed from the airborne navigation data and stereo equipment outputs. The grid line will lie parallel and normal to the flight path. The equipment will compute the orthographic position of image points, scan the imagery and print the corrected orthophoto.

ORR operation (greatly simplified) consists of scanning SLR film imagery with a non-linear scan, transferring the resultant data to the output film transport and scanner and exposing film with a linear scan containing the processed video. The output film is thus corrected for a perpendicular-look angle and is distortion free. Computer control is utilized throughout ORR operation for maximum speed and accuracy. This ORR is presently undergoing engineer design tests.

Stereo equipment

The stereo equipment will be used to provide elevation data. Although a photographic analogue of radar stereo can be established and visually observed, the model is not exact and correction factors must be introduced to determine the true elevation height. This is particularly true for the slant range system that will be used in the acquisition subsystem because when a radar stereo model is viewed optically, terrain that is actually flat will appear to be sloping. Another problem is that the scale of the imagery changes as a function of range which requires that the relative magnification between the photographs of the stereo pair be changeable. Past experiments have demonstrated that in certain parts of the stereo model, visual correlation can be most easily achieved between positive and negative radar photographs. In other sections of the model, both photographs must be positives.

The radar stereo equipment consists of the four units shown in figure XII. At the left is the ASR-33 teletype unit. Behind it is the cabinet which contains the H316 Honeywell computer. This same cabinet also contains the paper-tape reader and punch, the electronics for driving the photocarriages and the power supply. The stereo comparator is shown in the middle. To the right of the stereo comparator is the x–y plotting table.

The stereo comparator will permit the operator to view the stereo model with varying relative magnification between the radar images of the stereo pair. The stereo comparator will also be designed with three carriages, of which two will be mechanically linked. The two linked carriages

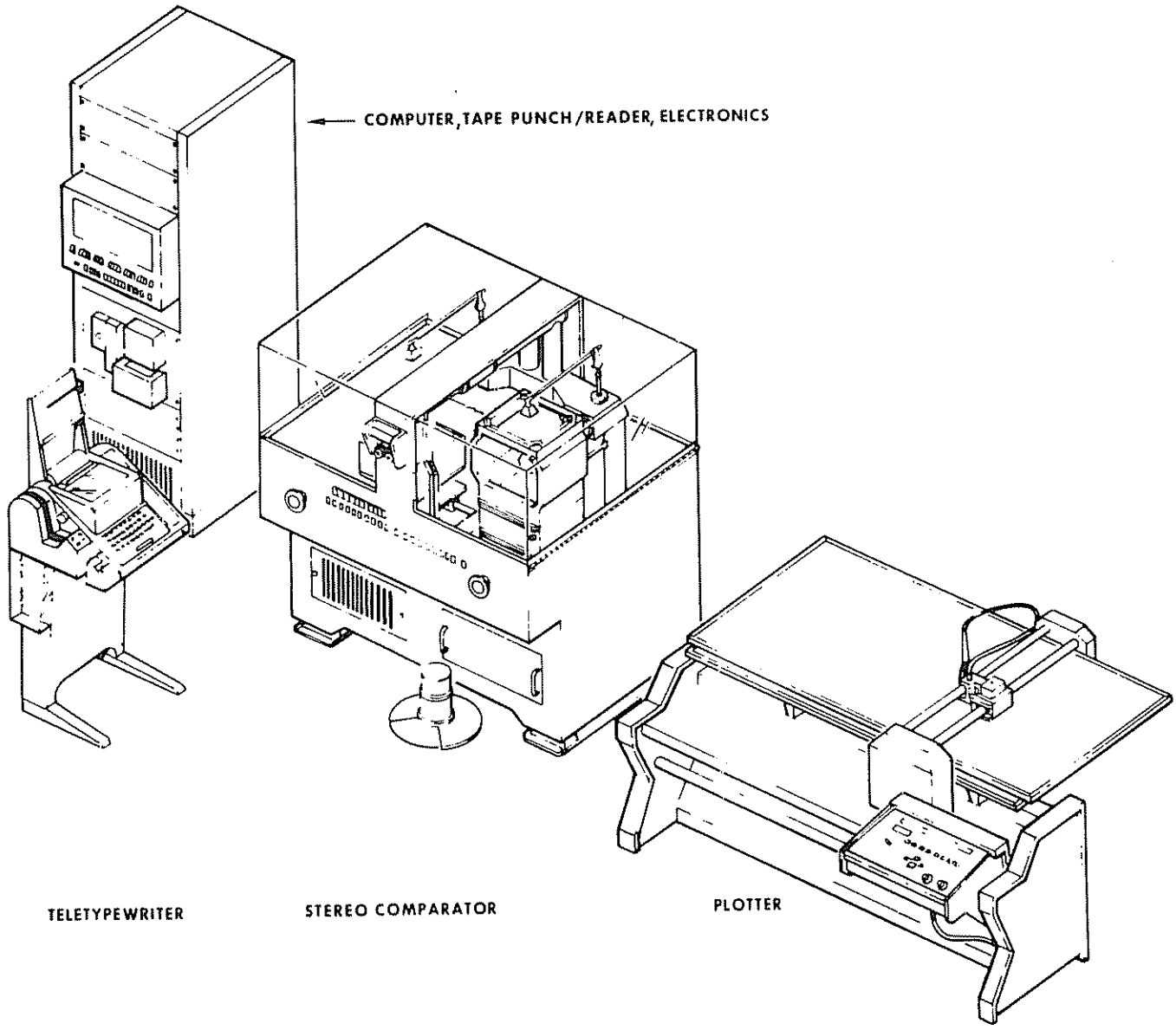


Figure XII. Radar stereo equipment

will hold the positive and negative of one radar image strip (9 × 9 inch) and the independent carriage will hold the other radar imagery of the stereo pair. The operator can, at his option, switch between positive to positive, or positive to negative radar imagery by the use of the two carriages. This allows the operator to compensate for shadowing effect on radar imagery. The operator will select control points, the co-ordinates of which will be automatically outputted on paper tape and on to the plotter.

Computer

A digital computer of the order of the IBM 7094 or larger will be required for the data reduction computations. This computer will perform two major functions. First, it will correlate the navigation information from the airborne navigator, radar antenna stabilization and data block information. Secondly, a two-dimensional surface fit to the terrain will be generated using information from the stereo equipment and the correlated navigation data.

SUMMARY

The all-weather mapping programme is being developed with the ultimate objective of providing a large scale radar mapping capability in the mid-1970s. However, to minimize risks and cost, a medium scale capability is being developed initially. This permits achievement of an early medium scale capability while concurrently providing a radar collection and data processing test laboratory for evolutionary development of all system components that will contribute to a progressive development programme with the final objective of a large scale mapping capability. The medium scale all-weather capability is scheduled to be completed in late 1971 with research and development testing to be completed by late 1972. The research and development tests will include a six-month evaluation programme to confirm that the collected airborne data (radar and navigation) processed by the data handling and ground-based data reduction equipment can effectively produce a medium 1:250,000 topographic scale map.

As reported herein, the United States of America engaged in a viable research and development programme to develop an urgently needed all-weather mapping system. Care is being taken to ensure that the development of the ground-based data reduction system is being carried out at a pace commensurate to that of the airborne data acquisition system. Ultimately, this radar mapping system will permit the establishment of a multisensor mapping system consisting of optical and/or radar imagery. This all-weather multisensor programme will ensure the capability to collect imagery at any time of day or night and process the imagery and related data that is necessary for the timely provision of maps and related topographic products to meet users' needs.

DRAFTING METHOD TO MEET FREQUENT MAP REVISION

Paper presented by Japan[1]

HISTORICAL BACKGROUND

The Geographical Survey Institute (GSI) recently developed a new map revision drafting method. The method is aimed at solving cartographic problems caused by frequent revision of maps and at maintaining topographic maps up to date. Minor corrections and revisions such as inserting newly constructed highways, towns etc. should be frequently done on maps. To meet these requirements, cartographic work must be performed in the shortest possible time at each revision.

The idea of redrafting only new features and preserving unaltered features was adopted at the time of pen-and-ink drafting of small revisions. With the general adoption of plastic film in the field of cartographic work, photolithographic film with a mat surface for drafting was applied in revision drafting. Revision survey documents were also generally prepared on mat transparent plastic film at that time. A photoprint of features was prepared on the underside of a sheet from the former edition of a map with a colour-dyeing emulsion. Then a revision survey document was made. Addition of new features was drawn on the front of the sheet in black or coloured ink and deletion of features that had disappeared was done by erasing them on the underside. It was desirable to change the colour of ink each time for addition of features. To obtain more distinct colours in preparing a revision survey document, new features were drawn in vivid coloured ink such as true black, dark red or dark green while former features were printed in light colours.

A positive image of features was made on photolithographic film from a negative of the former edition of a map. The revision drafting was performed by drafting in additions and erasing deleted features according to the revision survey document which was placed under the sheet. This revision drafting method using positive film is also used now for maps for which scribed sheets have not yet been prepared. Revision drafting for scribing sheets, namely revision scribing, was developed according to this method.

REVISION SCRIBING AND TECHNICAL PROBLEMS

There were several methods for revision scribing.

(*a*) *Trace revision scribing*. Coating of the parts necessary to be redrafted was removed and these parts were recoated with opaque liquid which was visually transparent yet actinically opaque. The trace scribing of new features was done according to the guide on the revision survey document placed under the scribed sheet on a light table.

(*b*) *Composite revision scribing*. A guide copy was prepared on a new scribing sheet and only new features were scribed on it. Features that had disappeared were deleted with opaque liquid on the former scribed sheet. Then the newly scribed sheet and the corrected former sheet were composited during the lithographic stage.

(*c*) *Direct revision scribing*. Features that had disappeared were deleted with opaque liquid on the former

[1] The original text of this paper, prepared by the Geographical Survey Institute, Ministry of Construction, Tokyo, appeared as document E/CONF 57/L.32.

scribed sheet and new features were taken from the revision survey document and scribed.

(*d*) *Revision scribing attached with photomechanical etching.* Features that had disappeared were deleted with opaque liquid on the former sheet. The sheet was then photoprinted on a new presensitized scribing sheet. Next, the sheet was photomechanically etched and the features were developed as negative images. Finally new features were taken from the revision survey document and scribed.

In connexion with these methods, there are several problems that need to be solved.

Which method might be the most effective for preparation of a positive guide image on a scribed sheet from the positive-imaged revision survey document? This was solved by adopting the stable diazo type emulsion which was adaptable to the coating surface of a sheet for copying. This type of emulsion was developed and commercially supplied at that time.

Troubles develop in the process. The former scribed linework might be dyed with emulsion after developing. This trouble was solved simply by re-exposing from the underside of the sheet before developing.

It was very difficult to scribe accurately along former scribed linework or very close to methods (*a*) and (*c*). This trouble was solved by removing the coating and recoating with opaque liquid.

It was sometimes difficult to obtain desirable refinement of scribed lines where opaque liquid was applied. Moreover it was difficult to make guide copy on some opaque liquids such as red. This was solved by applying opaque liquid very carefully, smoothly and evenly. The same colour opaque liquid as the coating of the sheet was developed later.

Instructions for revision scribing

Trace revision scribing

(*a*) Remove the coating where features are not required on the former scribed sheet;

(*b*) Apply visually transparent yet actinically opaque red liquid on these places carefully, smoothly and evenly;

(*c*) Trace-scribe new features along the guide images on the revision survey document which was placed under the scribed sheet.

Composite revision scribing

(*a*) For precise registration, prepare a reference guide image on a new scribing sheet from the former scribed sheet by contact printing with watercote type colour such as reddish brown or neutral grey;

(*b*) Prepare guide copy of new features on the new scribing sheet from the revision survey document by diazo process with black dyeing emulsion after precisely registering the corresponding features between the former scribed sheet and the revision survey document. If it is difficult to obtain general registration it should be done part by part. The sheet should be held in place with adhesive tape each time and exposed, and then it is developed;

(*c*) Scribe the linework of new features on the new scribing sheet according to the guide image.

Direct revision scribing

(*a*) Opaque features are no longer required when the opaque liquid colour is the same as the coating on the former scribed sheet;

(*b*) Print the revision survey document on each former scribed sheet by the diazo process after precisely registering each feature of the scribed sheet and of the revision survey document;

(*c*) Directly scribe new features according to the diazo image.

Revision scribing attached with photomechanical etching

(*a*) Opaque features no longer required with opaque liquid on the former scribed sheet, according to the revision survey document;

(*b*) Apply sensitizer on the surface of the new scribing sheet;

(*c*) Print the former scribed sheet on the new sensitized scribing sheet;

(*d*) Apply developer and etching solution to the sheet, and develop the former linework as a negative, excluding the deleted linework;

(*e*) Prepare the guide image on the new scribing sheet from the survey document by the diazo process;

(*f*) Scribe new features according to the diazo image.

Preparation of proof sheet

Different colours such as darker colours for the new scribing sheet and lighter colours for the former scribed sheet are desirable in preparation of a proof sheet by composite photoprinting for easy proofing.

Applicability of the methods

Method (*a*): Use was limited only to the sheet on which the amount of rescribing linework was small and/or it was difficult to remove the former coating in deleting features no longer required.

Method (*b*): It was desirable to use this with the sheet on which the amount of rescribing linework was large especially double-lined roads and/or urban areas occupying large areas. Rescribing the former scribed sheets may be difficult because they have not been prepared recently and/or scribed surfaces are very dusty with the application of opaque liquid. This method is the simplest, but an additional number of new coating sheets and supplementary operations for copying are necessary. Method (*b*) may be adopted for sheets that have not yet been prepared for scribing. The reference guide image can be made on a new scribing sheet from the negative plate of a former sheet.

Method (*c*): This method is easier, simpler and more practicable than method (*b*). Use of this method is desirable when there is an average amount of revisions. However, technical troubles have not been sufficiently solved concerning removing the coating of the features to be deleted and applying opaque liquid.

Method (*d*): This method is as easy as method (*b*). However, an additional etching operation is necessary and this operation sometimes results in undesirable refinement of line quality. It may not be adaptable for sheets having dense features and/or minute linework.

Additional note: Revise or correct with photonegative film for maps for which scribing sheets have not yet been prepared.

General view of revision scribing

It was easy to obtain refinement of line quality by methods (*a*) and (*c*). However, in strict terms, dimensional stability of base material and durability of coating material were inadequate. Besides, additional operations were necessary, such as preparation of guide copy, preparation of a coloured proof sheet etc. These operations were considered to be an improvement in procedure, materials etc. Revision drafting was only performed by persons who were highly skilled and had considerable experience both in compilation and drafting. In this connexion, revision scribing can be done by those who have less experience and skill than those who work in pen-and-ink revision drafting on a positive film sheet. This was the very point referred to in the cartographic operation for revision of sheets although the additional operation was necessary. Another point, registration should be done very precisely. The punch-and-stud system was generally adopted and it was very helpful for precise registration. Since 1968, the Geographical Survey Institute has adopted methods (*b*) and (*c*) for its cartographic work in revising its sheets. The revision scribing method can be applied for revision drafting operation anywhere.

THE TRAINING OF SURVEYING AND CARTOGRAPHIC ENGINEERS IN JAPAN

Paper presented by Japan[1]

For the production of fundamental maps of national territories, it is essential to maintain geodesists, photogrammetrists, cartographers, draftsmen and printers.

In this country, however, the training facilities for these kinds of skills can rarely be found within the system of general education. The reason is that the required backgrounds for these skills are purely technical and do not form a part of general education. Furthermore, the skills for producing the fundamental maps were restricted within the realm of the army before the Second World War and the introduction of courses in these fields in general education was never realized.

In recent years, the demand for survey and cartography in regional development has rapidly increased in this country. For example, 2,900 million yen was spent in the field of surveying and mapping in 1969. As for technology in this field, the highly accurate technique of geodetic survey has been required to construct a tunnel under the sea-bed and a long bridge above the sea and to produce accurate large-scale maps for cadastral survey. From this it is easily seen that a large number of highly skilled surveying engineers are required in this country.

The Geographical Survey Institute (GSI), a governmental organization for surveying and mapping, has a technical school in which there are one-year courses for training new members of the institute as surveying and cartographic engineers and a one-year advanced course for selected members after five years' practice.

Recently, five private technical schools for training surveying technicians were established, equipped with highly expensive instruments such as geodimeters, stereoplotters and precise theodolites. Seven hundred technicians graduate from these schools each year to be engaged in surveying and mapping work for governmental organizations and private surveying companies. The graduates of these schools are eligible to be registered for the licence of professional surveyor (assistant registered surveyor). After their training and two years' practice, they are eligible to obtain the licence of full professional surveyor (registered surveyor).

[1] The original text of this paper appeared as document E/CONF. 57/L. 57.

Students trained at the GSI

Country	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*	*1970*	*Total*
Korea, Republic of		2			1				3
Laos		3			1				4
Thailand	3	1		2	1	1	1		9
Malaysia	4	4	2	2	2	1		1	16
Philippines	2	2	2	1	4	1	2		14
Indonesia	2	1	1	1	2			1	8
Pakistan		1	1						2
Ceylon				4	1				5
Nepal	1	1			1			1	4
Syria				1	1				2
Iraq					2				2
Kuwait				1					1
Saudi Arabia	2								2
Sudan				1	1				2
Nigeria			2	1	2				5
Bolivia							1		1
Iran								2	2
Netherlands							1		1
TOTAL	14	15	8	14	19	3	5	5	83

As far as the training of foreign students is concerned, the activity of the Geographical Survey Institute based on the Colombo Plan is given in the table of students trained in the institute.

This is one of the group-training courses prepared and sponsored by the Government of Japan as a part of its technical co-operation schemes for developing countries. Arrangements for implementing the course are made by the Overseas Technical Co-operation Agency, a semi-governmental body. The courses are held in the sequence, geodetic survey, photogrammetry and cartography and printing. The purpose of this course is to introduce modern techniques of surveying and mapping in this country to participants through lectures, practical training and study tours. The problem in this course is that the background of the students is different. Some students are university graduates, but some are not. Therefore, it is recommended that the course should be divided into elementary and advanced classes.

SMALL-SCALE MAPPING FOR THE NATIONAL ATLAS OF INDONESIA

Paper presented by Indonesia[1]

The main purpose of a small-scale map is to provide a general view of the area the map purports to show. Its effectiveness as a visual aid is essentially the product of a compromise between technique of presentation and choice of scale. Scale further determines the size of paper upon which the map is drawn. The reverse, however, is sometimes also true, i.e., the size of paper sets the limit in the choice of scale.

Indonesia on one piece of paper

Several difficulties have been encountered in the attempt to determine the scale of the maps for the National Atlas sheets of Indonesia so that the country can be shown on one piece of paper. In the field of photography there is such a thing as a "photogenic" face, meaning that such a face makes good pictures. In mapping, perhaps we can apply the term "mapgenic" to countries that can be shown clearly on a map of almost any scale on a "well-balanced" and handy size sheet of paper.

Indonesia cannot be referred to as mapgenic. The scattered nature of the land area of the country renders clear presentation on small-scale maps of most items almost impossible.

The dominant position of Djawa in practically every aspect of economic activity is incongruous with its size. In drawing thematic maps for the country, this dominant position can and should not be ignored. This is the main reason that the ideal scale is very hard to discover, allowing sufficient detail of Djawa to be shown and yet still using a reasonably acceptable size of paper to include the other island.

Scale of the National Atlas maps

At present the maps of the National Atlas of Indonesia are published on two different scales. For pattern maps the scale of 1:5,000,000 is used and for point distributions the scale is 1:10,000,000. Neither scale is really satisfactory, but this is about as far as we can go, especially if the cost factor of printing is also taken into consideration.

The programme and the data

The Atlas was originally compiled to provide the public with an over-all picture of the potential, distribution and availability of the resources of the country. The speed of compilation depends in the first instance on the availability of well-organized basic data. It was generally known that numerous data on many aspects of resources had been gathered in the past but this valuable material was either hidden in the shelves of various government agencies or was published in many unrelated statistical tables or articles so that they very easily slipped attention.

After drawing up a seemingly ambitious programme, compilation of the first set of around twenty maps was started. It soon proved that the going was more difficult than expected previously. Many roads led down blind alleys. Statistical tables were found showing serious gaps both in time and breakdown. More often than not they even provoked suspicion. Facing these circumstances one can not help thinking of Josiah Stamp's statement, "The government are very keen on amassing statistics. They collect them, add them, raise them to the *n*th power, take the cube root and prepare wonderful diagrams. But you must never forget, that every one of these figures comes in the first instance from the village watchman, who just puts down what he damn pleases." Needless to say, the lack of consistent and systematically arranged basic data along with too frequent changes in items of a political nature or due to it seriously hampered the effort.

Progress

At present, thirty-five sheets have been published, including, among others, three maps of a general nature, two maps on the physical aspects, two maps on population, five about food production, three about animal husbandry; one on fishery, two about mining and industry, one about power supply, one about drinking-water supply for urbanized areas, two maps on communication, one on tourism, twelve maps on plantation acreage and some other maps on other items. The sheets are available individually.

Since in many cases we had to rely on "temporary, still to be revised, data", although officially endorsed, the sheets are labelled "provisional". The policy adopted by the board was to get the maps published first with the data available. In the meantime we hope that the published maps will encourage the collection of further and more reliable data in the future with which revisions can be made.

[1] The original text of this paper, prepared by I. Made Sandy, Directorate Land Use, Department of the Interior, Djakarta, and submitted under items 9 and 11 of the agenda, appeared as document E/CONF.57/L.77.

Prospects

The experience after the first year of the first five-year plan shows encouraging signs with regard to the quality and the availability of basic and other data in general. Although the village watchman's mentality and practices are all but vanished, the general awareness and requests from all quarters for accurate and reliable data resulted in the availability of more funds for data collection and, not to be underestimated, the necessary attention. With the funds now available, the mechanism for data collection and facilities is improved.

The coming population census will shed new light on population details. Improved facilities and quality of personnel can be expected to turn out more reliable figures. Finally, it is up to the map-makers to make out of them all that they can.

PHOTOGRAMMETRIC SURVEY AND MAPPING OF METROPOLITAN MANILA: A CO-ORDINATED PROJECT

Paper presented by the Philippines[1]

The photogrammetric survey and mapping of Manila and its surrounding cities and municipalities was conceived by the Board of Technical Surveys and Maps (BTSM) in April 1965. In early 1967 the National Waterworks and Sewerage Authority (NWSA) referred to the Board its urgent need for large-scale photomosaics and blueprint copies of topographical maps for the United Nations-assisted sewerage master plan covering these areas.

The project was intended to meet the demand for large-scale, comprehensive and up-to-date topographical maps of the area, with particular attention to sewage disposal, flood control, housing, taxation and traffic control. It was started in the middle of 1968.

Objectives

To satisfy NWSA and the requirements of other government agencies the following objectives were adopted.

(*a*) To prepare controlled photomosaics and topographic maps, scale 1:10,000, utilizing existing large-scale topographic maps, scale 1:2,000, 1:4,000 and 1:5,000 and other information;

(*b*) To compile by photogrammetric method other areas not covered by previous large-scale survey;

(*c*) To publish the results of the compilation.

Project organization

The work was undertaken by the BTSM as a co-ordinated project. A management committee was created to implement and give direction to the work. The committee consisted of the Vice-Chairman and Executive Director of the BTSM as Chairman, the General Manager of the NWSA and Director of National Planning, National Economic Council as members. The BTSM acted as the office of primary interest.

Area coverage

The project covered the four cities of Manila, Quezon, Caloocan and Pasay, the municipalities of Navotas, Malabon, Pateros, Pasig, Taguig, Las Piñas, Parañaque, San Juan, Mandaluyong and part of Muntinglupa, San Mateo, Marikina, Montalban, Antipolo, Taytay, Angono, Cainta, Makati, Marilao, Meycauayan, Obando, Valenzuela, Bacoor and Imus. This comprised about 715 km².

[1] The original text of this paper, prepared by the Board of Technical Surveys and Maps, appeared as document E/CONF 57/L.96

Agencies participating

NWSA contributed a levelling party which was attached operationally to the board. The Bureau of Coast and Geodetic Survey (BC&GS) organized three topographical survey parties and one precise level party for the field work. The photogrammetric facilities of the Bureau of Lands (BL) and the BC&GS were extensively utilized. The Training Center for Applied Geodesy and Photogrammetry, University of the Philippines (UPTCAGP), Land Authority (LA) and 516th EBTCO made available their laboratory and other facilities. The Bureau of Soils, Philippine Fisheries Commission and the local governments of Manila and Quezon City agreed to contribute financially to the project. Other co-ordinated agencies indirectly assisted in the gathering of source materials.

Financing

The NWSA allocated *P*100,000[2] as its contribution to the project. The Bureau of Soils and the Philippine Fisheries Commission contributed *P*15,000 each. The City of Manila and Quezon agreed to contribute *P*50,000 and *P*30,000, respectively.

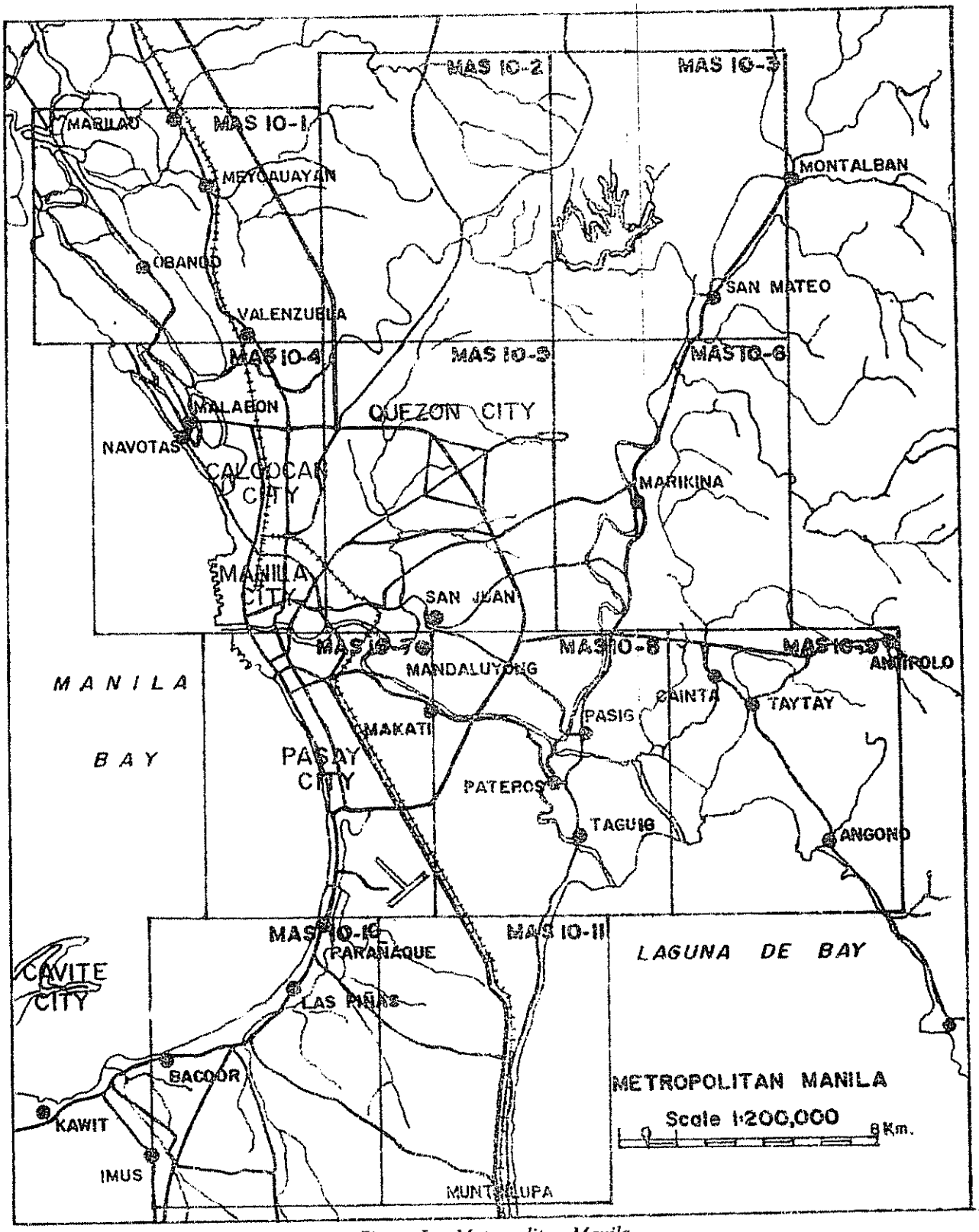
Estimates for undertaking the project tendered by private companies quoted a minimum cost of around *P*400,000. Records on the project showed that *P*118,000 was spent excluding salaries of personnel detailed to the project.

Planning and designing

Project areas were determined, delineated and identified by the NWSA. At an agreed scale of 1:10,000, metropolitan Manila was covered by eleven sheets with neat-line dimensions of 80 cm by 100 cm. Philippine plane co-ordinate grids were at 1 km² and geographic co-ordinates at one minute intervals. The map sheets, each covering 80 km², were numbered consecutively from left to right and top to bottom and a title based on their major area of coverage was allotted (see figure I).

The controls, both horizontal and vertical, consisted of recovered existing stations and those established by the field parties. An additional 18 horizontal and 48 vertical picture points were established and used in the mosaic and stereocompilation. These picture point controls were tied into the primary and supplementary controls of the area. The reference datums for horizontal controls

[2] At the then current rate $U.S. 1 was worth *P*6.40.



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Figure I. Metropolitan Manila

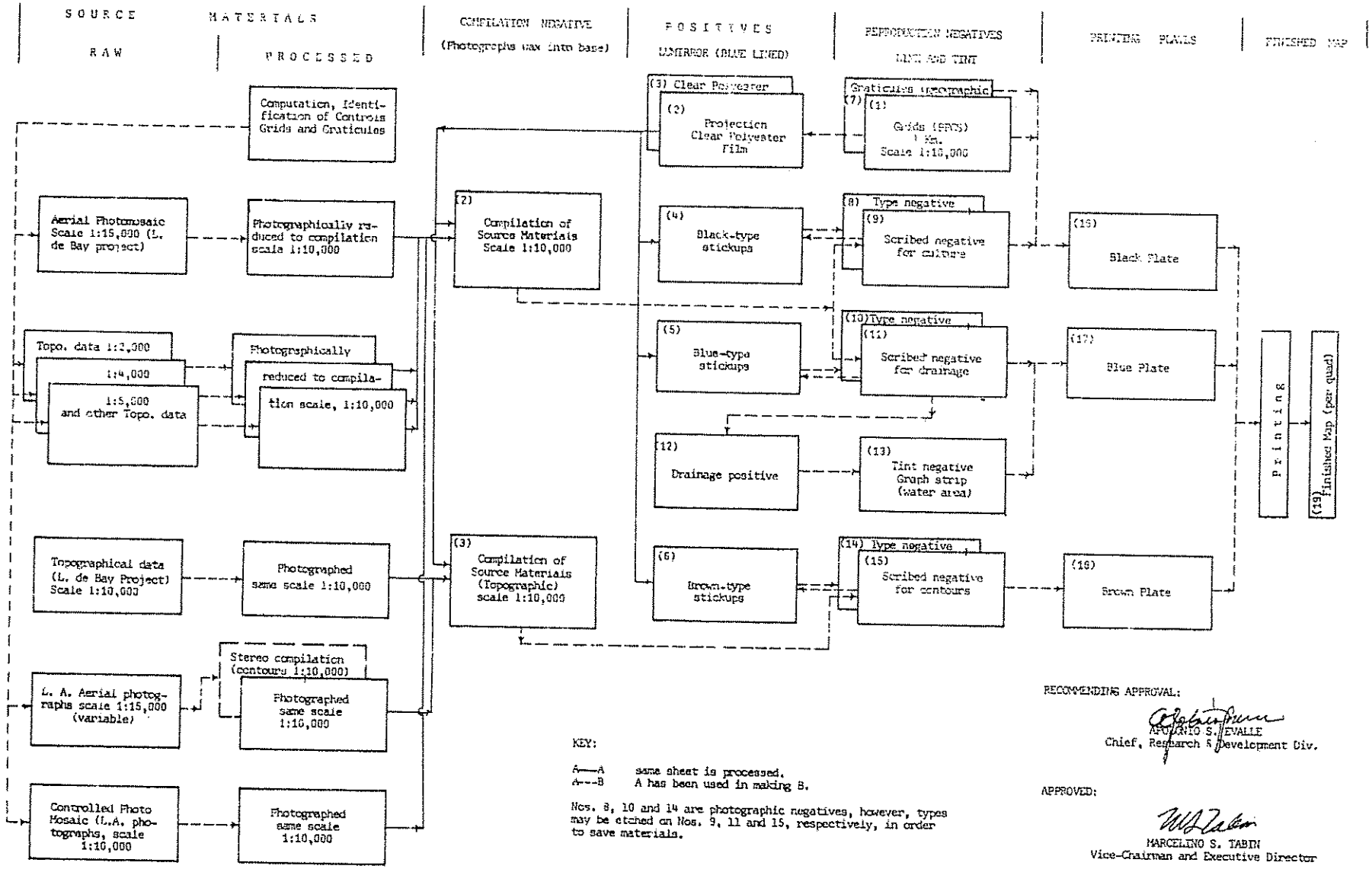


Figure II. Schematic diagram: Photogrammetric survey and mapping of metropolitan Manila

and elevations are the Luzon datum and the mean sea level, respectively. The projection used is the transverse Mercator.

Stereocompilation standards adopted by the BC&GS were made as a basis for plotting areas not covered by previous large-scale survey. Contour intervals were at 2 m with supplementary contours of 0.50, 1.00 and 1.50 m. Spot elevations were indicated on areas devoid of contour lines.

Wherever they exist, drainage and topographic features were shown on the map in accordance with accepted symbols. Other items were indicated as required by good mapping practice.

Surveying and Mapping Procedures

Scope of work

Specifically, the project called for the following:

(*a*) Establishment and/or recovery of ground and other supplementary controls needed for the execution of a controlled photomosaic and the compilation of topographic maps;

(*b*) Preparation of controlled mosaics and topographic maps.

Field work

Reconnaissance and preliminary observations were started by the NWSA levelling party, assisted by the BTSM technical personnel. Field work for the establishment of additional horizontal and vertical point controls and recovery of existing triangulation stations was undertaken by survey parties from the Bureau of Coast and Geodetic Survey (BC&GS). Three BC&GS topographical survey parties and one precise level party covered the area from Navotas to Parañaque and east to west from Taguig to Manila Bay. The NWSA levelling party executed the field verification and establishment of vertical picture point controls within some portion of the project of the project area.

Aerial photography

The vertical aerial photographs used in the mosaic and stereocompilation were taken by a private company for the LA using a Fairchild T-11 aerial camera with a focal length of 152.585 mm (6 inches). The scale of photography averaged 1:15,000.

Making photomosaics

Photomosaics were made at the UPTCAGP and Photogrammetry Division of the Land Authority.

The radial plot assembly utilized 14 × 14 inch Bristol boards and RS-11 radial secator. The slotted templates were assembled with the aid of metal studs on the assembly projection board scale 1:15,000. This was later enlarged to 1:10,000. Herculene plastics were adopted as base sheets during rectification on a SEG-V rectifier. The rectified prints were used in the mosaic operation.

Stereocompilation

Stereocompilation of areas not covered by previous large scale survey was executed by the BTSM and BC&GS with the co-operation of the 516th EBT Co. and the Bureau of Lands. Some 200 glass and film diapositives were prepared at the laboratory of the 516th EBT Co. Wild A-8, Wild A-7 and Stereoplanigraph C-8 stereoplotters of the BC&GS and the Bureau of Lands were utilized. The glass transparencies were used in the plotting of relatively flat and built-up areas.

Reproduction negatives

Source materials came from varied sources. Existing topographic data at 1:2,000, 1:4,000 and 1:5,000 were furnished by the Bureau of Public Works (BPW), numerous sketch maps by cities and municipalities and topographic maps and mosaics of areas around Laguna de Bay by Laguna de Bay Projects and L.A. aerial photographs. Statistical data and other information were furnished by some private agencies and co-ordinated government offices.

Most of these materials were reduced to the compilation scale of 1:10,000 by photographic process. Contours and elevations were referred to mean sea level (MSL) as some of the source materials have a NWSA datum of 0.472 m below MSL. Geographical co-ordinates of controls located and identified were converted into the Philippine plane co-ordinates or vice-versa. The positions of important landmarks such as road intersections and identifiable features were also determined. These data were used as guide in the final negative compilation (see figure II). Other topographical information was verified and checked with the data gathered by the NWSA field party personnel.

The negatives of the source materials were compiled and waxed on a (blue-lined) lumirror sheet. The compilation negative of each quad was finally contracted to three scribe coats reverse reading, for colour separation, planimetry drainage and topography. The scribe coat paints used were developed by the Research and Development Division of the BTSM. These sheets were coated at the BC&GS since the size of the sheet (1.00 × 1.20 m) was too big for the BTSM whirling machine.

Scribing was done in accordance with the specification for this type of map. A double-line scribing needle was extensively used in this project to produce such features as roads, drainage and other planimetric information.

Typed names were prepared on stick-ups printed by a Morisawa type-setting machine. The waxed stick-ups were pasted on clear lumirror sheets using the scribed features as a guide in the alignment. These overlays were photographically contacted to produce the negatives.

The NWSA requirement called for a final blueprint copy. To comply with this, it was necessary to combine all the negatives into a single reproducible positive. Seven negatives were preregistered and exposed separately on a single film. The processed film became the compiled positive for the white printing of the NWSA requirement.

After the NWSA requirement had been met, the negatives were readied for publication. Each of the eleven quads was finally edited to ensure that all the necessary information was included. Place names, street names and other information were carefully updated and verified. A colour proof of each quad was prepared to facilitate the editing. When the final corrections had been made the negatives were transmitted to the printer.

Maps Produced

The reproducible negatives of this project were used in the publication of a topographic map series of metropolitan Manila covering four cities and 24 municipalities

at a scale of 1:10,000. The printed series included additional features such as government buildings, schools and important factories. Both horizontal and vertical control points are indicated. The maps were published in three colours, black for culture, brown for contour and blue for drainage.

Topographic maps at 1:25,000 in two sheets of the same area were prepared out of these negatives. The first printed land-use map of metropolitan Manila at 1:25,000 utilized the same base.

Remarks and conclusion

The 1:10,000 topographic map provided the necessary data to support preliminary planning of the United Nations sewerage master plan for metropolitan Manila and opened new venues for the reproduction of other economic maps with this map as a base.

The expense incurred in the preparation of the maps was much less than the estimates made by some private companies.

The technical personnel of the board gained practical experience in map compilation from various sources and in co-ordinating with agencies and the staffs of other offices.

The project demonstrated that co-ordination of surveying and mapping agencies by the BTSM is effective and can deliver the goods on time. The last map sheet was delivered as scheduled.

The information furnished by these maps will greatly contribute to the planning of future engineering projects such as roads, subdivisions, zoning etc. Contour intervals of 2 m will facilitate future development of the area in the absence of large-scale topographic maps.

MAXIMUM UTILIZATION OF PHOTOMAPS FOR LAND PATENT SURVEY

Paper presented by the Philippines[1]

The most significant feature of the photomap for land patent survey is that it shows the configuration of the parcel of land as it appears on the ground. Using this as a guide, the possibility of committing a serious mistake in defining the position of the corners of the bounded land is reduced to the minimum. Moreover, a photomap can be used for defining boundaries especially where the corners of the lots are clearly distinguishable and well defined such as those present in rice lands, fish-ponds and other areas bounded by artificial or natural features. These types constitute a major portion of the total agricultural land area of the Philippines.

Needless to say, for a general type of terrain, the photomap may not be capable of yielding the end-product of a land patent survey which is the technical description of the lot, the sides of which are described by means of bearings to the nearest minute of arc and distances to the nearest centimetre and the position of the first corner of the lot defined by a tie-line from the Bureau of Lands Location Monument No. 1 of the municipality where the lot is located. Rather, it is an aid or a means of expediting the conventional ground survey or numerical photogrammetric survey. But if it is realized that in the Philippines no less than 300,000 hectares of public lands are being surveyed annually (including isolated surveys, public land subdivision surveys and cadastral surveys by ground method and numerical photogrammetry), then it would not be difficult to appreciate the value of a photomap if, as an aid, it can expedite the completion of the land patent survey of the country. There are compounded problems that delay the execution of field survey, office verification of survey returns and the final approval by the Lands Director. Worse, approval could have possibly been made for surveys which are erroneous, fictitious or otherwise encroaching on inalienable lands. With the aid of a photomap, these problems are minimized if not entirely eliminated. This can be realized if the photomap is utilized to the fullest extent in the projection of isolated, public land subdivision and cadastral surveys, in lot sketching, in old survey adjustment and in the production of cadastral maps.

Characteristics of a photomap

A photomap is a mosaic consisting of one or more rectified photographs joined together in such a way that it is bounded by a quadrangle of one-minute arcs of geographic latitude and longitude at the standard cadastral map scale of 1:4,000 on a convenient size of 0.5 m^2. If the sizes of the lots are very small, then larger scales of 1:2,000 or 1:1,000 may be prepared on the same size with quadrangles of 30 seconds or 15 seconds of arc, respectively. Photomaps at 1:8,000 or smaller scales may also be produced for indicating big survey projects.

The control for the rectification of photographs is provided by the main survey control of the project consisting of traverses or triangulation. A minimum of four photo control points located at the corners of each photograph is required. These points may be established from the main control by ground traverse or by serial triangulation.

The photomap as base map for projection of surveys

In the absence of a cadastral survey, all isolated surveys are projected on a one-minute-quadrangle map sheet by plotting the co-ordinates of the corners of the lots. This is done to prevent overlapping of surveys and to check against wrong geographic position of surveys. This does not, however, prevent the approval of fictitious surveys or surveys falling inside the forest zones, government reservations or even seas and lakes. So it can easily be seen that if the photomap is used as a base map for projection instead of a blank sheet, this cannot possibly occur, for the photomap provides more detailed information of the land where the survey is located.

In another aspect, the photomap offers a distinct advantage when it comes to the delineation of unoccupied

[1] The original text of this paper, prepared by R. B. Bautista, Supervising Photogrammetrist, Bureau of Lands, Department of Agriculture and Natural Resources, Manila, appeared as document E/CONF 57/L 97



Figure I. A photomap

alienable and disposable lands, forest reservations and national parks which have not yet been surveyed by precise methods. Here the photomap can also serve as a base map for the determination of the approximate technical description of these large tracts of land with sufficient reliability.

The photomap for lot sketching

Lot sketching is the delineation of the lots on the photomap. This is done in the field during the first phase of a cadastral project wherein the lot corners and property lines indicated by the claimants on the ground are marked by proper symbols and the names of the claimants are printed inside the lots. The photomap serves also as a guide in monumenting the lot corners and the final survey by the ground method or by the numerical photogrammetric method. *Barrios* and municipal boundaries are easily delineated on the photomap and the physical features such as roads, irrigation canals, rivers, creeks, lakes etc. can be clearly identified. Where the lot corners are not well defined, sketching may be made by tape measurements from well-defined nearby objects appearing on the photomap. In built-up areas such as the *barrios* and towns, sketching done with the use of surveying equipment may be reflected on the photomap by plotting the corners of the lots thereon.

It can be stated with certainty that in this phase of the survey, the use of the photomap accounts for a 50 per cent reduction in time and cost as compared with the use of plane table and stadia.

The photomap for old survey adjustment

It is a common occurrence in any cadastral project that there are several parcels of land which have already been surveyed and some of which may have been patented or titled. In this case, the bearings and distances of the boundaries of the old survey as stated in the technical descriptions of the patent or title are given more importance over the new survey of the adjoining lands within the cadastral project. In other words, if the discrepancies in the common boundary corners between the old and the new surveys are within the tolerance, the measurements of the old survey shall be adopted for the corresponding boundary corners of the new survey. The tolerance specified by the Philippine Land Surveyors Manual is 10 cm for the towns and 30 cm for the agricultural lands. It is admitted that the adjustment of old surveys to fit into the new cadastral survey is a tedious job and in most cases mainly responsible for the delay in the completion of the cadastral project. Observations reveal that many old surveys yield large discrepancies which are obvious on the photomap. These discrepancies are characterized by changes in the boundaries of the old surveys probably due to the following.

(*a*) Some old surveys were done with the use of less precise methods using a magnetic compass. Distances were measured in "varas" the exact relation of which to the "metre" is not defined;

(*b*) The monuments of the lot corners may have been moved by natural or artificial means;

(*c*) Natural boundaries such as those of the rivers, seas or lakes may have changed in the course of time;

(*d*) The old survey was erroneously executed.

The result is that the technical descriptions appearing in the titles are not correctly represented on the ground.

Large discrepancies are determined graphically by plotting the technical description of the old surveys on the photomap using one corner of the lot as a common point. These large discrepancies are visible on the photomap and are characterized by noticeable deviation in the shape of the bounded lot and/or decrease or increase in the number of corners.

If the discrepancies are not noticeable on the photomap, these may be determined by computations by comparing the photomap co-ordinate and the old survey co-ordinates. Statistical results showed that if the discrepancies between them exceed two metres (equivalent to 0.5 mm at photomap scale 1:4,000), it is most likely that the old survey does not correspond to the present corners on the ground by a horizontal displacement of more than two metres.

If the actual boundary is respected by both the owner of the old surveyed lot and the claimant to the new surveyed adjoining lot, there is the likelihood that the owner of the old surveyed lot will conform to the new survey if there are any discrepancies appearing on the photomap. This facilitates the old survey adjustment and eventually expedites the approval of the project. In fact, showing the actual boundaries of the land on the photomap to the landowner during the lot-sketching operations in the field is the most expeditious way of accelerating amendments to old surveys which are not truly represented on the ground.

Otherwise, if the title has to be followed, the actual boundaries on the ground must be changed in accordance with the relocation survey of the corners in question.

The photomap for determination of co-ordinates and tracing of cadastral maps

It is possible to obtain numerical data of lesser but sufficient accuracy from photomap co-ordinates in the same way as from stereoscopic model co-ordinates in numerical photogrammetry. These numerical data may provide the basis of the technical description of the land patent for a perfectly flat terrain. Otherwise, this may be used for purposes of proclamation over large tracts of unoccupied lands.

Unlike the stereoscopic model as observed in a first-order stereoplotting machine which gives the horizontal as well as the vertical positions, the photomap gives only a two-dimensional perspective position of the corners. A projective transformation of the photomap co-ordinates into the ground system using the four photo control points will automatically correct for the tilt and scale of the photograph. But the error due to height differences cannot be eliminated in this manner. Although it is possible to correct the photomap co-ordinates for relief error, it is a tedious job for so many points. Hence, it is advisable to make use of photomap co-ordinates in places where the differences in elevation in one photograph are less than one per cent of the flying height of the aircraft.

A comparison between the photomap co-ordinates and the stereomodel co-ordinates showed that under practical conditions, the standard deviation of the differences is well within one metre. Much more accuracy can be expected with ideal conditions where the photograph is rectified on a stable film transparency which is placed in the co-ordinatograph, and co-ordinates are measured with a magnifying

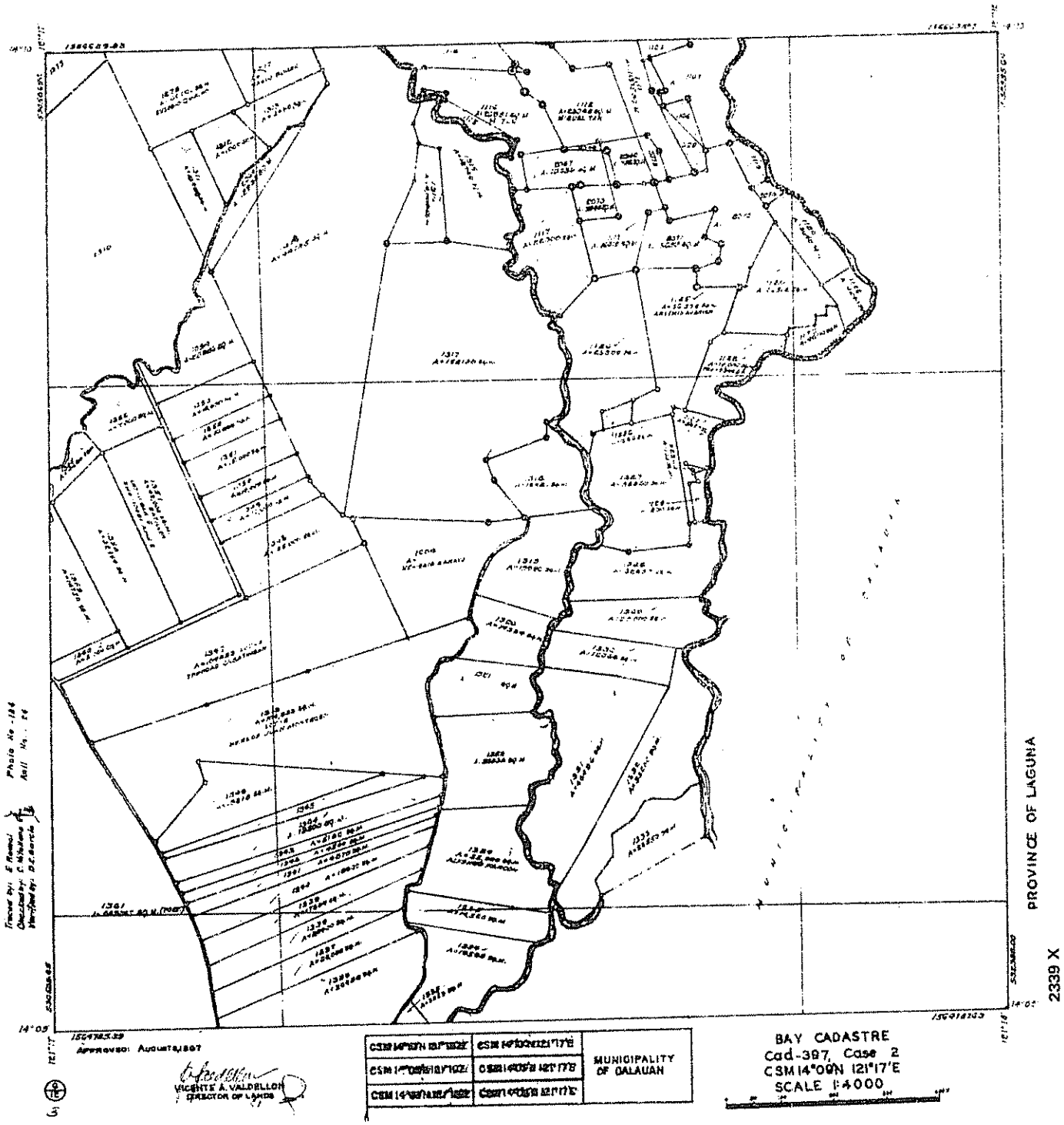


Figure II. A cadastral map traced from a photomap

lens to the nearest 0.1 mm. In this case, the photomap consisting of more than one photograph cannot be used for measuring co-ordinates since the points appearing at the joints are erroneous due to stretching and pasting.

When the corners are clearly visible on the photomap and the ground is relatively flat, the corresponding cadastral map can be traced from the photomap with sufficient drafting accuracy. This eliminates the tedious job of plotting the co-ordinates of many corners in a cadastral project.

ILOILO TAX MAPPING PROJECT

Paper presented by the Philippines[1]

The purpose of the Iloilo Tax Mapping Project in the Province of Iloilo, Central Philippines is to prepare tax-assessment sketch enlargements (photo tax maps) and accurate photomosaics for a province-wide application of inventory of real properties and their improvements and for economic development planning.

The project covers an area of 526,797 hectares of varied

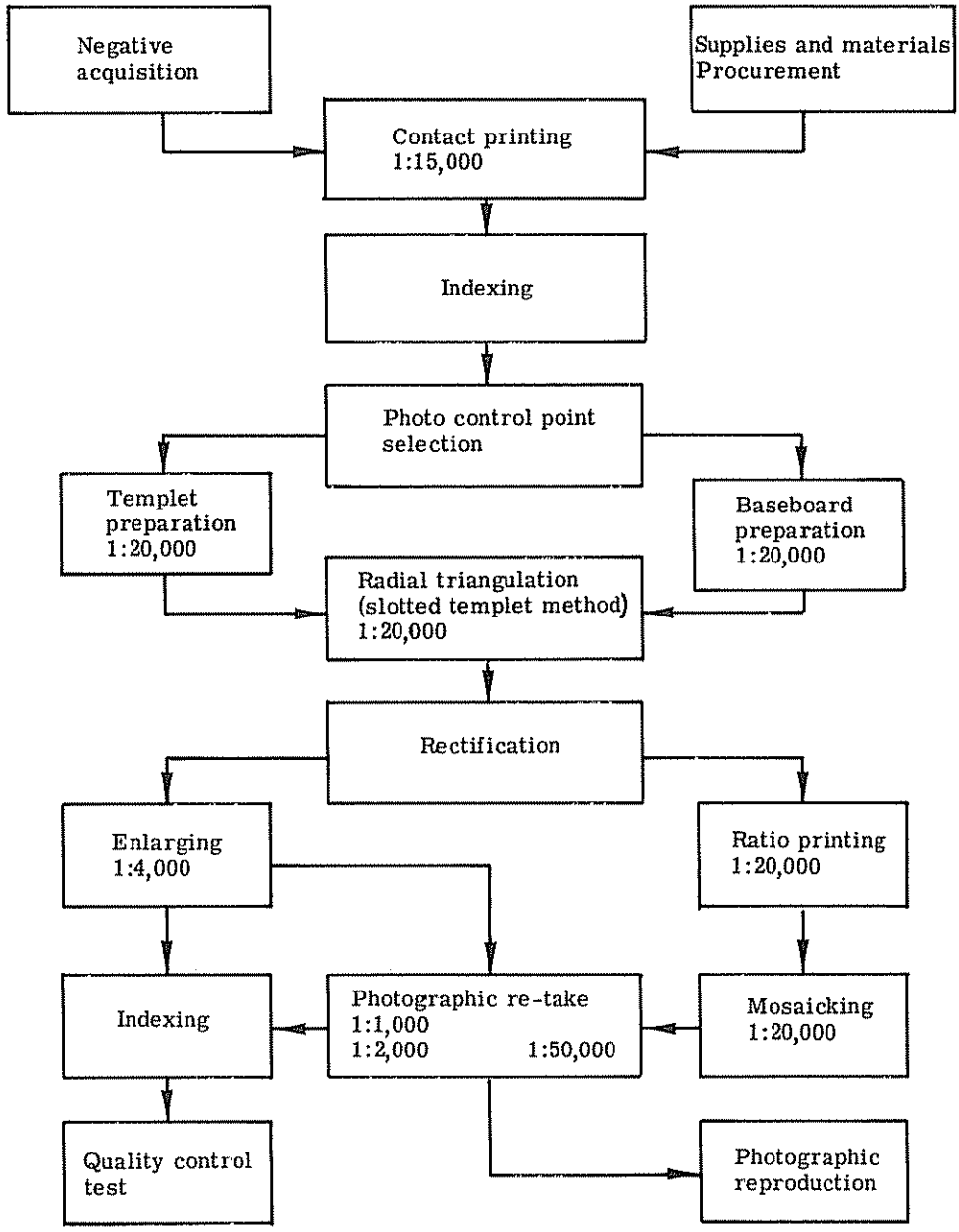


Figure I. Iloilo tax mapping project: Work flow diagram

photographic techniques of tax assessment, public works, agricultural, industrial and administrative development. In addition to these purposes, the project is intended to serve as a basis to effect an efficient, fast and equitable topography. The execution of the work is divided into five phases as follows:

Preparation of rectified sketch enlargements;
Construction of a controlled mosaic;
Lot-sketching using photo tax maps;
Photo-interpretation in land appraisal and property valuation;
Tax assessment or revision.

[1] The original text of this paper prepared by G. J. Umadhay, Assistant Professor, Training Center for Applied Geodesy and Photogrammetry, University of the Philippines, Diliman, Quezon City, appeared as document E/CONF.57/L.99.

The University of the Philippines Industrial Research Center (UPIRC) accepted the work as a research project and through its implementing arm, the Training Center for Applied Geodesy and Photogrammetry, University of the Philippines, assisted in the execution of the first two phases only of the work programme. The other phases of work are now being undertaken by the provincial government with a nucleus of 12 personnel trained at the Training Center for Applied Geodesy and Photogrammetry.

In the first two phases of the operation, the work flow diagram shown in figure I was followed. The project was initiated in July 1968 and was completed on 31 October 1969 at a cost of *P*9,741 (a progress chart is shown in figure II).

(*g*) 1,720 unrectified contact prints, 1:15,000, 10×10 inch SW;

(*h*) 406 rectified prints, 1:20,000, 10×10 inch, SW;

Observations

This project is unique in the sense that it is the first one of its kind to be conducted locally in an extensive area (526,797 ha). As such, procedures and techniques effective in foreign countries have and will have to be modified to suit local conditions. As an implementing unit, the Training Center for Applied Geodesy and Photogrammetry gained additional knowledge and experience and developed further its capabilities in rectification and in the construction of a controlled mosaic.

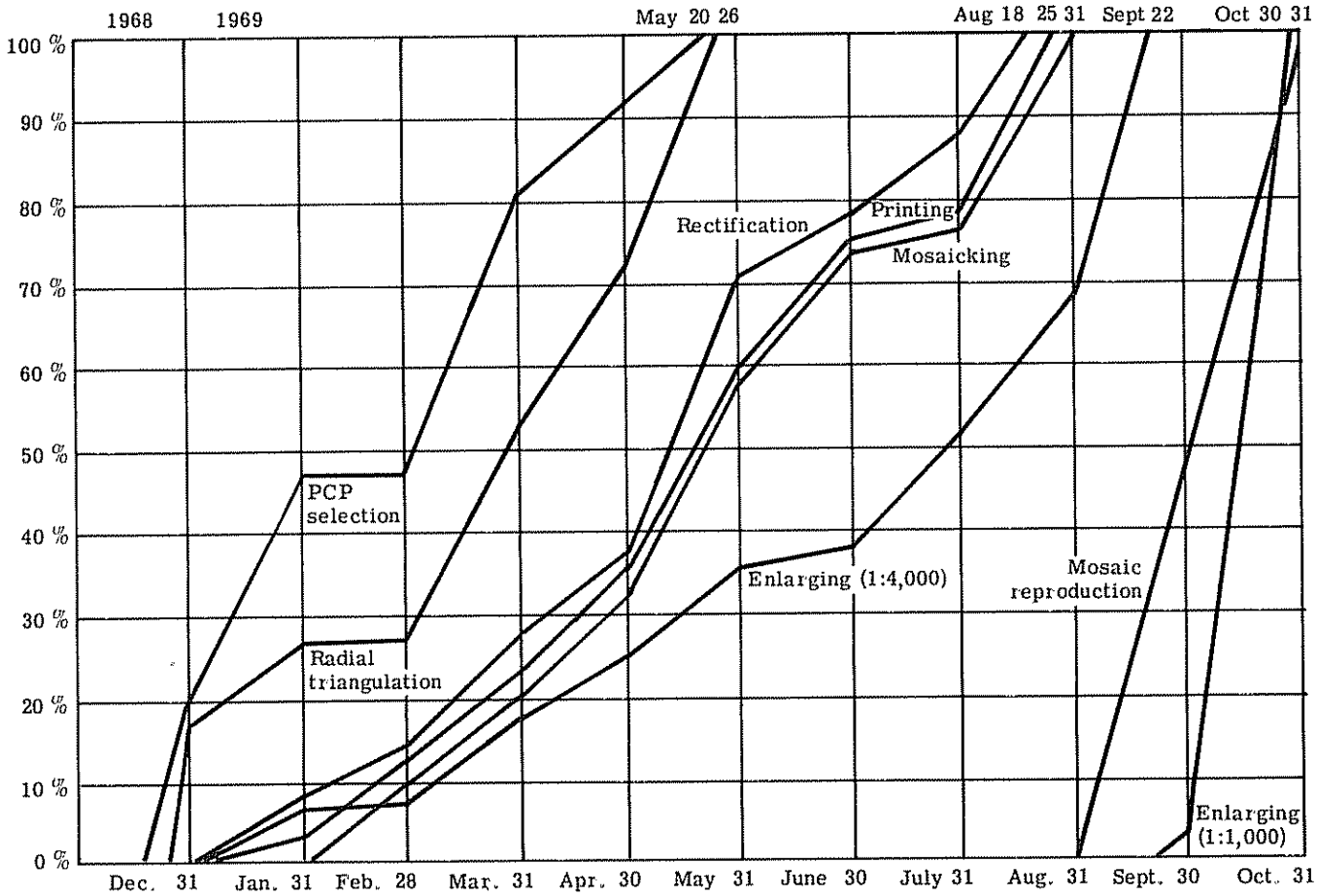


Figure II. Iloilo tax mapping project: Progress chart

The following materials have been delivered to and accepted by the Iloilo Provincial Assessor's Office:

(*a*) 212 sheets of 1:1,000 rectified enlargements, 20×24 inch DW;

(*b*) 119 sheets of 1:2,000 rectified enlargements, 20×30 inch DW;

(*c*) 1,505 sheets of 1:4,000 rectified enlargements, 20×33 inch DW;

(*d*) 115 sheets of 1:8,000 rectified enlargements, 10×15 inch DW;

(*e*) 9½ sheets of 1:20,000 controlled mosaic, 4×8 ft;

(*f*) 60 reproduced copies, 1:50,000 of the controlled mosaic;

Theoretically, rectification is applicable only in relatively flat terrain where the relative relief is about 3 per cent and in no case exceeds 10 per cent. In this project, relative relief averages 10 per cent in rolling areas and 50 per cent in mountainous areas. This is a defensible example of clearly extending the efficacy of photogrammetry beyond its normally expected capabilities. The justification for this action is the production of economically and expeditiously second-quality tax maps in areas of relatively low values having no tax maps at all.

As a research project, trials and tests have to be conducted. Consequently, needed materials and supplies as well as the time required for conducting the research could not be accurately estimated in advance. These

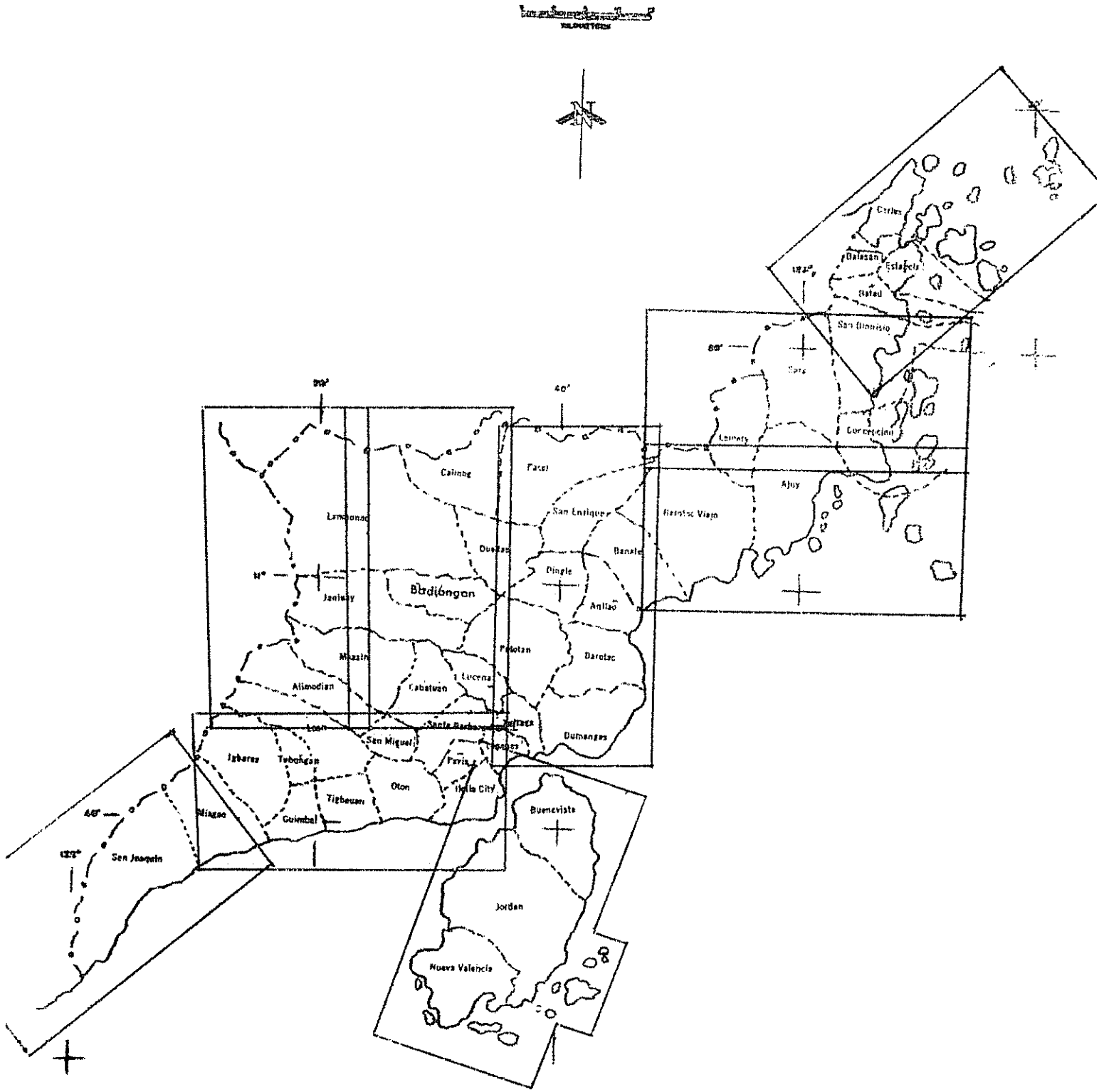


Figure III. Iloilo tax mapping project: Location index of controlled mosaic, 4′×8′, 1:20,000

2340 X

uncertainties affected the funding of the project. Another problem that hampered the progress of the work was the scarcity and, in some cases, the unavailability of the needed materials and supplies in the local market. This was compounded by delayed delivery of the imported materials and supplies.

SURVEYING AND MAPPING THROUGH AERIAL PHOTOGRAMMETRY AND PHOTO-INTERPRETATION FOR INVENTORY OF RESOURCES, DELINEATION OF BOUNDARIES AND GRAPHICAL CADASTRE

Paper presented by the Philippines[1]

Surveying and mapping the national territory can be done most effectively and economically in the shortest time possible by the following methods and techniques of aerial photogrammetry.

(*a*) *Aerial photography.* Photographic missions have to be flown over the area to be mapped using a precise survey camera. The scales to be used vary depending on what is appropriate to the demands of the areas and the uses of the photographs.

(*b*) *Geodetic field controls.* To fix the position of photographs accurately on the ground, and for rectification and adjustment of scale of photographs before assembling them into mosaics, ground controls should be established. These consist of horizontal controls for planimetry and vertical controls for elevation. They should be established at the proper intervals and density and referred to national datum. Use of the Philippine plane co-ordinate system has just begun and many local systems have not yet been connected. This is essential in a country-wide photogrammetric surveying project.

(*c*) *Preparation of photographic mosaics.* In order to provide base maps for the various phases of the mapping project, photographic mosaics have to be prepared at scales demanded for the specific use desired. For example, if it is to be used for property land surveys, the mosaics have to be prepared at 1:4,000 covering one-minute quadrangles, or if it is used for photo-interpretation for forest classification, it is prepared at scales of 1:15,000 etc. In areas which have not yet been mapped, mosaics at 1:50,000 may be prepared to be used as base and index maps.

(*d*) *Property mapping.* Perhaps the most important photomapping project that should be given the first priority is property land mapping or photo-cadastral mapping, which is simply the delineation of property boundaries on the photomaps, because of the current national problem of land-grabbing. Cadastral surveys have been in progress since 1906 using the conventional ground method, but this is very slow and expensive. In about 64 years, surveys of only 480 municipalities have been completed out of the 1,380 cities and municipalities of the archipelago. With the present values, the cost averages *P*400,000 per municipality. It can easily be seen that it would take a hundred years more to complete the whole Philippines at a tremendous cost. With the use of photogrammetric techniques, it is possible to complete the delineation of property boundaries on photomosaics of all unsurveyed municipalities within the next 10 years at about one fifth of the present cost.

Under present rules and regulations, Torrens titles are not issued with these photo-cadastral maps, but cadastral titles may be issued based on the photographic description of the property with some limitations or conditions which should be the subject of a thorough study.

(*e*) *City topographic mapping.* With the photographs topographical maps can be prepared at a scale of 1:2,000 and with one-metre contour interval, of all cities and municipalities. These maps are necessary for planning and development.

(*f*) *Photo-interpretation.* Through the techniques of photo-interpretation with a minimum of field investigation, plenty of essential information can be gathered and tabulated from the photomosaics. This may be called a natural resources inventory of land, water, mines or forests, so that well-integrated plans can be prepared for their exploitation and development.

Information and data are classified as follows:

(*a*) *Land-use maps.* Through the programme of photo-interpretation and field checking, land-use maps can be prepared with the use of photomosaics prepared at convenient scales;

(*b*) *Geology and geomorphology.* Using a combination of photo-interpretation and field investigation, essential information on the shape of lands, slopes and origin of materials for agricultural soils can be shown on the photomaps. Geologists and scientists can also show structure, textures and limiting factors of agricultural soils;

(*c*) *Forestry.* Through photo-interpretations and field checks, forest engineers can delineate on the photomaps, permanent forest reserves, timberland, agricultural land that can be released, pasture lands, rate of growth of forests, species etc.;

(*d*) *Canal mapping and road layout.* On the mosaics and on the photostereopairs, the ground surface can be seen in three dimensions so that it is a simple matter to plan and draw canal locations and other installations like dams, headgates etc.

(*e*) *Hydrology.* From the photomosaics, the quantity of water and capacity of watershed reservoirs can be accurately determined and combined with other data on meteorology and climatology. Essential data is made available for the location and kind of dams that can be used for irrigation, hydro-electric power and other engineering construction such as bridge sites, levees etc.;

(*f*) *Mineral resources inventory.* In areas which are suspected of having mineral deposits such as oil, coal, iron, copper etc., it is necessary to attach a sensitive instrument known as a magnetometer to the photographic plane on missions. Essentially, this instrument detects magnetic anomalies and records them at every instant of film exposure. With these data plotted on the photomosaic, the geologist or mining engineer can localize the area for prospecting and investigation in the field;

[1] The original text of this paper, prepared by A. A. Salvador, Chief, Surveys Division, Bureau of Lands, Manila, appeared as document E/CONF.57/L.100.

(g) *Land-use capability and economic studies.* Through the integration of results of many of the above studies, a national index of the market value of all lands in the Philippines as well as the determination of the agricultural use and capability of land can be prepared.

This is a list of many of the possible uses and applications of the photomosaics prepared through the method and techniques of aerial photogrammetry.

DELINEATION OF POLITICAL BOUNDARIES

One of the problems retarding development in the Philippines is the non-delineation of political boundaries between municipalities, cities and provinces. Much effort and time have been wasted in court and administrative cases which had been dragging on for years.

Graphical cadastre by photogrammetric methods appears to be the best and fastest solution to this perennial problem. The following is the recommended method:

Case 1—Boundary is agreed upon by adjoining political subdivisions. The ground survey party with the aid of local governments will simply monument agreed boundary and paint the ground area with whitewash to a diameter of three feet before aerial photography. The political boundary can be delineated in the resulting photomosaic. The job should be done simultaneously with a graphical cadastre of the area.

Case 2—Dispute in the boundary line. The contending parties will be required to direct the ground survey crew to place smaller monuments along the line which each believe to be the correct boundary. These would likewise be surrounded with whitewash before aerial photography is executed. These lines will also be indicated in the resulting graphical cadastre map of the area. This map will be the basis for the proper authorities of the government to decide on the true and correct political boundary.

In conclusion it can be said that photogrammetry and photo-interpretation can be very useful in discovering the natural resources of the country as well as in providing useful cadastral maps containing private and political boundaries.

EDUCATION AND TRAINING OF CARTOGRAPHIC PERSONNEL AND SENIOR CARTOGRAPHERS OF DEVELOPING COUNTRIES AT THE INSTITUT FÜR ANGEWANDTE GEODÄSIE (INSTITUTE FOR APPLIED GEODESY)

Paper presented by the Federal Republic of Germany[1]

According to resolution 20 on training facilities adopted by the Fifth United Nations Regional Cartographic Conference for Asia and the Far East, Canberra, 1967, all countries were invited to present detailed information about their educational facilities in cartography and hydrography in so far as they are or can be made available to foreign trainees and to send this information to the Cartography Section of the Department of Economic and Social Affairs, United Nations, for dissemination to all countries and to the International Hydrographic Bureau in respect of training in hydrography.

For several years cartographers, coming from official or private institutions of developing countries, have been trained at the Institute in special subjects such as geodesy, photogrammetry, cartography and reproduction techniques in courses of different duration. In response to many inquiries received from developing countries, the Institute has arranged for a training course in mapping techniques which lasts one year. This course is held in connexion with the general measures of promotion and furtherance of developing countries taken by the Government of the Federal Republic of Germany.

The admission to such a training course is only possible if the trainee, after a full education in a primary school, has worked several years as a cartographic draftsman and has attended a four-month course of German in a Goethe Institute. As a rule, the age of the applicant should be between 18 and 35 years.

The aim of this twelve-month training course is to convey practical skills and theoretic fundamentals in the field of cartography.

The training programme includes the preparation of map originals and map manuscripts of all kinds and of different scales on paper, transparent plastic foils or other drafting bases. Thus the trainee, by using diverse tools and drafting instruments, also gets as broad a view as is required for choosing rational working methods.

The training covers mapping, surveying, construction of map projections, mathematics for cartographers, photogrammetry, reproduction techniques in connexion with a course in reproduction, town surveying and thematic mapping.

There are practical exercises in map design, generalization for derived map scales, lettering, colouring, scribing on plastic foils, mounting, representation of relief and map maintenance and revision.

A schedule for this training course has been established and is shown in the annex. After the first three months the trainee has to pass an examination, the result of which will decide whether or not he satisfies the requirements for a continuation of the training as cartographer or senior cartographer. If this examination is passed the training is continued according to the schedule. The course ends with a final practical and verbal examination to ascertain the acquired skill and knowledge of the trainees. The successful completion of the training is confirmed by a certificate.

A trainee who has acquired this certificate is now able to work as a cartographer or senior cartographer in his home country. The range of his activities may extend from the design of maps to the preparation of printing originals, as well as to advising or directing a working group of younger cartographers.

In case the first examination after three months is not passed, the following nine months are provided for an activity in a special field of cartography according to the capabilities of the trainee.

[1] The original text of this paper, prepared by H. Knorr, Director, Institut für angewandte Geodäsie, Bonn, and submitted under items 9 and 12 of the agenda, appeared as document E/CONF 57/L.101.

Persons interested are invited to contact the Embassy of the Federal Republic of Germany in their home country, and to refer to the training course for cartographic personnel and senior cartographers at the Institut für angewandte Geodäsie, Kennedyallee 151, Frankfurt am Main.

ANNEX

Institut für angewandte Geodäsie, Frankfurt am Main: Time schedule for the training course in cartography

First month	Second month	Third month
First week Introduction General information Organizational and administrative affairs Introduction into work	*First week* Basic mathematics Mapping Surveying Map projections Elaboration and exercises	*First week* Mapping, photogrammetry and topography Reproduction techniques Large- and small-scale mapping and thematic cartography Geography and morphology Elaboration and exercises
Second week Basic mathematics Mapping Elaboration and exercises	*Second week* Basic mathematics Mapping Surveying Map projections Elaboration and exercises	*Second week* Mapping, photogrammetry and topography Reproduction techniques Large-scale mapping and town surveying Small-scale mapping and thematic cartography
Third week Basic mathematics Mapping Surveying Elaboration and exercises	*Third week* Basic mathematics Mapping Photogrammetry and topography Map projections Reproduction techniques	*Third week* Mapping Reproduction techniques Large-scale mapping and town surveying Small-scale mapping and thematic cartography Elaboration and exercises
Fourth week Basic mathematics Mapping Surveying Elaboration and exercises	*Fourth week* Basic mathematics Mapping Photogrammetry and topography Reproduction techniques Geography and morphology	*Fourth week* Mapping Problems of organization Examination
Fourth month	**Fifth month**	**Sixth month**
First week Draft and generalization of a section of a wall map	*First week* Generalization of contour for the International Map of the World on the millionth scale and for the World Aeronautical Chart ICAO 1:1,000,000	*First week* Visit to the Institute's branch in Berlin
Second week Explanation and practice in the selection of symbols and their location in the legend of a map 1:1,000,000 scale (exercises on astralon)	*Second week* Generalization of culture at various scales	*Second week* Draft and generalization at 1:100,000 for the 1:200,000 scale map
Third week Draft and generalization of culture for the World Aeronautical Chart ICAO 1:1,000,000 (WAC)	*Third week* Continuation of the generalization of culture	*Third week* Generalization of contours for the 1:200,000 scale map
Fourth week Draft and generalization of culture for the International Map of the World on the millionth scale (IMW)	*Fourth week* Continuation of the generalization of culture and draft for lettering Tinting of the drafts for WAC and IMW 1:1,000,000	*Fourth week* Exercises in engraving on plastics

Annex (*continued*)

SEVENTH MONTH	EIGHTH MONTH	NINTH MONTH
First week Engraving on plastics for topographic map 1:200,000 scale	*First week* Exercises in the preparation of relief shading	*First week* Same as above and subsequent week
Second week Continuation of engraving on plastics for topographic map 1:200,000 scale Mounting based on Gauß-Krüger co-ordinates	*Second week* Continuation of the preparation of relief shading	*Second week* Preparation of large-scale maps in State survey offices
Third week Preparation of a relief model	*Third week* Practical work in reproduction procedures	*Third week* Same as above
Fourth week Preparation of a relief model Explanation of vacuum forming Theoretics and practical instruction in silk-screen printing	*Fourth week* Same as above	*Fourth week* Same as above
TENTH MONTH	**ELEVENTH MONTH**	**TWELFTH MONTH**
First week Participation in a course on photographic procedures held by Messrs. Klimsch	*First week* Same as above Visit to Aeroexploration, Frankfurt	*First week* Intensified training according to individual requests of participants
Second week Visit to the town survey office and practical work	*Second week* Explanation of photo setting and electrostatic printing Cartographic research Research in reproduction	*Second week* Same as above
Third week Visit to the "Institut für Landeskunde", Bad Godesberg	*Third week* Explanation and practical co-operation in the service of map maintenance	*Third week* Same as above
Fourth week Visit to the photogrammetric division of this Institute and practical work	*Fourth week* Examination	*Fourth week* Same as above Final work Farewell

Note. Duration of the course: twelve months. Examinations after three months and at the end of course.
Special arrangement: Participation in the German Cartographic Congress.
Certificate: Cartographer.

BASIC DIRECTIONS FOR LARGE-SCALE (URBAN AND CADASTRAL) TOPOGRAPHICAL SURVEYS IN THE UNION OF SOVIET SOCIALIST REPUBLICS

Paper presented by the Union of Soviet Socialist Republics[1]

In the USSR, the following scales have been adopted for large-scale plans: 1:5,000, 1:2,000, 1:1,000 and 1:500. The scale 1:10,000 serves as a connecting link between the large-scale and medium-scale surveys (1:25,000 to 1:50,000).

Plans on these scales are widely used in different branches of the national economy. Each branch sets up its own demands concerning the contents of planimetry and relief representation on such plans, and their corresponding accuracies. Some years ago an attempt was made to introduce some unification of these requirements. Following the analysis of voluminous material, it was possible to formulate the *Basic Directions for Making Topographic Plans on the Scales 1:5,000, 1:2,000, 1:1,000 and 1:500*.

The main features of the *Basic Directions*, which were approved as a State standard, are the following:

(*a*) As the principal methods of making plans, the stereotopographic and combined methods are recommended, depending on the height and density of the vegetation cover. The plans may be presented both as graphic or digital models of the mapped area, the latter models being obtained with the aid of electronic computing machines. The making of digital maps is now in its infancy. At the same time, research work in this direction is being carried out. This is one of the promising methods

[1] The original text of this paper, prepared by the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography, Moscow, appeared as document E/CONF.57/L.108.

of evolution of large-scale topographical surveys, especially as regards investigations in engineering geodesy, cadastral and underground work;

(*b*) An attempt was made to define the types of plans that are needed for solving various engineering–geodetic and other problems encountered in different branches of the national economy. This is a most complicated question, which it has not as yet been possible to solve in full;

(*c*) In the *Basic Directions* the problem of making topographic plans differing in accuracy as to relief representation depending on the purpose of the plans has been solved in the following way. Unified contour intervals of 0.5 m, 1.0 m, 2.0 m and 5.0 m, and constant accuracy requirements with regard to vertical data were established. The mean elevation errors should not exceed: $\frac{1}{4}$ of the contour interval at $\alpha \leqslant 2°$; $\frac{1}{3}$ of the contour interval at $2° \leqslant \alpha \leqslant 6°$ for plans at 1:5,000 and 1:2,000, and at $\alpha \leqslant 10°$ for plans at 1:1,000 and 1:500.

The maximum admissible errors of the vertical survey should not exceed twice the value of the mean errors. The number of maximum admissible errors should not be more than 10 per cent of the number of check measurements. In wooded land these tolerances are increased half as much again.

By a proper choice of contour interval—the accuracy requirements for relief survey being constant—the technical-economic problem of producing plans of different accuracy to satisfy simultaneously the requirements of numerous projecting organizations could be solved. Any reduction of the contour interval which is not strictly necessary leads to an increase of the cost of the survey;

(*d*) The mean square errors in planimetry should not exceed 0.5 mm at the scale of the plan. In the cases when the indicated graphic accuracy is not necessary for technical calculations on hand, the plans may be made with an accuracy established for neighbouring plans of a smaller scale. So, for instance, plans at 1:5,000 may have their accuracy fixed by maps at 1:10,000 and so on.

The plans may be edited in the form of photomaps or line originals drawn on paper or scribed on plastic. The possibility of substituting decalcomania for drawing and scribing of single conventional signs and digital data is contemplated. This should make it possible to reduce expenses.

The *Basic Directions* also define the requirements concerning the density of geodetic control, the size of survey sheets, the methods of serial survey and those of photo-interpretation. The sequence and terms of revision of topographic plans have also been established.

This standardization of requirements to be met by large-scale surveys will secure better and fuller utilization of these surveys in various branches of the national economy and in this way there will be a reduction in expenses.

ANALYTICAL PHOTO-TRIANGULATION IN TOPOGRAPHIC MAPPING

Paper presented by the Union of Soviet Socialist Republics[1]

The essence of analytical methods consists of the mathematical description of the adopted process of increasing the density of the geodetic ground-control network and in solving the problem by means of electronic computers. Progress in these methods is inseparably linked with the state of computing technique and the broadening of the field of its application.

The principal advantages of analytical methods are that they allow rigorous mathematical solution, make it possible to take into account various sources of the image errors in the best way, use compensating computations, reveal coarse errors etc. In short, they provide a good opportunity to improve accuracy, raise labour productivity and increase economic efficiency. The development of analytical methods in the USSR follows two main directions.

The first is three-dimensional photo-triangulation with simultaneous least-squares adjustment, the usual procedure using single images, i.e. directly measured values as units. The programmes based on this principle call for aerial block triangulation.

A number of problems have to be solved in this case. These are the determination of the optimum methods for solving the systems and selection of computers best suited for this purpose, the search for the best ways of allowing for systematic image errors, acceleration of the convergence of the iterative methods etc. For the solution of such problems high-speed computers are normally used.

Increasing the density of the geodetic ground-control network by forming blocks of single images proved to be particularly expedient in mapping at 1:25,000 to 1:100,000 and smaller scales. The largest blocks which can be adjusted with such programmes comprise up to 150 photos. In this case, using aerial photographs with a 60 per cent lateral overlap makes it possible to cut down the volume of expensive work considerably.

The second method, namely photo-triangulation, using approximate methods to solve the problem, has found wide application in the USSR. This involves different variances of programmes, all based on joining dependent, independent and partly dependent models, that is the solution to a greater or lesser extent of simulating constructions on analogue instruments. One of the above variances is represented by the analogue–analytical method.

The advantage of using approximate methods lies in the possible use of medium-scale computers, allowing for accumulated systematic errors by the method of least squares using polynomials, and in relatively simple mathematical descriptions of processes which can readily be estimated and checked by stages.

Research in the problems related to the method considered is focused on looking for the optimum variances of mathematical description of individual processes, taking account of weights and correlations in a complex multi-stage transformation of the measured values, increasing the accuracy of photo-triangulation as well as the efficiency and flexibility of the programmes used.

Analytical triangulation gives a 30 to 40 per cent gain

[1] The original text of this paper, prepared by the Central Scientific Institute of Geodesy, Aerial Photography and Cartography, Moscow, appeared as document E/CONF.57/L.109.

in planimetric accuracy as compared with analogical aerial triangulation. Again, it is more effective economically.

Analytical block triangulation provides a further increase in accuracy and enables one to raise the problem of substituting some field geodetic determinations by photogrammetric ones.

Analytical triangulation in the USSR is performed with a Carl Zeiss stereocomparator and high-precision stereocomparators manufactured in the Soviet Union. The main constructional features of the Soviet high-precision instruments are that each photograph can move independently along two co-ordinate axes, that the principle of precise measurements with fixed optical observation system (Abbe's principle) has found the fullest application in this instrument and that an automatic reading and recording device graduated to 1.00–1.25 μm and based on meteorological diffraction gratings is provided for each of four co-ordinate movements. The current co-ordinates measured are displayed on a light panel and punched automatically into the tape suited to serve as a computer input tape. A binocular optical observation system with magnification of $\times 8$ to $\times 20$ ensures a precise stereoscopic and monocular fusion crossing the two optical paths to obtain a commutation of images and image rotations. The precise stereoscopic identification of corresponding points in two adjacent models can be attained by restoring the readings obtained from the measurement of the previous stereo pair. The instrument is provided with photorecording and projecting devices which can be used to identify corresponding points in the adjacent strips stereoscopically.

The accuracy of stereoscopic fusion to the points of good-quality images is characterized by a mean error of ± 2.8 μm, whilst the over-all precision of the instrument is given by

$$M_{x,y} = \pm 1.0 \text{ to } 1.4 \text{ μm}$$

Devices for identifying and marking image points are produced in the USSR for the identification of corresponding points in the adjacent strips when using analytical methods.

Further studies in the field of analytical photo-triangulation are aimed at working out methods for estimating photogrammetric constructions and at increasing the accuracy and economic efficiency of the programmes for block and strip triangulation, as well as at making them more universal.

EXPLORATION OF THE EARTH'S NATURAL RESOURCES BY AERIAL METHODS

Paper presented by the Union of Soviet Socialist Republics[1]

Aerial methods are widely used for different types of exploration and work directly or indirectly connected with the study of the Earth's surface, with processes occurring on it and with the mastering of its natural wealth. Of all the aerial methods used at the present time, the most widespread and efficient is that of aerial photography.

Development of technical means and methods to record information concerning the Earth's surface by photoreceivers, as well as methods of data selection and processing, are closely related to the perfection of our notion of the objects to be explored. Many external manifestations of the internal characteristics, unknown before, have best been revealed only with the use of aerial methods, as was the causal relationship between natural objects.

Natural complexes are depicted on aerial photos, the separate elements of the complexes being in a complicated interrelationship. That is why the aerial photoprint of a locality always becomes a landscape imprint by its content. Combinations of methods of topographic and landscape identification of the aerial photographs provide even more complete information on a locality. Landscape methods are successfully used for the exploration of tectonics of the sedimentary cover of level areas, for engineering geology and hydrogeological investigations, for study of the quaternary deposits, etc.

Most recently the variety of manifestations and the non-functional nature of the causal connexions between the natural objects raised the hope among explorers of introducing schematic geometrical constructions and methods of mathematical statistics in quantitatively evaluating these connexions and increasing the reliability of the forecasts on this base. The coverage of large areas, accuracy of the representation of the Earth's surface and the possibility of obtaining more precise data on natural objects are provided either by aerial survey material or by maps compiled from aerial survey data.

Further increase in the efficient use of aerial photographic methods is possible by the reduction of the scale of aerial survey as compared with the scale of the map being compiled and by research on high-quality air photographs.

As is generally known, during flights of "Soyuz" space ships, synchronous air surveys of the same areas were carried out from both the space ships and aircraft. At the same time optical and other observations of natural objects were done on the ground. The main objects of the experiment were to determine the reliability of photoprint quality, whether any optical and geometric generalizations concerning the altitude for photography could be made and to find any comparative evaluation of the opportunities for geological and geographical identification from the photographs obtained.

Photography of the surface of the Earth from high altitudes, even from Space, taken at small and very small scales with lenses of high resolution power opens qualitatively new ways for geological, geographical and other investigations.

Space photographs cover considerably larger areas, as compared with the aerial photos, with a view of vast territories under the same guaranteed natural conditions (illumination, state of the photographed objects, etc.). Thus, tasks which are not provided for by the air survey can be solved with the use of space photographs. As compared with the available cartographic data of the same scale, the space photographs guarantee the accurate representation of the locality to be surveyed, with the unilateral principle of generalization, whereas any map

[1] The original text of this paper, prepared by the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography, Moscow, appeared as document E/CONF.57/L.122.

reflects the preconceived ideas of its author and includes faults of heterogeneous initial data.

Refinement of methods and instruments to study the reflected spectrum of the natural objects requires choice of the most suitable type of film and absorption filter, with the aim of recording the largest amount of information on the photographs produced by the new photo-electronic method of aerial survey. This method is based on taking the aerial photos in the narrow zones of the spectrum and it is of greater spectral distinction than the conventional aerial survey. It allows for the identification of objects by their own specific, distinctive features.

The air magnetic survey, that is the measurement of the magnetic field of geological complexes is the basis of the oldest and most widely used aerial method. Air magnetic surveys at large scales are carried out at the present time (1:25,000, 1:10,000) which are being introduced as substitutes for the ground field work. The efficiency of high-precision magnetic investigations depends to a considerable degree on success of interpretation and on the development of new methods of evaluating parameters. Computers are widely used in this particular field.

Aerial gamma-ray surveys are used considerably for geological mapping and for prospecting for mineral resources. They are based on the study of natural gamma-radiation. Considerable absorption of gamma-radiation by the atmosphere of the Earth limits the altitude of the survey to 150 to 200 m and that is why the method is not suitable for study of the Earth's surface and radiation from planets.

Electroprospecting is also a classical method of air-geophysics. Different modifications of the electroprospecting methods are comparatively slow in development at present, which to a certain degree is connected with the high cost and complicated nature of the apparatus.

Thermal and radar air surveys are developing widely and are being used for study of mineral resources. The thermal air survey, which is based on the use of the deep infra-red zone of the spectrum with wave lengths from 1 mcm to 25 mcm, enables objects to be revealed by their thermal contrast.

Radar air survey in the USSR is carried out by "side-looking" radio-locating stations (RLSBO). An airborne RLSBO pulse radiates to the surface of the Earth within the narrow azimuthal angle formed by the projections on both sides of the flight path.

The main feature of the radar survey, allowing for its wide use, is its complete independence from weather conditions, natural illumination, etc. This permits recording of the imprints without decrease in quality at any time of day, under any meteorological conditions, as well as securing the coverage of large areas at a small scale, which is not always possible with the conventional air survey.

Radar survey was used for the first time in the USSR for exploration of the ice cover of the Arctic Ocean. The exploration showed that seasonal ice can be differentiated from the older polar ice by the radar imprint, that iceberg clusters can be detected and that parameters of the ice situation can be obtained throughout the year under any weather conditions.

At present there are wide possibilities for the use of the radar air survey data for geology owing to the wide strip view of the radar air survey and the high sensitivity of the method employed to variations in the shape of the reflecting objects, that is, the topography of a locality. Small features of topography are also fixed on the radar imprint, so that geological identification can be done, geological structures and their fragments can be traced and the main irregularities of geology can be understood.

The use of the dependence of intensiveness of the reflected signals on humidity and magnetic and electric permeance is of special interest.

The investigation of data of the radar air survey of desert areas has shown that by variation of the humidity of the rocks in these areas it is possible to trace some structures which either are not detected or are detected with great difficulty with the use of conventional methods. Presumably this is related to the fact that in the arid zones even negligible variation in the lithological content of the rock brings a considerable alteration in humidity, especially after precipitation. The more humid parts reflect the weaker signals owing to a considerable absorption of radio waves. Thus these parts are represented with a lesser density on a radar imprint. This phenomenon can be used for geological study of terrain and for underground-water prospecting.

Knowing the dependence of the reflected signal strength on the physical characteristics of an object (its magnetic and electric permeance) will permit the determination of zones with an abnormal content of certain elements in soils by the method of quantitative interpretation of radar survey data (measuring the coefficient of reflection).

The use of radar imprints is very promising in the study of vegetation cover. Analyses of the texture of the imprint and tint comparisons, allowing for geographical conditions, permits regional maps to be compiled of vegetation at different stages of growth and makes it possible to identify forests with the same growth. The dependence of strength of reflected signals on the characteristics of the reflecting surface allows for the use of radar airphotos for mapping of agricultural crops. The boundaries of soil difference are clearly seen on the radar imprints. For instance, newly ploughed flat soil is depicted with very small density and produces a dark-tint image independent of the time and direction of the radar radiation.

The results of the investigations performed therefore show considerable promise in the usage of radar air survey for studying and mastering natural resources.

Each of the aerial methods described uses different physical characteristics of the objects and is in a number of cases quite distinctive. The most complete information on a particular object can be recorded only by a combination of several aerial methods used according to their peculiarities, and this is a challenging task.

Further and deeper study of the physical phenomena of objects to ascertain the correlation between the characteristics of natural formations and the data of different aerial methods is necessary. This may produce criteria for selection of the most rational and efficient combination of different aerial methods and make it possible to initiate new methods of aerial study of objects.

THE NEW 1:50,000 TOPO-MAPPING IN THE UNITED ARAB REPUBLIC*

Paper presented by the United Arab Republic[1]

OLD TOPOGRAPHIC MAPPING IN CULTIVATED AREAS

Topographic maps have been produced since 1905. They were first produced for the Nile valley. The old 1:25,000 topographic series covering the whole cultivated area of the Nile valley and oases was prepared from 1:2,500 cadastral maps by photo-reduction to 1:10,000 scale for field revision and then lessened to 1:25,000 as a first edition. The second edition was reproduced to 1:15,000 scale for field revision, then was fair drawn and reduced to 1:25,000 for publication. The 1:100,000 topographic series was based on the 1:25,000 series. The work of mapping the desert relief up to the sheet edges was accomplished by the classical ground methods of survey. In 1958 the entire cultivated area of the Nile valley and oases had been covered by the 1:25,000 and 1:100,000 topographic maps.

OLD TOPOGRAPHIC MAPPING IN DESERT AREA

Up to 1914 the only properly mapped part of the desert area was the northern half of the Sinai peninsula at 1:100,000 The actual mapping of the desert features followed in 1920. The principle adopted in compiling the survey was that the field surveyor should complete his map in the field, observe his own triangulation points, compute, plot them, sketch the topographic features and ink them. The scale of these surveys in the field was 1:80,000, which was reduced to 1:100,000 for publication. In 1958, 55 per cent of the entire desert area had been covered by the 1:100,000 topographic maps.

THE NEW 1:50,000 TOPOGRAPHIC MAPPING

Since 1958, the topographic and original cartographic compilation by the classical plane table, compass and route survey, has been replaced by photogrammetric means of compilation. It is since then that an extensive programme of mapping has been carried out at 1:50,000, compiled from 1:25,000 manuscripts. The 1:25,000 manuscripts are based on the Universal Transverse Mercator (UTM, Gausskrüger) projection, with dimensions of 7.5′ × 7.5′. The sheet frames of the 1:50,000 are denoted in geographic co-ordinates of 15′ × 15′ and gridded by a kilometric network in Cartesian UTM co-ordinates.

AERIAL PHOTOGRAPHY

The basic photography in the United Arab Republic, for the new topographic series has already been taken with the Wild wide-angle $RC5_a$ cameras. The flying height is 20,000 ft with east–west runs. Normal overlaps are at least 60 per cent fore and aft and 25 per cent lateral. This work has been done by a foreign company under contracts concluded for that purpose. At present we have our own photo missions, carried out with our own aircraft equipped with Wild automatic film cameras (RC_8). Aviotar 21/18 × 18, Aviogon and Infragon 15/23 × 23 lenses are now in use.

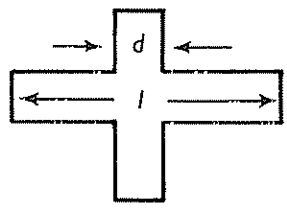
FIELD OPERATIONS

In the course of preparatory work, the fore and aft overlaps as well as the laterals are marked on the aerial photographs to identify and interpret the appropriate location of the ground control necessary for orienting the stereo pairs. Immediately after, the geodetic survey of the control takes place. Generally, four ground-control points, at least, should be identified and located at the four corners of each stereo pair.

The horizontal and vertical data necessary for the ground-control points, are based on triangulation points and bench-marks as outlined and previously determined in the course of establishing the old 1:100,000 topographic map series of the Nile valley and the old 1:80,000 topographic manuscripts in the desert area. In some cases, it is necessary to establish or extend the available triangulation points at different classes as well as the levelling lines.

Lack of convenient field details and sometimes the poor quality of the aerial photography or the inaccessibility of the area considered for mapping require the application of aerial triangulation methods. However full ground control would be needed for the stereo pairs in rather flat and open terrain to increase the accuracy of height compilation.

In a few cases the control is signalled if the area under consideration must be rephotographed. White chalk paints or black tar paints are used for signalling depending upon the contrast between the signal and the background. The signals are cross-shaped with the dimensions $l = 5\sigma$, $d = \phi$ (see the figure), where ϕ = floating mark diameter. Good results have been obtained by adopting this procedure in the High Dam area resurveyed recently.



AERIAL TRIANGULATION

In the United Arab Republic aerial triangulation is carried out by using the aeropolygon method. The Wild Universal instrument A_7 is used for connecting the successive models. The compensating co-ordinate errors in x, y and z are effected by interpolation methods for the strips. Yet, the heights are readjusted in blocks by the Jerie set, the well-known analogue computer. Mention should here be made of the use of the Zeiss Jena co-ordimeter, an electro-mechanical programmed computer. It is used extensively in the linear X and Y co-ordinate transformation (Helmert's method). The parameters of the transformation are calculated immediately and the instrument co-ordinates are converted to the geodetic system or vice versa through the co-ordimeter. The results of this method of bridging are consistent and accurate enough for topographic map compilation purposes.

On the other hand, the survey of the United Arab Republic has not been equipped with many more expensive universal instruments. It is well known that one universal instrument used for bridging stereo pairs can

* Now Egypt.

[1] The original text of this paper, prepared by S. K. H. Mohamed. Survey Department, Giza, appeared as document E/CONF 57/L.132.

keep three or four autographs occupied with detail compilation from the bridged strips. It has been decided to follow a new practice in aerial triangulation methods.

Recently a test was made of the method of independent models with our precision autograph Wild Ags and Zeiss stereometrographs. The results were encouraging. We believe that a wide test in this field of application should be carried out. It would be worth the effort if aerial triangulation by independent models should prove favourable and the precision autographs moved parallel with the universal autographs.

Stereoplotting

Following the field work and the aerial triangulation stereoplotting successively progressed. Ags autographs and stereometrographs are extensively used for plotting. The collection of source data, preparation of data sheets, gridding of compilation manuscripts, etc. are routine work. Contact glass plates (transparencies) are prepared and checked for quality. Contour intervals are of 10 m, but they are varied in the mountainous terrain to make a suitable clearance between the contour lines. On some occasions, particular problems occur in the sand plains where distinguishable details do not exist and the stereoscopic effect is weaker or entirely lost. In such cases additional ground vertical points are established in the field.

Table 1

Terrain	*Standard performance* (km^2/hr)
Flat with little relief	2.0
Undulating, thickly settled and developed	1.0
Partly open	1.5
Rugged	1.0

The standard performance of the detail plotting as attained by Egyptian operators is shown in table 1.

Revision and cartography

No attempt is made to ink a compilation sheet directly through the plotting instrument. The surplus details are normally controlled at the reproduction stages. Mosaics to the scale of 1:50,000 are provided to serve as guides for plotting and fair drawings.

Details are added or revised on the compiled sheets with Sketch Master equipment. This addition of details takes place in the cultivated, thickly settled and developed areas, since aerial photography at 1:10,000 is carried out three times a year for the survey of Egyptian crops.

Details are added or revised in the desert area by the classical field methods of survey. This addition is in case some details are absent from the basic photography for the survey of 1:50,000 maps.

Some estimates had been made of the percentage cost of different phases of operation. They showed figures similar to those indicated in table 2.

Table 2

Phase of operation	*Cost (percentage)*
Aerial photography and mosaics	5
Preparatory work	2
Supplementary ground work	45
Stereoplotting and aerial triangulation	30
Cartography	18

However, all the foregoing routine work is not regarded as final and further developments are always under consideration.

(a) *Air photography and photogrammetry*

POSSIBILITIES AND METHODS OF ORTHOPHOTO PRODUCTION

Paper presented by the Federal Republic of Germany[1]

The constantly growing volume of cartographic work in all parts of the globe has led to the increasing use of photogrammetric methods. Above all, the technique of orthoprojection is gaining considerable importance owing to its high output and economy. Orthophotos have proved to be a valuable basis both for the production of new maps and for map revision. Apart from the controlled mosaics assembled from rectified air-photo prints that have been in use for many years, orthophotos make it possible to combine the advantages of a photomap with the accuracy of a line map even in mountainous terrain. An essential asset of photomaps is that they reproduce all the information contained in the aerial photographs, thus presenting a considerably higher density of information than a line map, which for reasons of clarity and compilation cost can only offer a selection of typical detail (see figure I). As in the case of line maps, interpretation of the map content can be facilitated by adding symbols, lettering etc.[2]

Still unresolved is the problem of generalization. The number of details that can be recognized diminishes as the scale gets smaller and even in colour, photomaps can only be kept within practical limits over a certain range. From the viewpoint of interpretation, discussions have led to the acceptance of a map scale m_K 25,000 as still feasible. Orthophotos and controlled mosaics will therefore be used primarily in the base-map series, for city plans and planning purposes. Above all with large-scale map series, the problem of revision is very critical in view of the large number of sheets involved. On account of its high output, the orthophoto technique here offers a solution which will

[1] The original text of this paper, prepared by D. Hobbie, Carl Zeiss, Oberkochen, appeared as document E/CONF.57/L.8.

[2] R. Schweissthal, *Grundlage, Bearbeitung und Herstellung grossmassstäbiger Luftbildkarten, Wissenschaftl.*, Arbeiten der Lehrstühle für Geodäsie, Photogrammetrie und Kartographie der Technische Universität Hannover, No. 34, 1967.

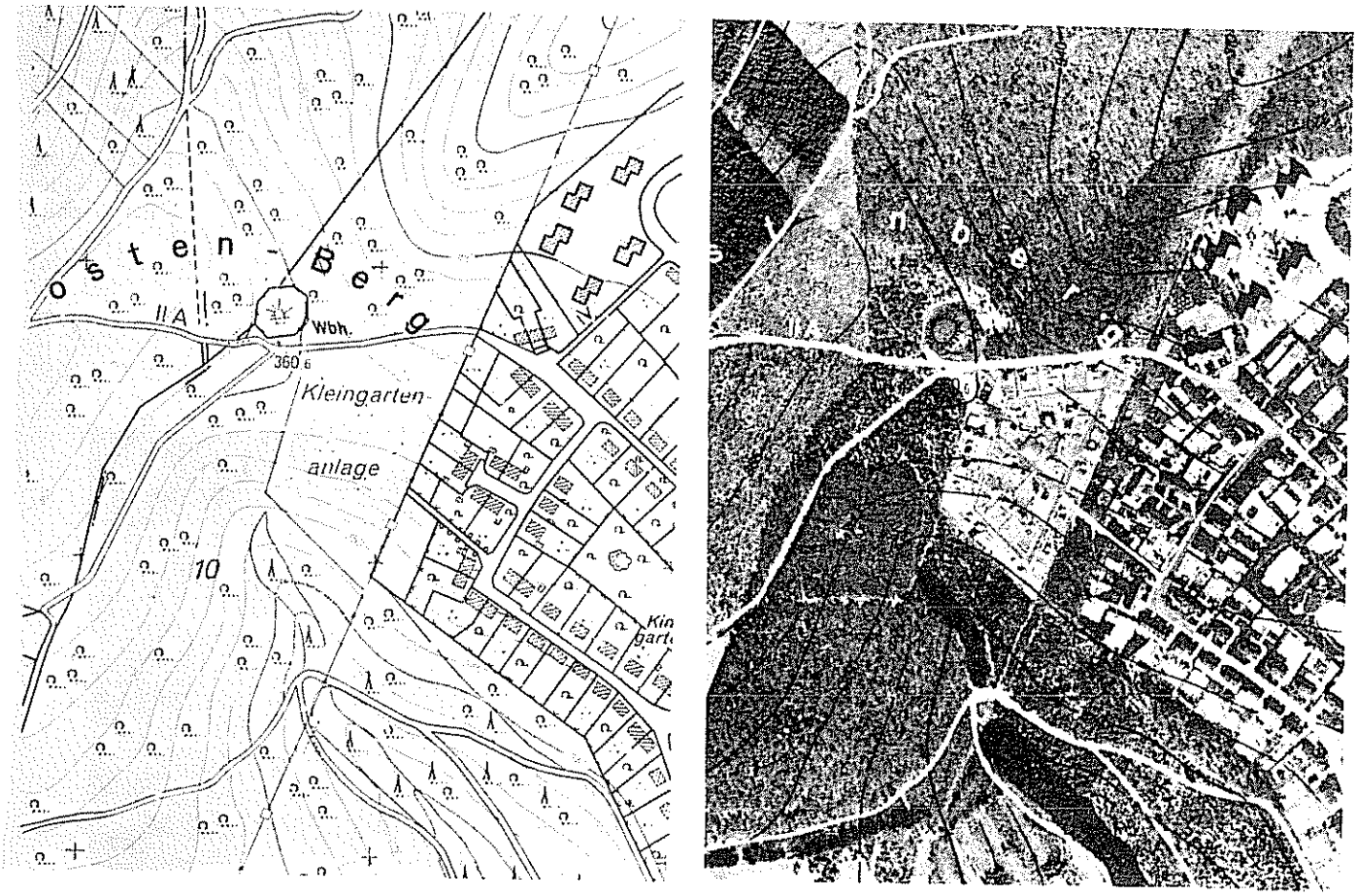


Figure I. Comparison of 1:5,000 line map and photomap

allow the supply of up-to-date maps to be kept up; for only maps that are up to date are of any use for planning purposes.

Methods of orthophoto production

It is the purpose of photogrammetric work to determine the size of objects in photographic records and to provide an analogue or digital output (maps or co-ordinates, respectively). One possible form of analogue output is the rectified air-photo print. Today we distinguish essentially between three stages of rectification (see figure II):

(*a*) Simple rectification to an average plane—which need not necessarily be horizontal—for example in an SEG-V rectifier;

(*b*) Differential rectification to a horizontal plane by strip-wise exposure with the aid of a scanning slit and continuous correction of the projection distance such as is obtained in the ortho-3-projector or the GZ-1 orthoprojector;

(*c*) Differential rectification as under (*b*), combined with simultaneous additional rectification within the scanning path by "tilting" the projection surface such as in the GZ-1 orthoprojector with optical interpolation system.

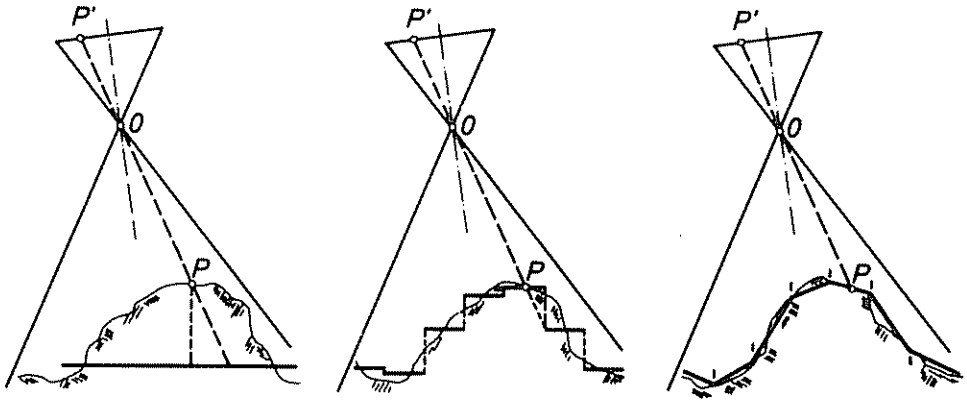


Figure II. System errors in simple rectification, differential rectification and differential rectification with optical interpolation

Whereas an aerial mosaic obtained by simple rectification exhibits more or less serious relief displacements of magnitude

$$dr = dh \tan \alpha \qquad (1)$$

which in the case of low mountains may reach a few centimetres, the horizontal error in the case of differential rectification to a horizontal plane remains within a few tenths of a millimetre in the orthophoto owing to

$$dr \frac{L \Delta x}{2} \tan \alpha \tan \beta x \qquad (2)$$

where α is the angular field, Δx the scan width, βx the terrain slope in the x direction (in both instances photo tilt has been neglected).

III). The two photos of an air-photo pair are first relatively oriented so that a virtual three-dimensional model is produced (relative orientation). With the aid of control points, the model is then oriented absolutely so that the model co-ordinates (position, height) coincide with the co-ordinate system of the instrument (x, y, z). Next, a copy of one of the two photos is inserted into the plotting camera of the orthoprojector and oriented in the same manner as the corresponding photo of the stereo pair. After setting the measuring mark in the plotting unit and the scanning slit in the orthoprojection unit to identical model points, the two modules are coupled mechanically or electrically in x, y and z. The plotting process then consists in that the operator keeps the floating mark in touch with the model surface during strip-wise scanning of

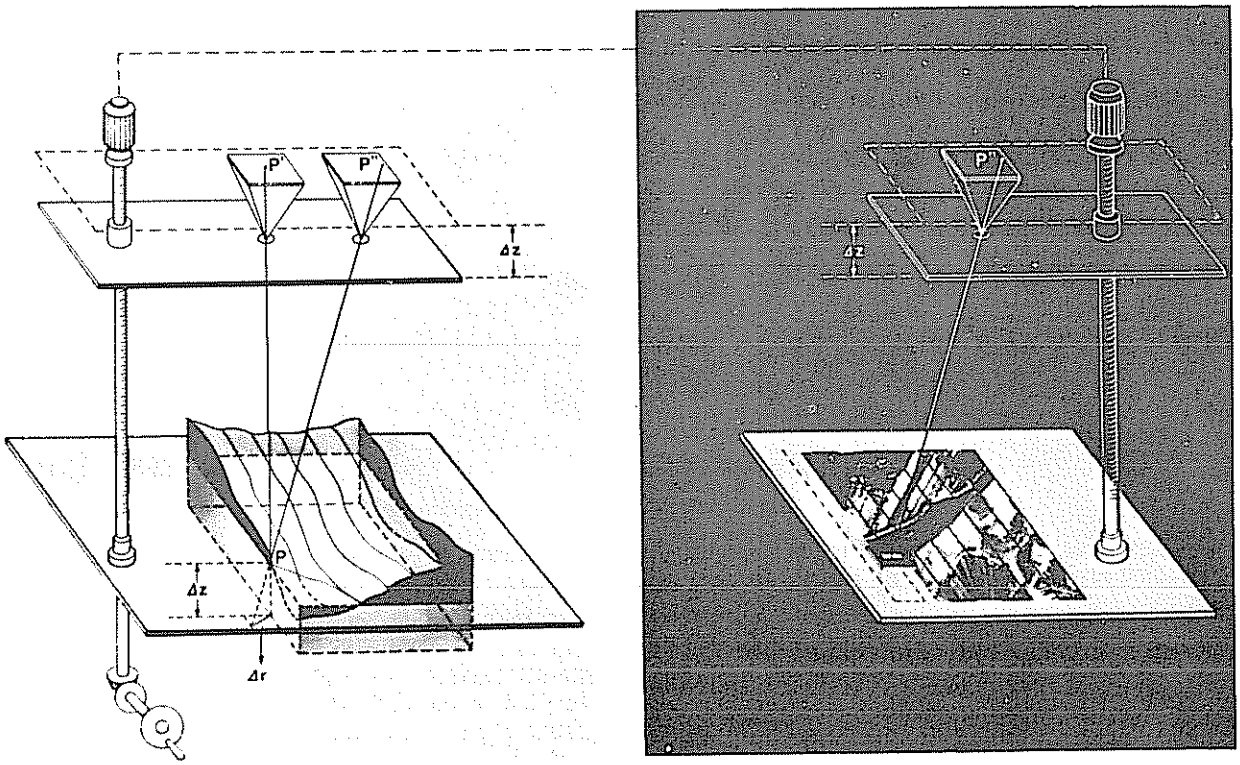


Figure III. Principle of orthoprojection in instruments recovering the bundle of taking rays

However, since continuous rectification is possible only in the scanning direction, the second type of rectification results in irregular imagery at the edges of the scanning path. These appear in the form of mismatches, double contours and loss of detail, and may be particularly troublesome in the case of linear detail (roads, paths). They can be avoided if additional rectification within the scanning path is introduced by "tilting the projection surface". At the same time, this approach will avoid the system error defined by equation (2) so that only small topographic features within the path will give rise to residual horizontal errors. The share of the system error in the over-all horizontal error will then remain within 0.1 mm. The third stage of rectification has been realized in the optical interpolation system for the GZ-1 and will be discussed in further detail later. The principle of differential rectification can best be described by using the example of orthoprojectors designed on the principle of geometrical recovery of the bundles of taking rays (figure

the model in a meander pattern (which is automatically controlled by a special drive system). In the case of the GZ-1 orthoprojector, this continuous correction of z is transmitted to the orthoprojector plotting camera by means of synchros so that the floating mark and the scanning slit are always at corresponding points of the model and the projected image.

Equipment for orthophoto production

Differential rectification generally requires a stereoplotter and an orthoprojection system. In the market, two types of equipment have imposed themselves: on the one hand, a stereoplotter with integral orthoprojection system, and on the other hand separate systems for stereoprofiling and projection, which are coupled either mechanically or electrically. As an example of an integrated system, the Zeiss ortho-3-projector will be described in the following.

Ortho-3-projector

The stereoplotting system of the ortho-3-projector draws on the design principle and components of the DP-1 double projector (figure IV). Wide-angle projectors equipped with Fresnel-lens condensers allow simultaneous illumination of the entire field of the photographs. Relative and absolute orientation of the stereo model are possible by means of the motions κ, ϕ and ω as well as common ϕ, b_x and the z adjustment of the projectors. For this purpose, the projected image is intercepted on the manually guided tracing table taken over from the DP-1. Interchangeable lenses with a depth of field of ± 20 per cent of the projection distance allow 2.5× or 2.0× magnification from photo to model or orthophoto. A third projector accepting a copy of the "left-hand" photo is mounted at the back of the z carriage. The third projector is oriented in relation to the "left-hand" projector of the DP-1 system by means of the ϕ_3, ω_3, κ_3, Δx_3, Δy_3 and Δz_3 motions.

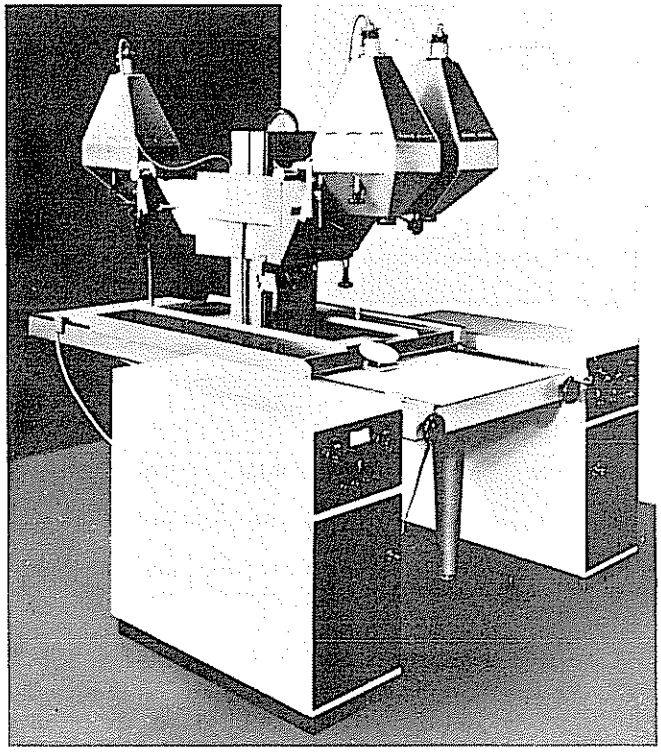


Figure IV. Ortho-3-projector

Once orientation has been completed and the hand-guided tracing table replaced by the floating-mark plotting table and the scanning slit mounted on a cross-slide frame, compilation may start. z control is effected with the right-hand wheel. Various slit widths (1 to 4 mm) and several scanning speeds (10; 5; 3.3; 1.7 mm/s in the model) allow proper adaptation to flat or rugged terrain. The ortho-3-projector is distinguished by the clarity of the plotting procedure and its simple operation. Above all, the relative and absolute orientation and the orientation of the third projector have proved to be very rapid and simple by comparison with other orthoprojection instruments. The hand-guided tracing table supplied with the instruments allows contouring and stereoplotting operations in the stereoplotting part of the system. In other words, the instrument is designed for both orthoprojection and conventional stereoplotting.

GZ-1 orthoprojector in the direct mode

For operation, the GZ-1 orthoprojector[3] needs a control instrument, which on principle may be any spindle-driven plotter that satisfies certain requirements. Above all the

[3] M. Ahrend *et al.*, *The Gigas-Zeiss Orthoprojector*, Bildmessung und Luftbildwessen 3, 1964.

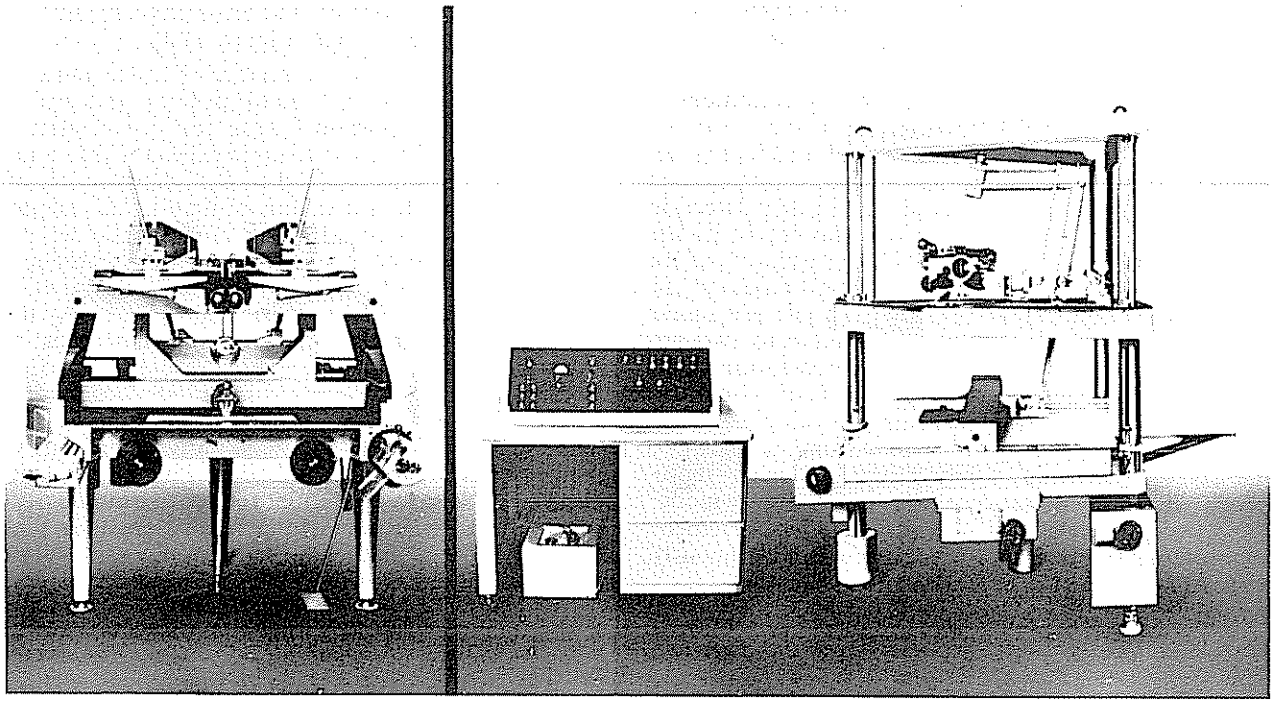


Figure V. GZ-1 orthoprojector used in direct mode with Planimat

Planimat and the C-8 stereoplanigraph can be connected to the GZ-1 without any modification. The GZ-1 orthoprojector consists of a projection system and the scanning-slit system. The projection system comprises the photo-carrier (κ, ϕ and ω motions), the auxiliary lens system for consistently sharp imagery and the follower-controlled illumination system is mounted on a cross-rail moving in z (figure V). The interchangeable scanning slit (2, 4 or 8 mm) is contained in a compound slide directly above the film plane, which moves in the x and y directions. The orthoprojector is electrically coupled to the stereoplotter in x and y and by means of synchros, once the relative and absolute orientation in the stereoplotter and the orientation in the orthoprojector have been completed. Interchangeable projectors allow the plotting of wide-, intermediate- and normal-angle photography in the GZ-1. Photography taken with other camera focal lengths, such as ultrawide-angle photography, for example, can be processed by affine plotting or projection. In view of the small tilt angles made possible by modern flight equipment, no serious loss of accuracy is produced either by affine plotting (stereo model in plotter likewise affine, e.g. for plotting ultrawide-angle photography in the C-8) or the preferable method of affine projection (stereo model in plotter not affine, e.g. ultrawide-angle photography in Planimat).[4]

Owing to a z range of 335 to 620 mm, 2.2 to 4× magnification can be obtained with the 15 cm equipment. Affine projection also covers the magnification range from 1.1 to 2.2× and—if the 11.5/18 photo-carrier is used for projection—even magnification up to 5.4×. This covers practically the entire economical range of scales[5] (figure VI). For very large scales of between 1:100 and 1:1,000 it is advisable to use a reduction for projection combined with subsequent enlargement, in order to avoid excessive plotting time. More than 4× magnification does not seem useful, since under practical conditions aerial photographs hardly exceed a resolution of 30 lines per millimetre, so that the resolution in an orthophoto obtained by 4× magnification would fall to 7 to 8 lines. Further reduction of resolution in the orthophoto would even be visible to the naked eye.

Adaptation to a great variety of plotting conditions is made possible by slit velocities variable in steps between 2.5 and 10 mm/s, by the possibility of introducing between 1× or 2× magnification between plotter and orthoprojector, by profiling either in the x or the y direction by an exchange of synchro connexions and finally by the possibility of using colour photography. A feature of the GZ-1 orthoprojector which is of great importance for the instrument's economy is the possibility of jointless model connexion. By using the air photo common to two adjacent models and performing a bridging operation in the stereoplotter after having plotted the first model, an orthophoto can be produced from an entire air photo. As a result, one photo map sheet can be obtained from a single orthophoto without any montage during reproduction. A considerable advantage of the "direct mode" is the simple, conventional operation of the equipment. Since profiling and orthoprojection occur simultaneously, checks are simple and uncomplicated.

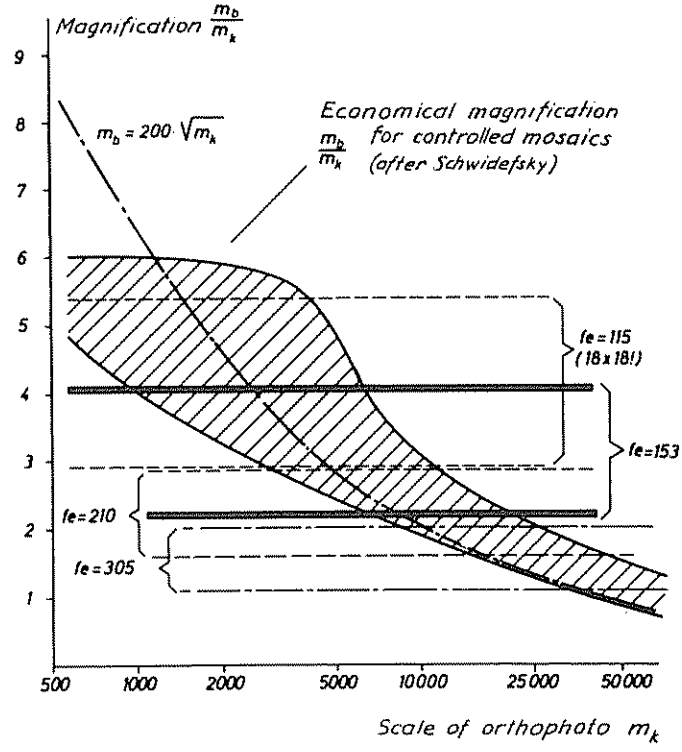


Figure VI. Range of economical magnification from photo to photomap scales and GZ-1 magnification range

GZ-1 orthoprojector in the storage mode

The GZ-1 orthoprojector may also be operated with the aid of a profile storage system. In this case, the profiles determined during scanning of the stereo model are recorded in the SG-1 storage unit connected to the stereoplotter (figure VII). The storage plate with engraved profiles can be inserted in the LG-1 scanning unit which then automatically controls the orthoprojector in accordance with the stored profiles (figure VIII).

The storage mode offers a number of interesting advantages. The separation in time of profiling and projection is not only an important factor for organization. In addition, it also allows the scanning speed within a profile to be varied and thus adapted to the configuration of the terrain. The result is a saving of time or an increase in accuracy as compared with the direct mode where the speed is a compromise between economic scanning time and required accuracy. Moreover, scanning errors in the storage mode can be easily corrected by covering up the erroneous part of the profile with ink and repeating it. In the direct mode, the entire plot would have to be repeated in the case of an error. The storage mode also allows optimum use of the equipment system by employing several stereoplotters with storage units to feed one GZ-1 orthoprojector with LG-1 scanning unit. Since orientation and profile storage account for about 60 to 80 per cent of the total time required for compilation, four plotters are employed in conjunction with one GZ-1. By means of electrical interpolation during automatic projection, the scan width in the orthoprojector can be reduced to one sixth of the distance between stored profiles. For this purpose a scanning slit of suitably reduced width is employed and the orthoprojector is controlled in accordance with an intermediate value electrically interpolated from

[4] D. Hobbie, *The use of affinity techniques in orthoprojection*, Zeiss-Mitteilungen 3, 1969.

[5] K. Schwidefsky, *Grundriss der Photogrammetrie*, 6th ed., Stuttgart, 1963, p. 137.

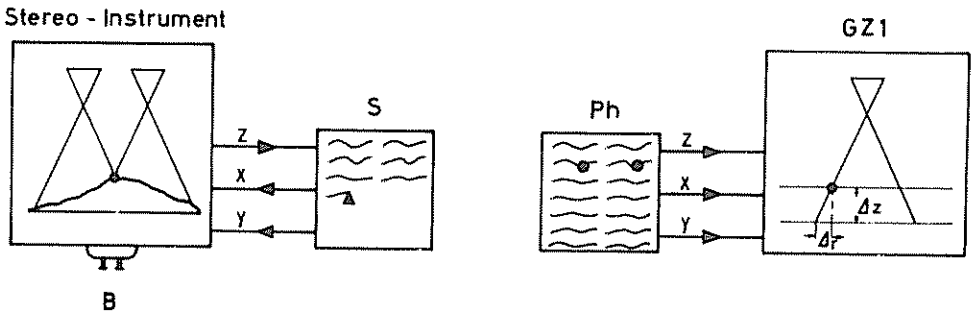


Figure VII. Principle of storage technique

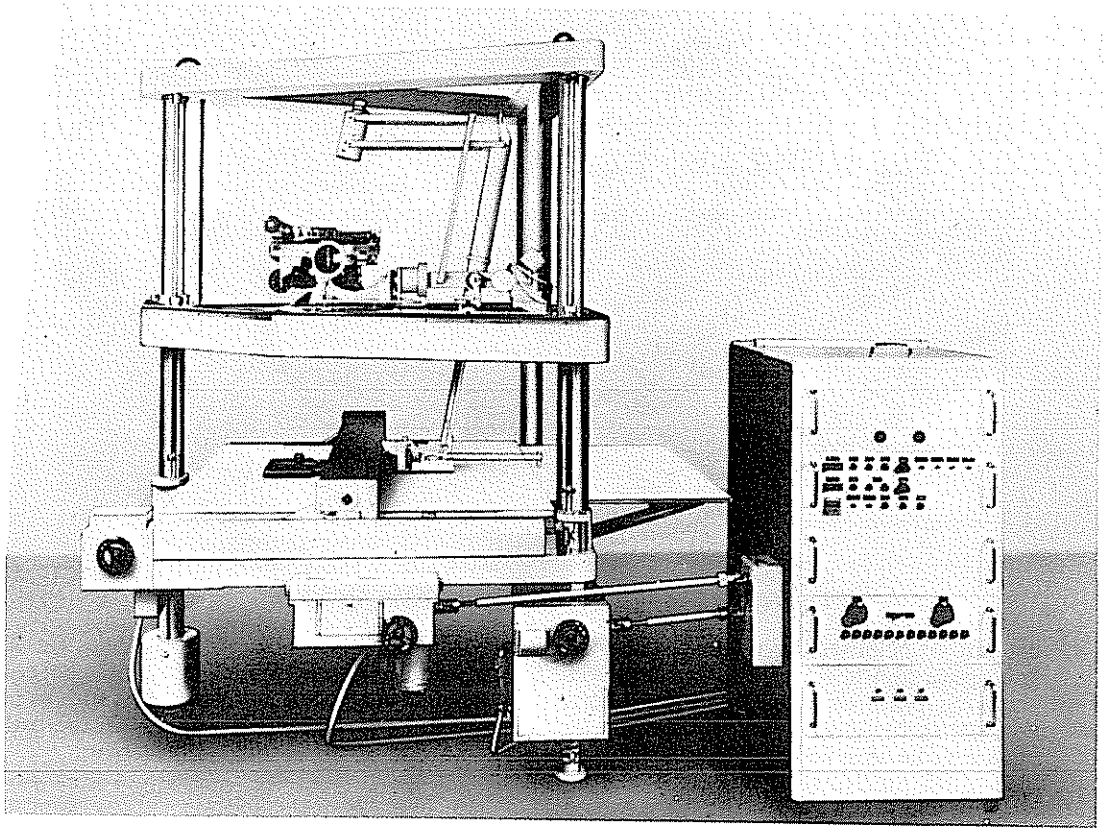


Figure VIII. GZ-1 orthoprojector with LG-1 scanning unit for operation in storage mode

two adjacent profiles. Whereas this reduces mismatches, the projection time is increased accordingly. In the direct mode, the selection of a smaller scan width would also increase the profiling time in the plotter and tire the operator. Further advantages of the storage mode are the possibility of using such accessories as the optical interpolation system and the electronic contourliner, described below. An additional factor resulting in a considerable increase in the production rate of the orthoprojector system is that the storage mode in conjunction with the Planimat and the SG-1 storage unit allows the use of the Itek EC-5 correlator (described later). However, the greatest advantage of profile storage is undoubtedly the possibility of re-using the storage plates. Thus the projection phase can be repeated at intervals of a few years, using the original storage plates in conjunction with up-to-date photography. This will allow rapid and economical map revision. Tests performed by RAK in Sweden and IFAG of Frankfurt[6] have proved this method to be quite feasible. There is only one condition: the entire model area covered by one profile storage plate must fall within one of the photos taken on the reflight. The storage plates will have to be renewed only if the configuration of the terrain has changed considerably in the meantime, as in the case of open-pit mining or after the construction of a dam. However, this will be the case only in a very small percentage of the maps to be revised.

[6] H. Schmidt-Falkenberg and R. Olach, *Über die Wiederverwendung von gespeicherten Geländeprofilen zur Herstellung von Orthophotos aus Luftbildern nachfolgender Bildflüge*, Bildmessung and Luftbildwessen 6, 1969.

Optical interpolation system O-Int

The optical interpolation system (figure IX) serves to avoid the system error and produces homogeneous orthophotos (without mismatches) of increased horizontal accuracy. As is evident from figure II, the system error can be avoided if during recovery of the taking bundle the projection surface has the same shape and position as the ground at the instant of exposure and if the projected image is then conveyed from the projection surface to the film plane by vertical, orthographic projection.

For both optical and design reasons it is not possible to compensate any desired amount of transverse slope. The optical interpolation system for the GZ-1 has therefore been designed for a maximum ground slope of 35°. Higher degrees of transverse slope will be corrected as for 35°. The system error is thus

$$dr \leqslant \begin{cases} 0 \\ \Delta x \tan\alpha(\tan\beta x - \tan 35°) \end{cases} \begin{matrix} \beta x \leqslant 35° \\ \beta x > 35° \end{matrix}$$

Theoretical considerations have shown that this limitation is of no practical importance. Using as a basis the

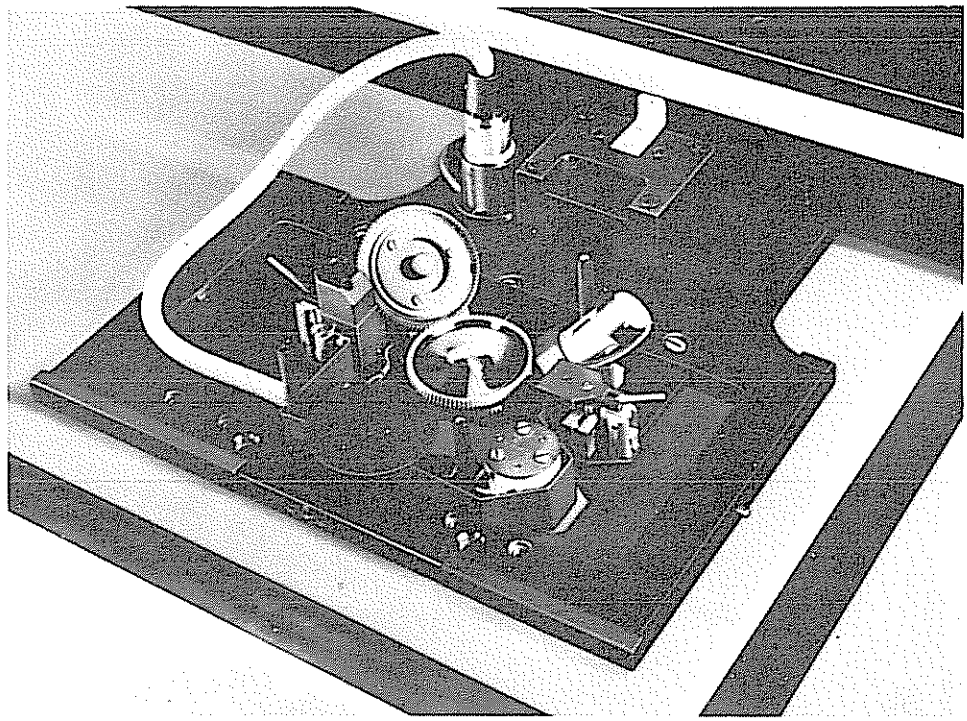


Figure IX. Optical interpolation system for GZ-1

In practice, this can be achieved by using a rectifying component of fibre optics (figure X). This component is attached to the scanning slit of the orthoprojector so that its base is perpendicular to the direction of the fibres. Its upper end is used as a projection surface which makes an angle corresponding to the transverse terrain slope (terrain slope at right angles to the scanning path) with the base surface and thus the film plane. The image intercepted is transmitted by the fibres to the film plane, point by point and in parallel. With fibres of 6 m thickness, the resolving power of the rectifying component is about 70 to 80 lines per millimetre so that the quality of the orthophoto is not impaired. The rectifying component is designed as a ring (figure XI), the upper end of which contains all degrees of transverse slope to be handled in practical work. A servo-control turns the ring so that the circular segment corresponding to the required amount of transverse slope is right above the scanning slit. The control magnitude is given by the transverse slope obtained in the LG-1 scanning unit from two adjacent profiles which are scanned simultaneously. A section of an orthophoto produced with optical interpolation is found in the reference below.[7] The increase in horizontal accuracy that can be obtained with this system has been proved by tests.

[7] *Gigas-Zeiss Orthoprojector Equipment News*, Bildmessung und Luftbildwessen 5, 1969.

frequency distribution of ground slopes (in the fall line) given in the reference below,[8] it may be considered as probable that any point selected at random in an orthophoto will be displaced horizontally in the orthophoto by $dr > 0.1$ mm owing to the system error.

	Δx GZ-1	4 mm(%)	8 mm(%)
Without optical interpolation	Flat terrain	8	31
	Low mountains	58	77
	High mountains	94	98
With optical interpolation	Flat terrain	—	—
	Low mountains	<0.5	<0.5
	High mountains	5	6

The improvement is obvious. The share of the system error in the horizontal error is negligible if the optical interpolation system is used. As a result, the horizontal accuracy of the orthophoto remains within ± 0.15 to ± 0.20 mm even in the case of high mountains—a value previously obtained only for low mountains.[9] Of greater

[8] M. G. Neubauer, *Die Geländeneigungen und ihr Einfluss auf die Lagefehler der differentiellen Entzerrung*, Bildmessung und Luftbildwessen 5, 1969.

[9] H. G. Neubauer, *Genauigkeitsuntersuchung des Orthoprojektors Gigas-Zeiss*, Nachrichten aus dem Karten und Vermessungwesen, Reihe I, No. 42, 1969.

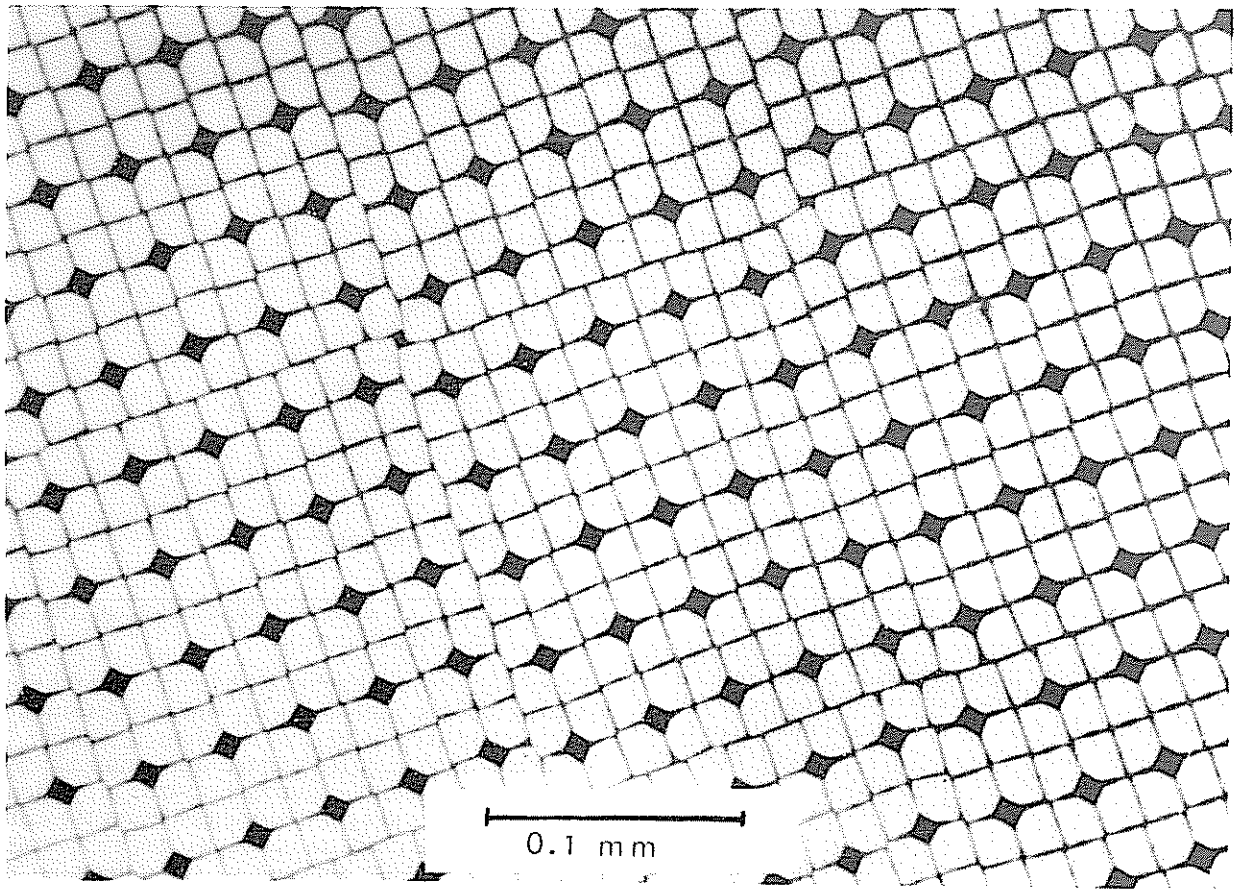


Figure X. Cross-section of image-conducting fibre bundle composed of 16 m fibres

practical importance is the increased production rate. Selection of the profile interval no longer need make allowance for the avoidance of mismatches so that in nearly all cases scan widths of 4 mm, frequently even of 8 mm, can be chosen, which considerably reduces the scanning time.

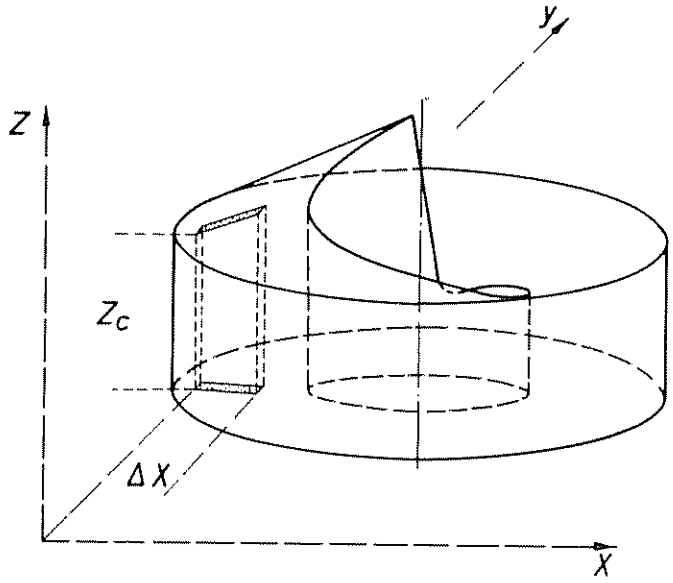


Figure XI. Rectifying component of optical interpolation system for GZ-1

POSSIBILITIES FOR SIMULTANEOUS CONTOUR PLOTTING

While in the ortho-3-projector contour plotting may follow the process of orthoprojection by tracing conventional contour lines with the aid of the hand-guided plotting table under the stereoscopic system of the instrument, the GZ-1 orthoprojector allows automatic contour plotting simultaneously with exposure of the orthophoto. In the following, two accessories designed for this purpose will be described.

HS dropped-line attachment

In this accessory, which was first described in the reference below,[10] a signal disc is connected to the z spindle of the orthoprojector via synchros (figure XII). A projection system rigidly connected with the scanning slit projects a section of the signal disc onto a second projection surface. If in the course of profiling the z value changes, the position of the signal disc will likewise be varied during exposure of the orthophoto. In other words, the so-called line-drop signal is projected On the photographic emulsion the signal variations produce changes corresponding to certain contour levels. By means of interchangeable signal discs and gears, different contour intervals can be marked. Contour lines can then be graphically constructed from the resulting line-drop contour chart.

[10] H. K. Meier, *Accuracy and Type of Contour Representation in the Gigas-Zeiss Orthoprojector*, Bildmessung und Luftbildwessen 2, 1966.

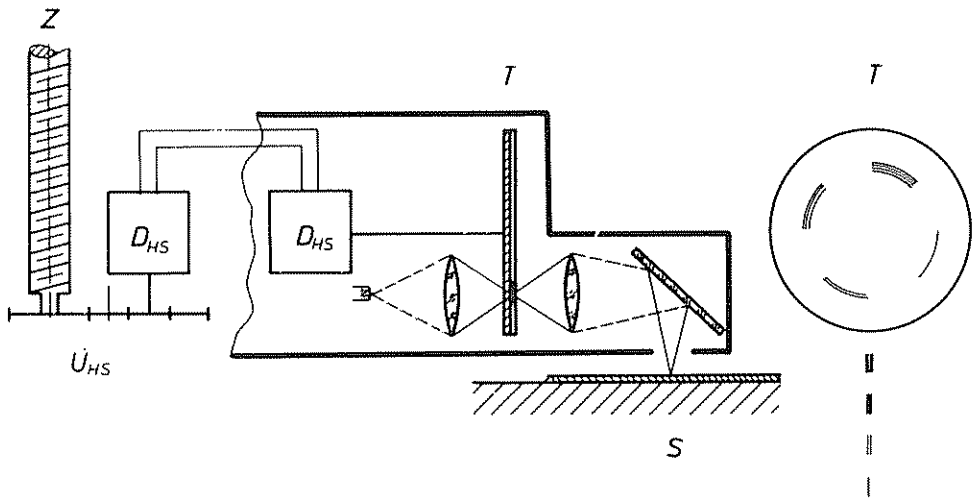


Figure XII. Principle of HS dropped-line attachment for GZ-1

HLZ electronic contourliner

A logical development based on the dropped-line attachment is the electronic contourliner,[11] which instead of dropped lines directly projects curved connecting lines between changes of contour level. Since this requires the simultaneous availability of two profiles, the advantage can be utilized only in connexion with the GZ-1 in the storage mode. The system consists of a central electronic unit in the scanning unit and the electronic "tracing" head (figure XIII) that is rigidly connected to the slit carriage of the orthoprojector. A schematic description of the system will be given in the following.

A pulse generator attached to the z spindle of the orthoprojector defines contour levels whose intersection with the model surface is to give the desired contour lines. The model surface is represented approximately by the stored vertical profiles. During strip-wise projection, the model heights z_A and z_B of the profiles limiting the scanning path are continuously available as electrical voltages. The electrical voltage supplied by the differential transformers of the two scanning heads defines a linear profile at right angles to the scanning path by differentiation and the introduction of the scan width Δx. This transverse

[11] K. Felle and W. Rösel, *Automatic Plotting of Contours in the Course of Orthophoto Production*, Bildmessung und Luftbildwessen 5, 1969.

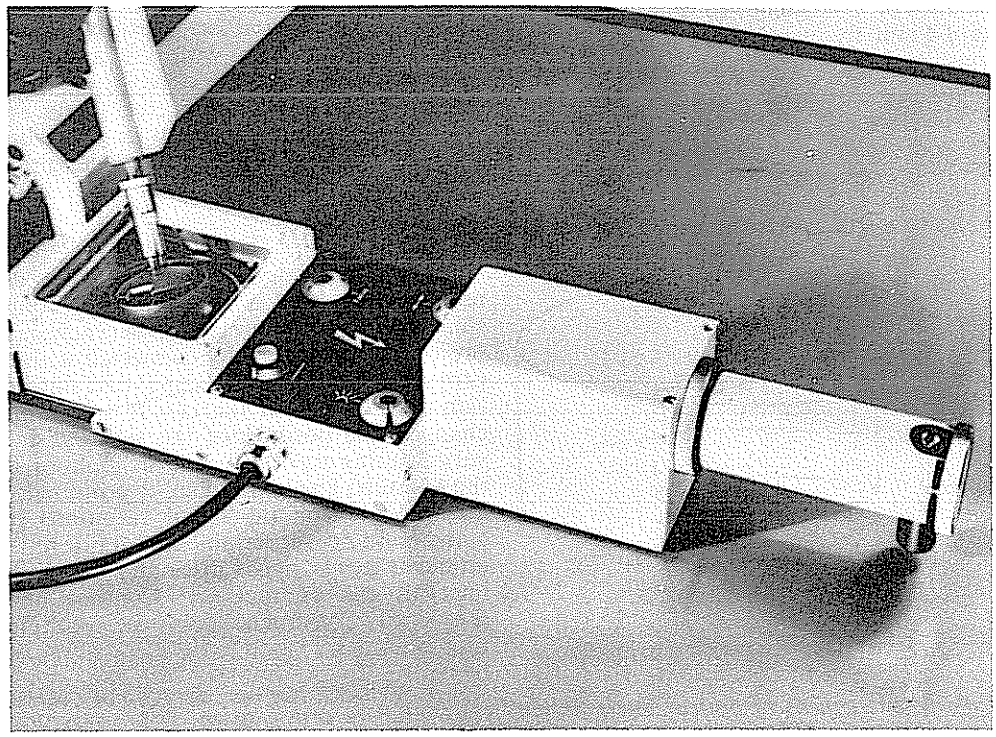


Figure XIII. Projection system of HLZ electronic contourliner for GZ-1

profile is scanned by a digital–analogue counting system and compared with the pulses produced by the pulse generator which may be considered as an electrical z scale. When the voltage is balanced, a synchronous electron beam of a cathode-ray tube, which is deflected in the x direction by Δx, is briefly unblanked. Finally, the screen image of the cathode-ray tube is reproduced in the film plane by an optical system. The transverse profiles are scanned by the counting system with a frequency that is variable from 100 to 800 Hz so that at a slit speed of 10 mm/s the transverse profiles are spaced at least 0.1 mm apart in the film plane. Figure XIV illustrates that this method produces approximate contour lines.

The electronic contourliner allows various contour intervals and makes it possible to stress every second, fourth or fifth contour. Figure XV shows a contour plot produced in this manner. Whereas in a line-drop contour chart only the intersections of contours with the profiles are marked, the contourliner also gives the course of the contours between the profiles. This results in a theoretical increase in accuracy, which has also been proved in practice[12] and is illustrated in figure XVI.

Of greater importance for the user, however, is the saving of time both in the case of the optical interpolation system and the electronic contourliner. As opposed to the method of dropped-line projection, no contours need be constructed by hand. Thus it is necessary to retouch the contour plot topographically. This should save at least one day's work per contour plot.

[12] *Gigas-Zeiss Orthoprojector Equipment News*, Bildmessung und Luftbildwessen 5, 1969.

Possibility of automating the production of orthophotos by means of electronic image correlation

Used in the storage mode, the GZ-1 orthoprojector allows automatic projection. However, it is also possible to automate the profiling process which takes about 30 to 40 per cent of the total plotting time, depending on the configuration of the terrain.[13] In this case, the operator's work is restricted to orientation and preparation. Automatic profiling is made possible by the EC-5 electronic correlator developed by Itek[14] for use in conjunction with the Planimat (figure XVII). Like the operator, the correlator's task consists in keeping the floating mark in contact with the model surface during strip-wise scanning of the stereo model. In other words, its purpose is continuously to clear x parallax by correlating the z position of the floating mark.

The correlator detects x parallax in the following manner: the two air photos making up the stereo pair are scanned around the floating mark by means of a flying spot. The scanning signal is modulated by the density distribution in the aerial photographs. The modulation caused by the two photos is compared. If a shift in phase is found, this indicates that there is parallax. In this case, parallax is immediately cleared by means of a servomotor.

The scanning pattern used (figure XVIII) not only allows x but also y parallax to be detected. As a result, the correlator facilitates relative orientation, since in

[13] W. Brucklacher, *Automatic Control of Orthoprojector by Planimat and image correlator*, Bildmessung und Luftbildwessen 2, 1968.

[14] J. W. Hardy, *Ein elektronischer Korrelator für den Planimat*, Zeiss-Mitteilungen 3, 1969.

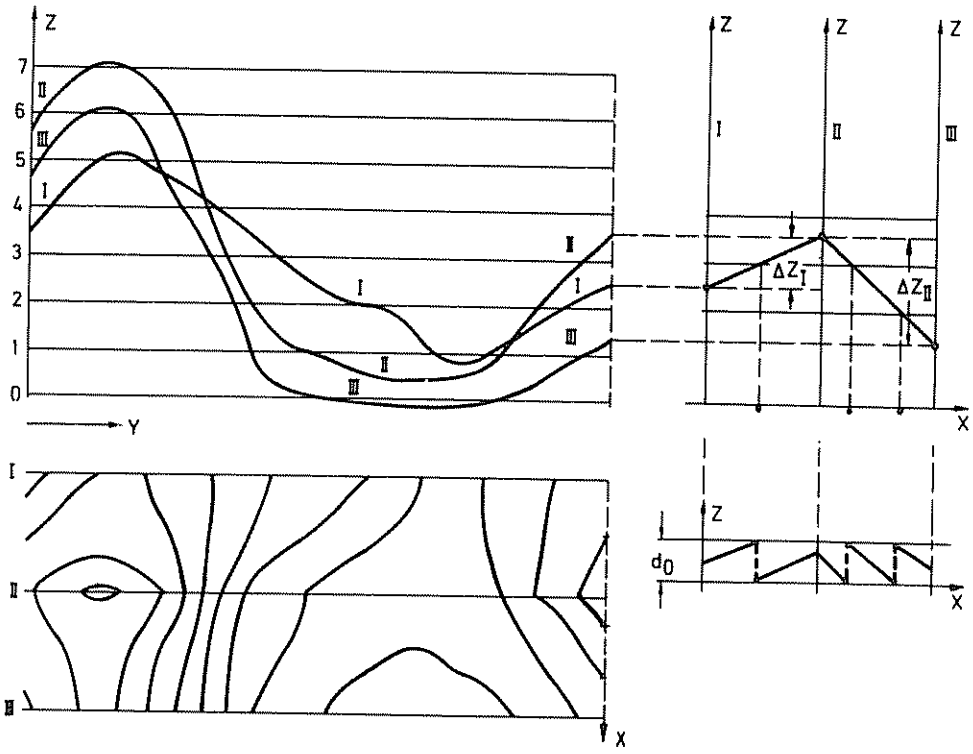


Figure XIV. Geometrical generation of approximate contour lines from profiles by linear interpolation between the profiles

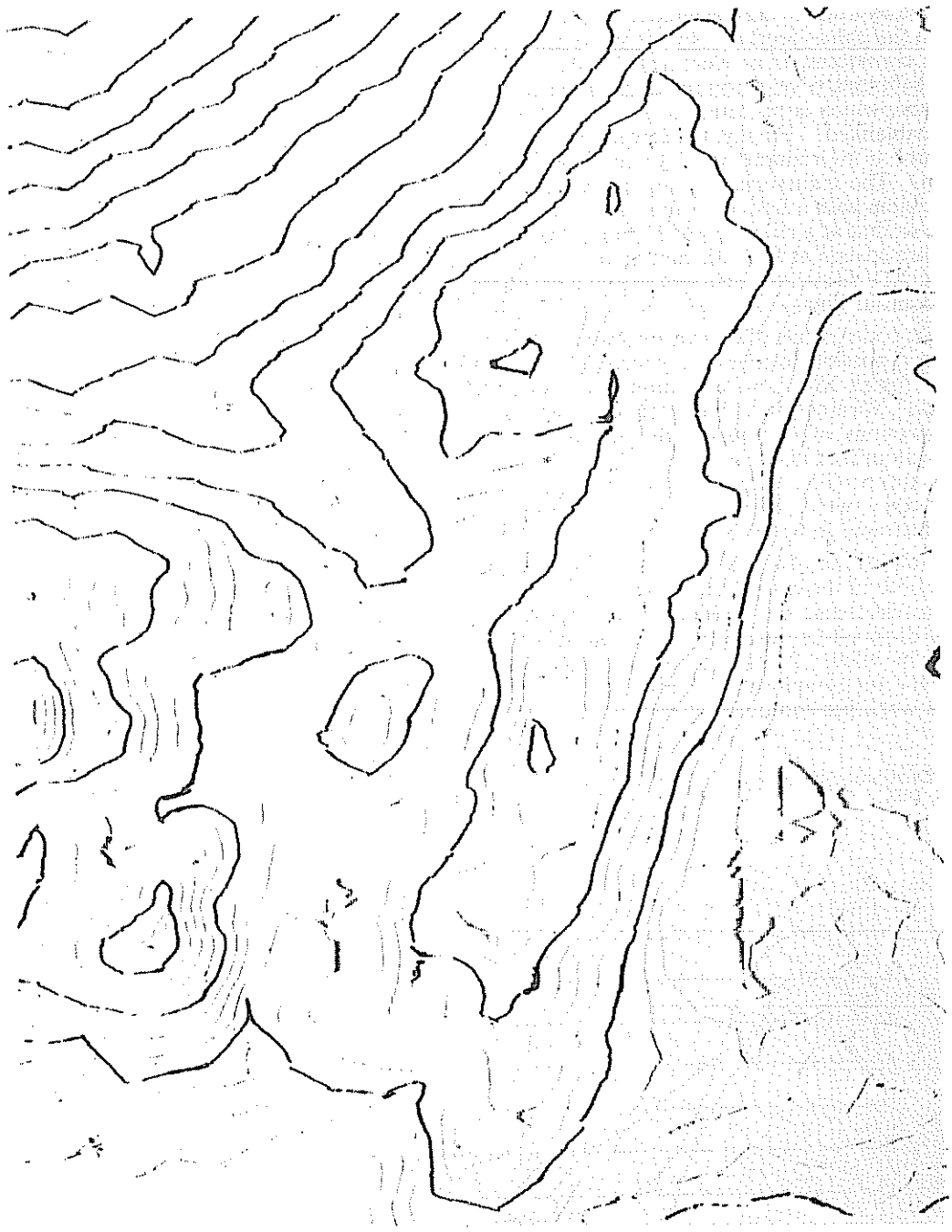


Figure XV. Part of a 1:10,000 contour plot produced electronically and simultaneously with the orthophoto (4 h = 5 m; 4 H = 20 m)

order to clear parallax, the operator need not view the photos stereoscopically, but only check a null indicator in the electronic cabinet. The correlator incorporates a number of features that are indispensable for reliable operation. For one thing the scanning pattern is varied in size to suit the spacing of detail in the photos. It is deformed to make allowance for image distortion caused by photo tilt. Should featureless areas (water bodies, deserts) make it impossible to obtain correlation, the tracing pencil will mark the area where correlation failure occurred on the integral tracing table of the Planimat. At the same time, the stylus in the SG-1 is lowered from the storage plate. Any gaps due to correlation failure can thus be easily filled in manually after automatic profiling of the model has been completed.

The combination of Planimat and EC-5 correlator allows four different modes of operation:

"Standby-manual": The correlator is switched off and the Planimat can be operated in the conventional manner;

"Orientation": x and y parallax is indicated on a null

indicator, y parallax is cleared in the conventional manner, x parallax automatically;

"Check mode": Planimetric motion is controlled by the operator, but the floating mark is kept in contact with the ground by the correlator;

"Automatic mode": Fully automatic profiling.

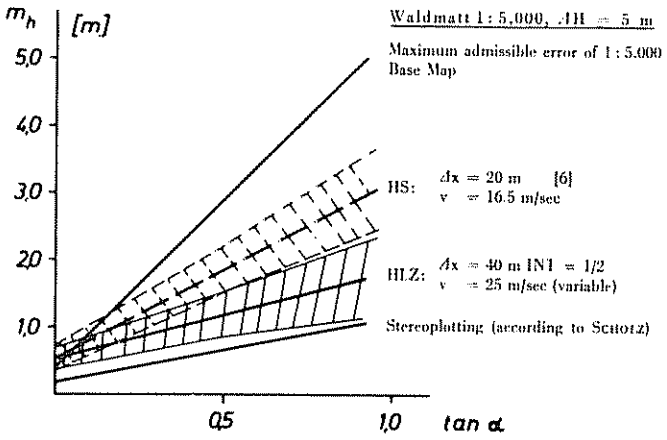


Figure XVI. Accuracy of contours constructed from dropped lines (HS) and of electronically generated contours (HLZ), plotted against terrain slope

The correlator not only offers the advantage that it relieves the operator of tiresome stereoscopic scanning; on account of its higher operating velocity, which automatically varies in accordance with the correlation quality of the aerial photographs, it also reduces the time required for profiling a medium stereo model to about one-third or one-fourth of that needed for manual operation. On the other hand, investigations have shown that the mean square vertical accuracy of complete models is not less than in the case of manual operation.[15] A slight increase in accuracy is observed on slopes. Peaks and valleys tend to be cut off and filled in respectively, owing to the finite area of correlation (integration of elevation over a certain area). As a result, there is a certain flattening of small topographic features.

Importance of Orthophoto Production

In view of the aforementioned multitude of possibilities offered by the GZ-1 system there are quite a number of aspects under which the technique of orthoprojection will gain considerable importance in the future. Depending on the sophistication of the system, its advantages can be utilized either singly or together. If the GZ-1 orthoprojector is employed in the storage mode, the projection process and—in conjunction with the Planimat with EC-5 correlator—the profiling operation can also be automated. In this case, the operator's intervention is limited to

[15] J. W. Hardy, *Automatic stereoplotting with the EC-65 Planimat*, Bildmessung und Luftbildwessen 1, 1970

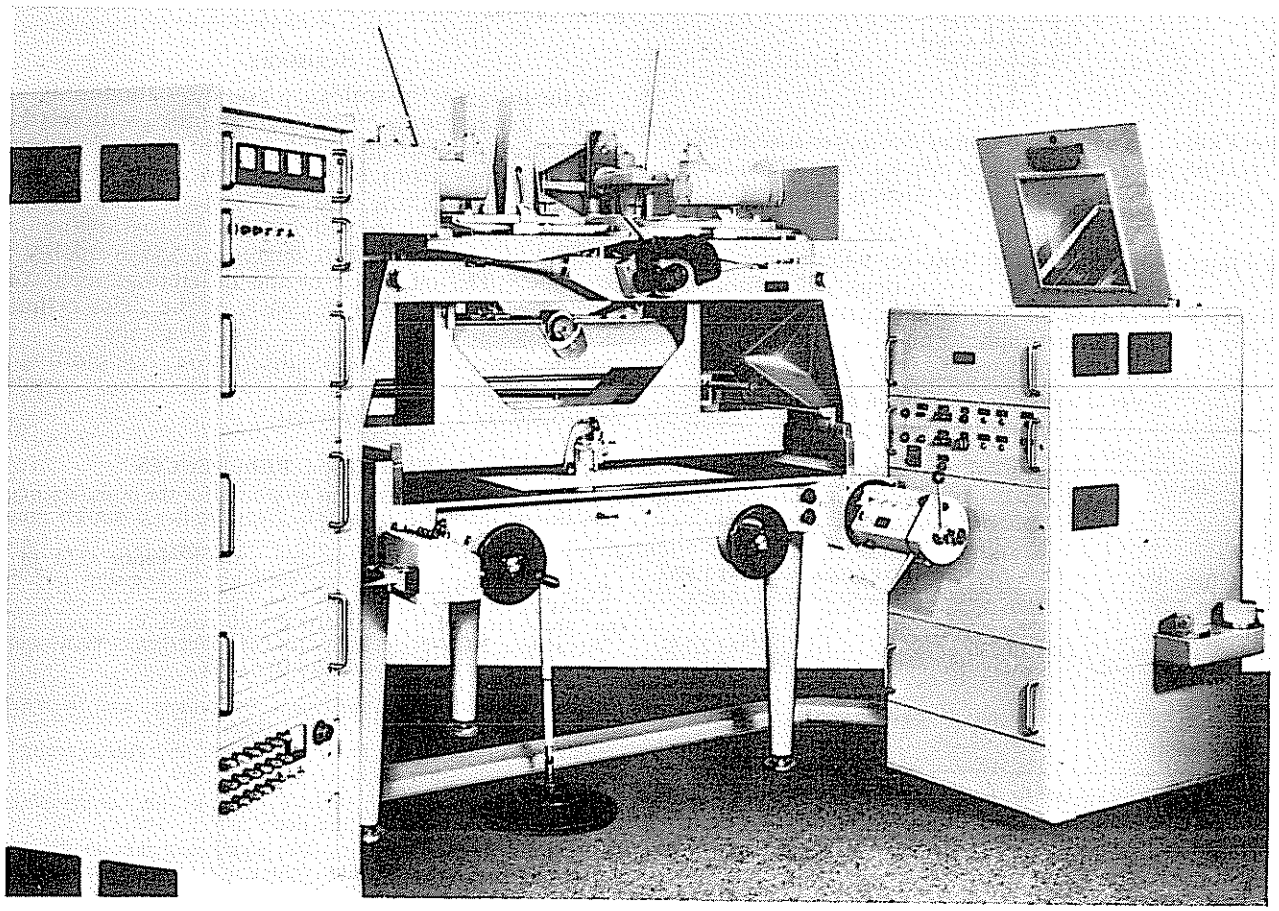


Figure XVII. Zeiss Planimat with Itek EC-5 correlator and SG-1 storage unit

orientation and preparation, so that the term "semi-automatic orthoprojector system" seems justified. However, apart from their susceptibility to automation, equipment systems and techniques are primarily judged by their economy. Both with respect to production rates and costs, orthoprojection is superior to stereoplotting. Thus the performance ratio between orthoprojection and stereoplotting at a scale of 1:5,000 (planimetry and contours) is about 10:1.[16]

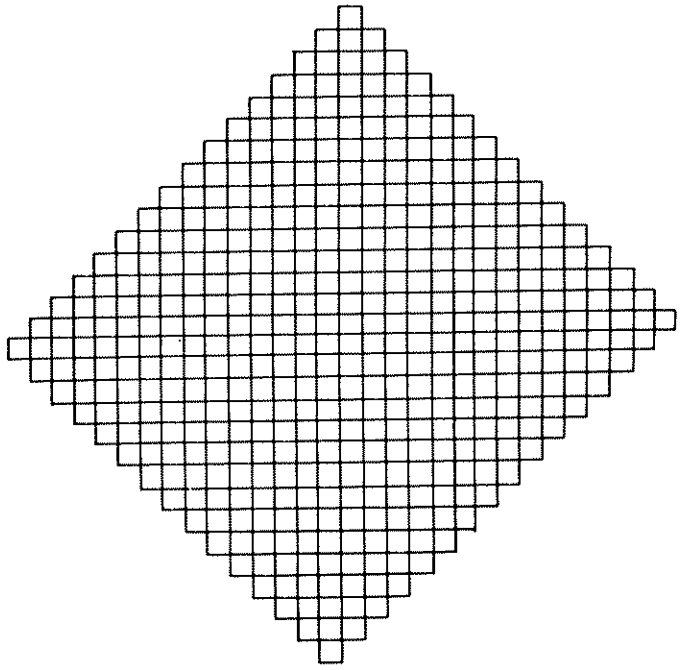


Figure XVIII. Scanning pattern of flying spot used in EC-5 correlator for determining the density distribution in the air photo in the proximity of the floating mark

A comparison of economy may be made by taking the cost of one map sheet as an example. The following summary will provide an idea of the costs of a line map, a photo map and an orthophoto map:

Costs of one map sheet (without flight)

Line map		*Photo map*	
Planimetry: Stereoplotter Contouring: Stereoplotter		*Rectifier Stereoplotter*	*Orthoprojector Orthoprojector*
1:2,000 2 km² (after Kersting 9.7)		DM 1,750 105%	DM 1,670 100%
1:5,000 4 km² (after Voss 17)	DM 12,130[a] 550%		DM 2,190 100%
1:10,000 25 km² (after Johansson 8)		DM 3,850 122%	DM 3,150 100%

[a] This includes DM 6,000 for field completion surveys.

[16] H. K. Meier, *Theory and practice of the Gigas-Zeiss Orthoprojector*, Zeiss Mitteilungen 2, 1966.

Also taking into account for the orthophoto map the saving in time made possible by use of the optical interpolation system and the electronic contourliner for the GZ-1 the following can be said: when using the GZ-1 orthoprojector system, the costs of one orthophoto map are only about 10 to 20 per cent of those for a line map. Even compared with a controlled mosaic assembled from several rectified prints (produced, for example, with the aid of an SEG-V), the costs involved when using the GZ-1 for orthoprojection only come to about 50 to 80 per cent. Line maps will continue to be of service in the future, however. Examples published by Schweissthal[17] and Schlager[18] show that even in this case the orthoprojection technique may serve as a basis. By photomechanical methods contour separation negatives can be filtered out of orthophotos, for example by printing a positive sandwiched with a negative of slightly different scale. The Pictoline, Pictotone and Pictodrome methods developed in the United States work on a similar principle. By producing special photographic material, e.g. the "Agfacontour" film,[19] it is possible to directly obtain contour representation when projecting. Figure XIX shows an example of the orthophoto projection technique as per R. Schweissthal. Orthophotos will not only gain in importance for the production of new maps, but also for the revision of existing maps. Only the method of differential rectification combined with storage techniques will some day make it possible to keep our maps up to date. The techniques and an efficient equipment system for the economical, rapid and precise revision of maps are not only available, but have already proved their worth in practical use.

Summary

In the field of large-scale cartography, orthophotography is gaining in importance over stereoplotting with respect to economical production. The present line of orthoprojectors extends from reasonably priced, simple models used for instructions and orthophoto production for planning purposes to systems for cartographing large areas requiring the highest degree of image quality and accuracy. The efficiency of the differential rectification method is described on the basis of the Zeiss orthoprojector system. In particular, the advantages of profile storage, simultaneous automatic contour line plotting and automatic stereoscanning by the electronic correlator developed by Itek are featured.

Additional References

O. Johansson, Orthophoto maps as a basis for the economic map of Sweden on the scale of 1:10,000, *The Canadian Surveyor*, January 1968.

R. Kersting, Erfahrungen mit dem Orthoprojektor GZ1 in der Landeskulturverwaltung Rheinland-Pfalz, Bildmessung und Luftbildwessen 5, 1969.

The production of 1:5,000 orthophoto maps in North Rhine-Westphalia, NOV-Nachrichten aus dem öffentlichen Vermessungsdienst Nordrhein-Westfalen, January 1968.

[17] R. Schweissthal, *Grundlage, Bearbeitung und Herstellung grossmassstäbiger Luftbildkarten, Wissenschaftl.*, Arbeiten der Lehrstühle für Geodäsie, Photogrammetrie und Kartographie der Technische Universität Hannover, No. 34, 1967.

[18] C. W. Schlager, *Die Orthophotographie im kartographischen Verfahren*, Bildmessung und Luftbildwessen 1, 1966.

[19] E. Ranz and S. Schneider, *Der Aquidensitenfilm als Hilfsmittel bei der Photointerpretation*, Bildmessung und Luftbildwessen 2, 1970.



Figure XIX. Comparison of orthophoto, contour separation print and the resulting line map

SUMMARY OF THE PHOTOGRAMMETRIC SURVEY FOR THE CONSTRUCTION OF A SPEEDWAY

*Paper presented by China** [1]

In order to improve traffic for economic development, the Government of China decided to build a 365 km speedway. Maps at 1:1,000 and 1:5,000 for the alignment and designing of the route will be compiled by the photogrammetric method. This project consists of a total of 598 map sheets (50 × 80 cm each sheet), covering an area of 1,410 km². The whole project, considered a big one in this area in recent years, will be completed by the end of June 1971. A brief account of this project is given below.

AERIAL SURVEY

Aerial camera: Wild RC8, 6 inch focal length.
Scale of vertical photos: 1:4,000 and 1:12,500.
Size of photos: 9 × 9 inches.
Side lapping: 30 per cent.
Forward lapping: 65 per cent.
Circle of confusion: not exceeding 0.03 cm.
Tilt: Not exceeding 2 degrees (average).

CONTROL SURVEY

A total of 259 third-order triangulation stations will be established with a Wild T2 theodolite, an average of one station per 5 km²; 767 control points are to be established, an average of one point per 2 km²; and 460 photogrammetric control points are to be established, an average of two points per ten stereoscopic pairs. The co-ordinates will be based on the Transverse Mercator map projection. Elevation is based on mean sea level, Keelung datum.

STEREOCOMPILATION

Photogrammetric control will be established with a Wild A7 autograph, with at least two points for each stereo pair. The error of horizontal displacement should not exceed 0.25 mm.

Topographic maps at 1:1,000 are to be compiled with a Wild A8 autograph and B8 stereoplotters, using 1:4,000 vertical photographs. The contour interval will be 0.25 m for plains, and 1 m for hilly areas. The error of position should not exceed half the interval. The error of relative position of the features on the maps should be limited to 0.5 mm.

Topographic maps at 1:5,000 are to be compiled with multiplex instruments, using 1:12,500 vertical photographs, with 1 m contour for plane and 5 m contour for hilly areas. The specifications for accuracy are the same as in the preceding paragraph.

FIELD EDIT

Field edit will be made on features such as geographical names, city and country boundaries, etc. Meantime, a supplementary survey will be performed on road intersections, elevation of river beds and areas not clearly shown on aerial photographs in accordance with the reference features or controls.

DRAFTING

Drafting will be done according to map symbols. Marginal data, geographical names, elevation numbers and spot elevations will be printed on paper and pasted on the sheet. The size of the map sheet is 50 × 80 cm.

REPRODUCTION

One negative and two positives will be made through the process camera from the drafted copy.

* See introductory note at beginning of volume.

[1] The original text of this paper appeared as document E/CONF. 57/L.37.

SUMMARY OF PHOTOGRAMMETRIC WORK, 1967–1969

*Paper presented by China** [1]

Photogrammetry is a new mapping technique developed in the late nineteenth century and introduced in China in 1930. Since then this mapping process has been widely applied to urban development, mine exploration, communications, water conservation and other engineering projects by the China Topographic Service. As the Service is the largest and best-equipped mapping organization in China, it has produced, by means of photogrammetry, a great number of map sheets. It has also contributed a great deal to national development by assisting other governmental organizations in the fields of surveying and mapping.

* See introductory note at beginning of volume.

[1] The original text of this paper appeared as document E/CONF. 57/L.38.

EQUIPMENT

List of equipment

Classification	*Description*	*Quantity*
Aeroplane:		
Civilian surveying planes	1	1
C45 military surveying planes	1	1
Aerial camera:		
Zeiss RMK 21/28, Aerial camera	1	3
Zeiss aerial camera	1	3
Wild RC8 12/23 aerial camera	1	1
K17 aerial camera	1	1
KA-1 aerial camera	1	1
KA-2 aerial camera	1	1
Rectifiers:		
Zeiss SEG I V rectifier	1	6
Bausch & Lomb rectifier	1	2
Stereo-mapping instruments:		
Wild autograph A7	1	1
Stereoplanigraph C8	1	1
Planimat D3	1	1
Bausch & Lomb multiplex equipment	1	13
Multiplex instruments, Zeiss	1	5
Kelsh plotter	1	3
Balplex plotter	1	1
Stereotope	1	1
KEK plotter	1	1
Processing equipment:		
Aerial film processing equipment, Zeiss	Set	4

COMPLETION OF PHOTOGRAMMETRIC WORK

Our national economy has developed to a great extent in recent years. As a result, map requirements have increased. In recent years, the China Topographic Service has undertaken various projects of photogrammetry on land utilization, city sewage, dam construction, highway and railway constructions and forestry and urban development at the request of other governmental organizations. The detail is shown in the table below.

SUMMARY

The photogrammetric work was developed quickly during the early stage and widely accepted as the best method to meet surveying and mapping requirements in various fields. However, the rapid growth of photogrammetric operations was affected by the war. In recent years, we have made some progress in photogrammetry by procuring the latest equipment and adopting new techniques. With a view to meeting the increasing mapping requirements in economic development, we will continue to improve our mapping capability and techniques in the coming years.

Map completed during the period under consideration

Type of map and description	*Scale*	*Area covered (km^2)*	*Method of preparation*
City development maps:			
Kaohsiung city development map	1:6,000	45	Rectification and
City plans for 5 cities	1:3,000	126	stereo mapping
Taipei city map	1:1,200	22	Rectification and
Kao-Hsiung city plan	1:1,200	126	stereo-mapping
Map of greater Taipei	1:1,200	280 (972 sheets)	Rectification and stereo-mapping
Communication maps:			
Round-the-island railway map	1:5,000	360	Stereo-mapping
Cross-island highway map	1:5,000	44	Rectification
Water conservation maps:			
Shih-men reservoir	1:10,000	763	Rectification
Keelung sewage map	1:1,200	18	Rectification and stereo-mapping
Nan-tze canal map	1:10,000	17	Stereo-mapping
Ta-Chia land reclamation map	1:10,000	450	Rectification
Taipei sewage map	1:1,200	75	Rectification and stereo-mapping
Land-use maps:			
Land-use map	1:20,000	17	Rectification
Yung-lin land reclamation map	1:5,000	120	Rectification
Taitung farm land map	1:1,200	14	Rectification
Ta-hsih-san forestry map	1:10,000	250	Rectification
Chin-san power plant map	1:9,600	12 sheets	Rectification
Pasture investigation map	1:25,000	3,000	Rectification
Mountainous area cadastral map	1:1,200	2,400	Rectification
Kao-hsiung cadastral map	1:1,200	396	Rectification

INTRODUCTION TO DIGITAL PHOTO-MAPPING

Paper presented by Japan[1]

The aerial photograph is an image of terrain features produced on photographic emulsion by central projection through a lens; naturally, the planimetric position of each image point is displaced as a function of its height and angular distance from the optical axis of the camera. Elevation of each terrain point cannot be read out directly from the photograph; it can be obtained only through processes of converting analogue values into digital ones with stereoscopic plotting instruments and computations. Thus, to express the object in digital form, drawings such as plans, profiles, cross-sections and/or digital terrain maps prepared by the photogrammetric technique must be adequately utilized.

However, in these drawings aerial photography is reduced to a mere surveying tool. Only a small portion of the total data (large in quantity and precise in quality) contained in aerial photographs is utilized. To eliminate this disadvantage, the orthophoto map, a combination of orthophotography and contour-line drawing, was adopted.

Owing to recent dramatic progress in electronic computers, on the other hand, data processing possibilities continue to increase. In the field of surveying and designing, the computer has come to be used as a data processing machine rather than as a calculating machine.

The conventional procedure of preparing input data for processing by electronic computer in surveying and designing entails very complicated processes of preparing maps from aerial photographs and reading the necessary data on these maps; most of the detailed data contained in the aerial photographs are lost.

We have developed the digital photomap in order to make full use of the abundant and precise analogic data contained in aerial photographs and so as to acquire digital values which could be easily processed at the same time in an electronic computer. This kind of photomap will be described briefly below.

The digital photomap (DPM) is a photomap of central projection showing the elevation of the intersection points of a square grid system assumed to be disposed on the terrain surface. To facilitate the stereoscopic observation of the DPM (by using stereo pairs of photographs), the square grid assumed on the terrain surface is superimposed on the photographs by central projection. The planimetric position of the grid on the DPM is therefore displaced as a function of the terrain height and the angular distance from the optical axis of the camera, but when these grid points are transferred on the actual terrain surface, they again form regular squares.

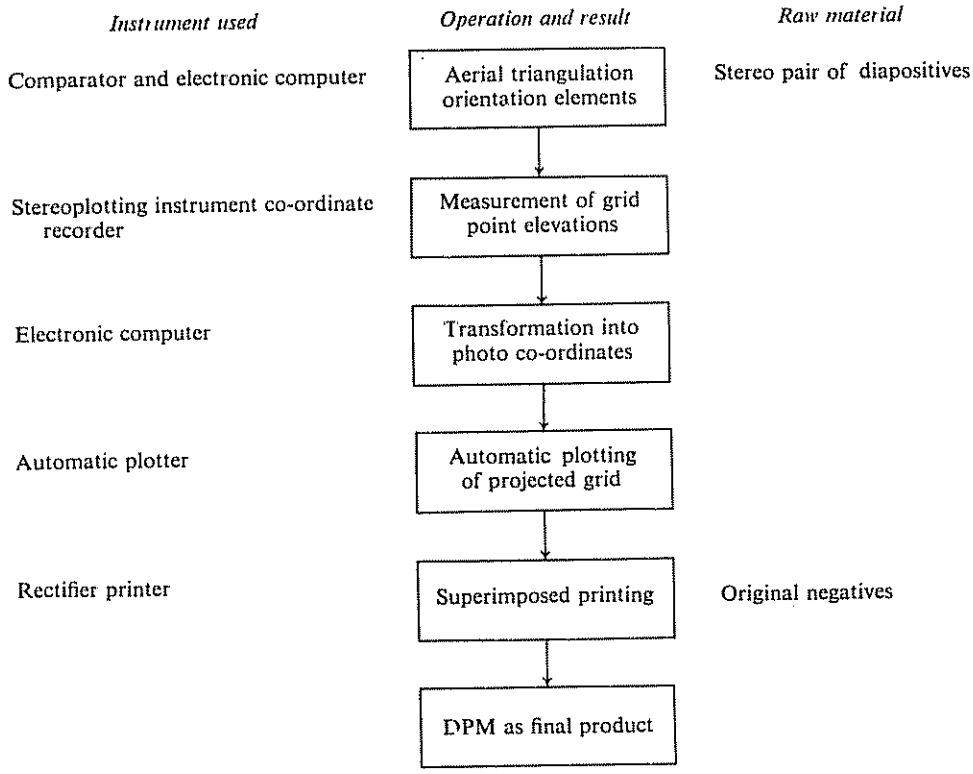
In the stereoscopic observation of a pair of photographs (DPM) (see figures I and II on pp. 255–256), it is possible to see the stereoscopic models not only of the terrain itself but also of the grid mesh in three-dimensional shape, closely attached to the terrain surface. The numbers at each grid point represent its elevation in metres.

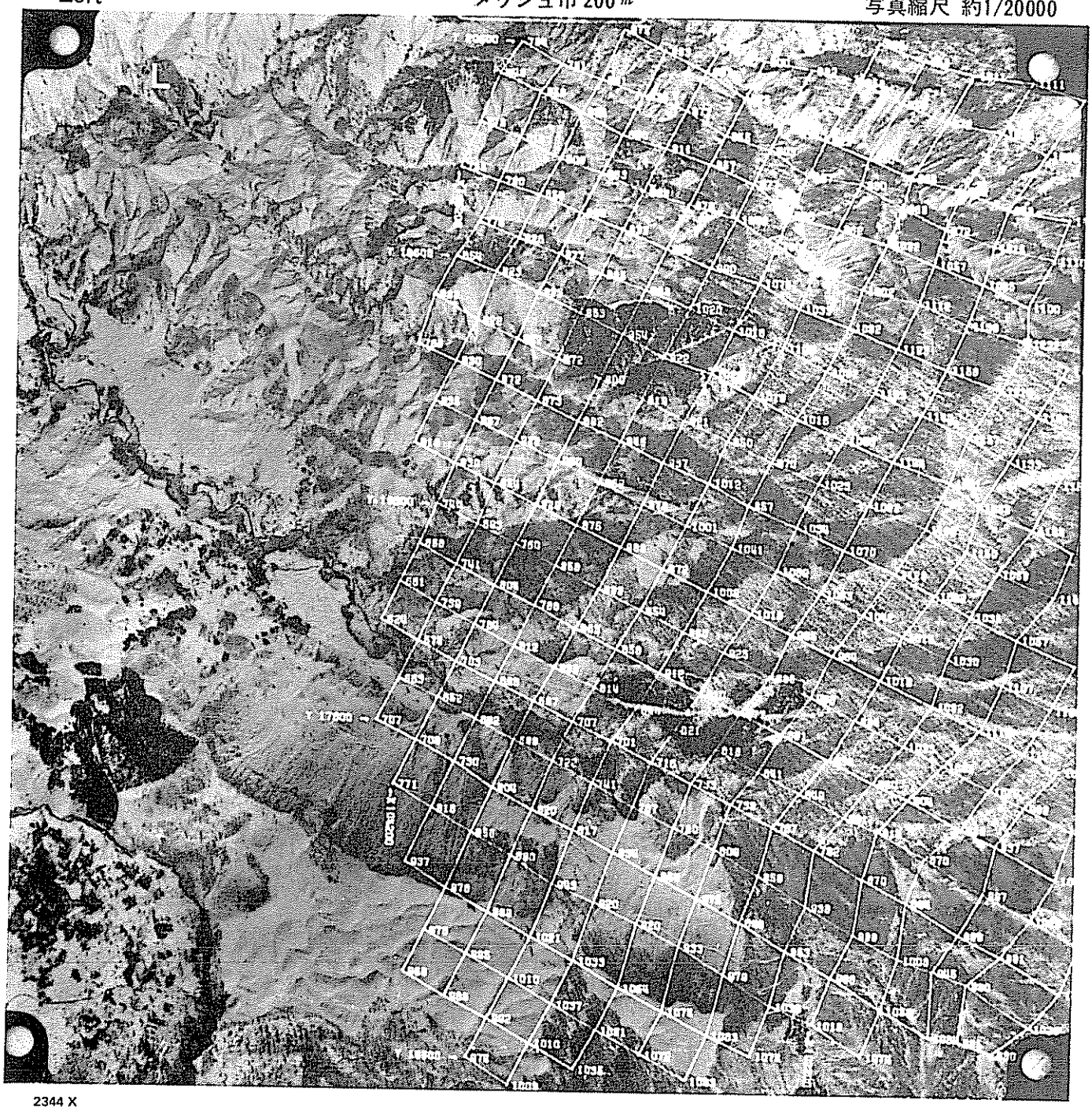
The grid interval of these sample DPMs has been selected to represent about 1 cm on the DPM, but any value can be selected for this interval; however, 4 mm should be a minimum, since anything lower might affect the stereoscopic effect adversely.

[1] The original text of this paper, prepared by M. Fuchimoto and R. Kamiya, Asia Air Survey Co., Ltd., Tokyo, appeared as document E/CONF.57/L.55.

ANNEX

Main steps in preparing a DPM





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Figure 1. Digital photomap (left)

Right　　メッシュ巾 200 m　　写真縮尺 約1/20000



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Figure II. Digital photomap (right)

DEVELOPMENTS IN ORTHOPHOTO MAPPING

Paper presented by Australia[1]

Introduction

In 1966 a federal programme was commenced for the coverage of Australia with maps at a scale of 1:100,000 having a contour interval of 20 m. For the coastal fringe, consisting of approximately 3,000,000 km², the maps will be published in traditional form at 1:100,000 but for the central region of approximately 5,000,000 km² manuscript maps will be compiled at 1:100,000 but maps will be published at 1:250,000 only.

The programme is, for the most part, being carried out by the two federal agencies engaged in mapping, the Department of National Development (Division of National Mapping) and the Department of the Army (Royal Australian Survey Corps). The State Lands Departments participate in varying degrees with the Federal Department of National Development reimbursing the cost. One State (Tasmania) is mapping the whole of its territory at 1:100,000.

Introduction of orthophoto techniques into the programme

Orthophoto maps have many advantages for geoscientists and for those engaged in the exploitation, administration and preservation of the Earth's natural resources, in that this particular type of map readily permits the plotting of the correct map position of data that has been identified on air photographs.

From the map production viewpoint, orthophotos have the advantage that identification and plotting of detail can be carried out with the aid of simple stereoscopic plotting equipment by personnel with reasonable interpretative and drafting ability. Where a mapping programme is scheduled for completion within a set time-frame, this particular aspect is of significance to management in that, first, it provides for a more flexible use of field staff who, on completion of control surveys, can be used not only for accuracy check surveys but also for the field and/or office identification of map detail and for the simple plotting of this detail; secondly, it opens up a much wider field for contract support from moderately equipped survey and drafting offices throughout the country.

Early experience in various organizations throughout the world has shown that orthophoto mapping techniques have obvious time-saving advantages over traditional techniques where the orthophoto and contour overlay in themselves provide all the necessary data. Furthermore, if orthophoto maps can be obtained as a by-product in the production of traditional "line" maps, without loss of specified map accuracy and without very materially increasing production costs, then it will certainly be very worth while to adopt this form of production, particularly for medium- and small-scale national mapping programmes.

Another possible benefit from orthophoto mapping techniques can be obtained by the simultaneous recording of digital terrain data. Whether it is worth while doing this in every case is unknown at this stage, but future user experience may justify such a course of action.

When the 1:100,000 mapping programme commenced, test models were forwarded to various manufacturers for processing into orthophotographs, but little was known of the economics of orthophoto mapping techniques, and for the coastal perimeter of the country where publication is intended at the basic scale, it was decided to rely primarily on traditional "line" mapping procedures, but to include some orthophoto mapping techniques, as appropriate, and almost certainly to use them in the course of future revision of areas of intensive new development. Within the central area where compilation is required at 1:100,000 for publication at 1:250,000 and where the terrain is for the most part extremely flat and sparsely vegetated, orthophoto mapping techniques were an obvious choice.

Much of this orthophoto mapping can be accomplished by simple rectification supplemented by contouring in stereoplotting equipment. In fact about 20 per cent of the area is so flat that contours can be directly interpolated from airborne profiles.

(It should be explained that the sand ridges which cover a great part of central Australia are fairly stable, and, in most areas, lightly vegetated. They are usually roughly parallel at varying distances apart with a flat area between them. In sand-ridge terrain it is the intention to contour the flat areas only, and include a general note as to the height of sand ridges.)

Present application and plans for use in Australia

While topographic mapping is generally continuing along traditional lines, the regular production of orthophoto maps has now commenced in the Division of National Mapping, and other agencies are now starting to introduce the technique.

The Division of National Mapping will convert 1:84,000 superwide-angle photography into 1:80,000 orthophoto maps on 1:50,000 series sheet lines with a separate contour overlay at the same scale. When viewed with the original photography, the orthophoto map at this scale will enable simple semi-stereoscopic examination and annotation of the detail on the orthophoto map to form a basis for the production of standard 1:100,000 and 1:250,000 line maps in certain areas. The 1:80,000 orthophoto maps will also be made available to users in various disciplines where the advantages outlined above will prove a valuable aid to field investigations.

Types of equipment installed in Australia

Wild B8 stereomat

The B8 stereomat consists of two basic components which are intimately tied together to make one efficiently operating instrument. The optical-mechanical part of the photogrammetric instrument is derived from the Wild B8 aviograph. It retains the ability of the B8 to accommodate wide-angle photography of the prevailing focal lengths 100 mm, 115 mm, 152 mm (6 inch), as well as the superwide-angle photography of 88 mm focal length. The electronic part of the instrument is an ingenious combination of scanners, detectors, correlators and servomotors, which to a large extent replace the functions of the human

[1] The original text of this paper, submitted under items 9 (*a*) and 9 (*b*), appeared as document E/CONF.57/L.63.

operator. The Division of National Mapping has three B8 stereomats installed and two are equipped with digitizing facilities.

Zeiss topocart—orthophot—orograph

This system consists of three interconnected units: the topocart, which can function as a normal stereoplotting instrument; the orthophot, which is a differential optical rectifier; and the orograph, which is a special contour drop line drawing-head attached to the topocart drawing table. The Division of National Mapping has two complete systems installed.

Zeiss GZ-1 orthoprojector

This equipment is of the optical projection type incorporating multiple stage rectification. The required vertical information is supplied either directly or via a storage unit.

For direct operation the GZ-1 is set up in a dark room adjacent to the stereoplotter. The interconnection is by synchro drives, the X and Y motion being under full automatic control by the GZ-1 with the Z motion controlled at the stereo plotter by a handwheel.

For operation via storage the vertical profile and control point registration marks are scribed on storage plates in a unit connected directly to the stereoplotter. This storage plate is inserted into a scanning unit, the profiles are scanned by photo cells and the resultant data is fed into the GZ-1 to control the rectification process. An advantage of the indirect method is that interpolation procedures may be used and it is not necessary to scan every profile in the stereoplotter.

The Department of Lands and Survey, Western Australia, and the Department of Lands, South Australia each have a GZ-1 installed, connected to a Zeiss planimat stereoplotter.

Operational notes—Wild B8 stereomat

The first Wild B8 stereomat was delivered to the Division of National Mapping in January 1968 and finally accepted in September of that year. The second such machine was delivered in October 1969 and finally accepted in March 1970. A third machine was in process of installation during October 1970. Since acceptance, the first two machines have been in continuous operation except, in the case of the first machine, for periods of maintenance. In the first year this consisted of 36 days for electronic maintenance and 7 days of mechanical maintenance, which included early delays due to non-availability of spares. In recent operations there has been a 5 per cent "down time" for adjustment and maintenance of equipment and an additional 5 per cent while awaiting servicing.

The two stereomats, in operational production by the Division, require a team of two personnel per machine/shift and this team attends to preparatory activities, machine operation, editing of contours, preparation of photomap and preparation of contour overlay.

For the last fifty models processed on the two machines the average "set-up time" was 1 hour per model with an average variation of ± 5 minutes; this included placing the diapositives in the machine, relative and absolute orientation and the loading and unloading of cassettes. The average time for production of an orthophoto plus digital output and/or contour segments was 2 hours with an average variation of ± 15 minutes. Additionally, a commercial contractor both develops the orthophoto negative and produces the corresponding colour separated prints at the rate of eight models per day.

From the above figures and the earlier figures quoted for traditional stereocompilation, it will be seen that the machine time and manpower required for production of an orthophoto map and contour overlay via the stereomat equipment is about one-third of the time required to produce a manuscript compilation in traditional form. The additional inspection and annotation of the orthophoto map, using simple stereoscopic equipment, should certainly not extend this over-all time to more than that required for traditional stereoplotting.

Provided the photographic image possesses good detail, the stereomat does not appear to be worried either by the ruggedness or the flatness of the terrain. In light to medium timber the floating mark appears to move over the ground surface, and in dense timber it appears to travel slightly below the treetops.

The orthophoto produced by the stereomat is at 1:40,000 and when reduced to 1:80,000 or 1:100,000 it is of quite good quality considering the production process. A work flow diagram is shown in figure I.

Operational notes—Zeiss topocart—orthophot—orograph

The Division of National Mapping has installed two topocart equipments. About twenty test and experimental models have been produced up to October 1970, and on the basis of this limited experience a preliminary assessment of the equipment has been made.

The over-all operating procedures should present no difficulty to an experienced stereoplotter operator. Some care is required in performing the relative and absolute orientations. No X or Y movements of the picture carriages are permissible when the ω and φ clamps are in the release position since the clamp levers are connected to the clamps with rather fragile wires and any large carriage movement will break them. A warning alarm has been fitted but is only operative if the orthophot unit has been switched on.

The manual operation of the Z column control during scanning has, predictably, proved rather monotonous. It is possible that this could be performed by assistant technician type staff, either male or female, with supervision by senior staff. Within limits, the basic scanning speed does not appear to greatly affect the quality of the orthophoto image. However, the reliability of the contour drop lines is affected if fast scanning speeds are used and alternate and opposite displacement along the scan direction can occur due possibly to a combination of mechanical and operator response delay. The variable scan speed facility is very useful and no exposure variations were detected throughout models where full use had been made of it.

The drop line scribing head would only function on coated glass plates and could not produce satisfactory lines on coated film. A unit incorporating "microdraft" ball-point pens was designed and satisfactory drop line charts have been produced on conventional drafting film bases.

The orthophoto quality in relation to image resolution and absence of scan join lines is considered very satisfactory, but insufficient production work has been done at this stage to assess the over-all electronic and mechanical reliability of the equipment. A work flow diagram is shown in figure II.

Operational notes—GZ-1—Department of Lands, Western Australia

The Department of Lands, Western Australia, undertook initial testing with the following equipment in September 1970: Gigas-Zeiss orthoprojector GZ-1; planimat D2; relay unit LG1; and storage unit SG1.

The objectives of these tests were to produce orthophotomaps at 1:10,000, 1:5,000, 1:2,500 and 1:1,200.

1:10,000 test

Aerial photography at 1:30,000 enabled three stereomodels to give complete coverage of the map sheet. The total processing time to produce the required orthophoto negatives was 15 hours, or 5 hours per model.

The negatives were cut and fitted together to form the map sheet. The drop line chart was interpreted and nomenclature and contour overlays produced for combination with the negative to obtain bromide or stable-base prints.

1:5,000 and 1:2,500 test

Basic photography at 1:13,700 required two full photographs for complete map sheet coverage. The utilization of north–south photography runs flown at 6,835 ft so as to

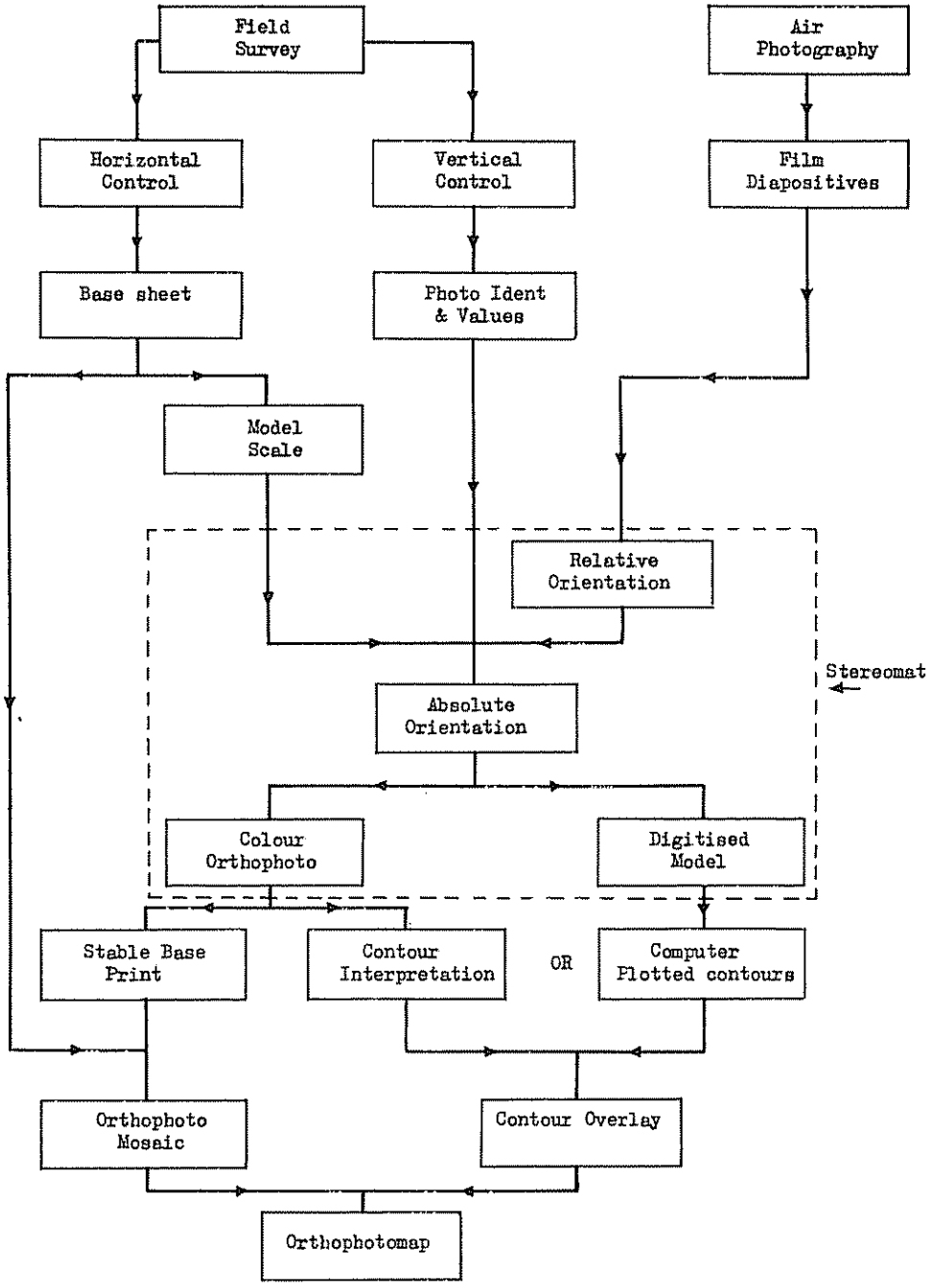


Figure 1. Work flow diagram: Orthophoto map production: B8 stereomat

give a complete 1:2,500 map sheet from every model was considered possible, and 1:5,000 map sheet coverage could be obtained by joining together two full plates.

Photography flown from 4,400 ft at 1:8,800 required three models to give 1:2,500 map sheet coverage. Interpolation procedures were used to improve the drop line chart, and the total instrument time to process the three models was 20 hours.

1:1,200 test

This test was designed to assess the large-scale capability of the GZ-1. Basic photography scale was 1:3,600 and the drop line contour interval was 2 ft, and, again interpolation procedures were used.

Summary

The test based, of necessity, on limited practical experience suggested that: (*a*) the placement of air photo exposures will enable minimum negative joining and if 80 per cent forward overlay is obtained a single exposure overlap will be available for every map sheet; (*b*) the orthophoto map will require to be produced on a stable medium; and (*c*) the cost of orthophoto mapping will be quite competitive in relation to normal instrument compilation

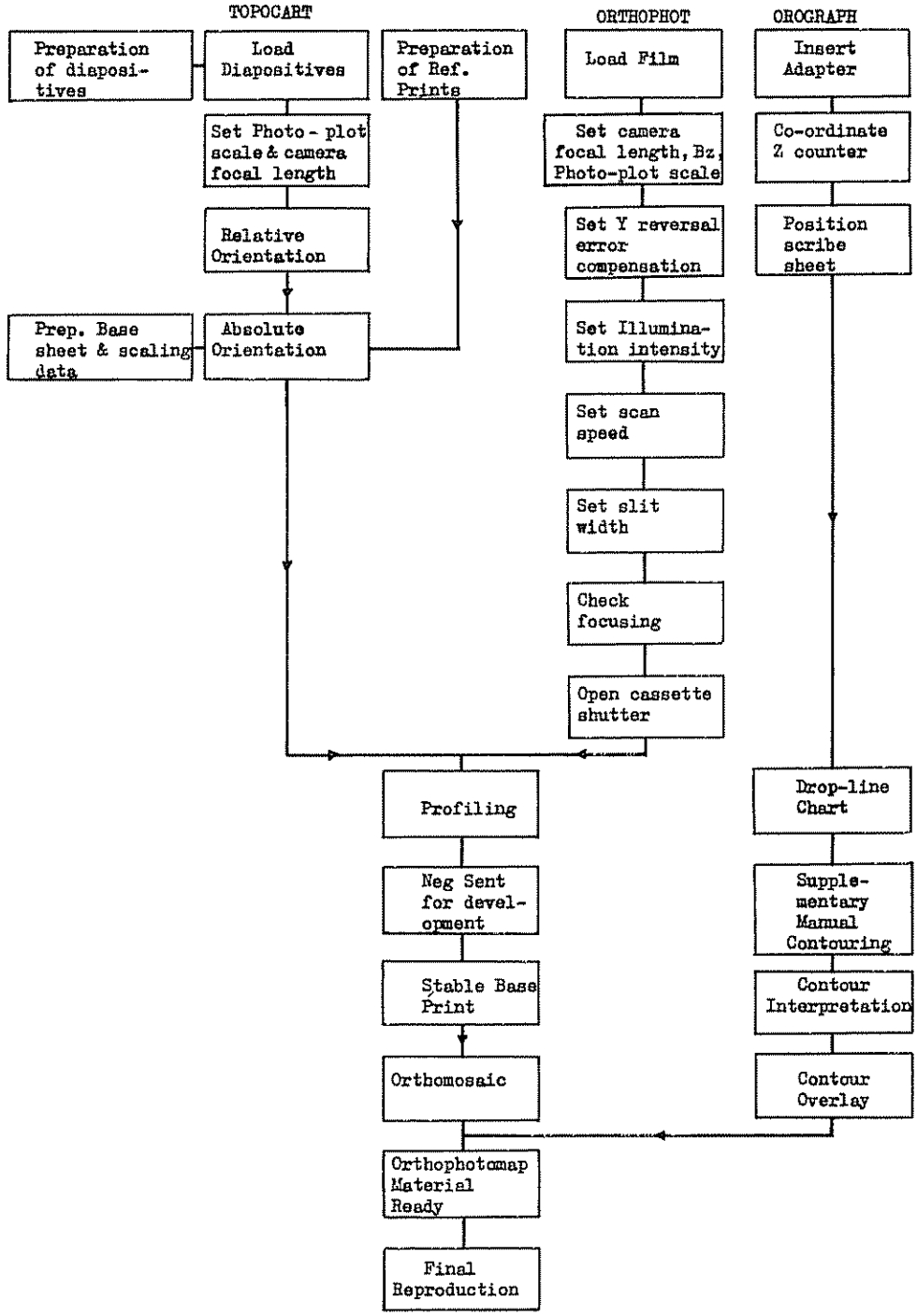


Figure II. Work flow diagram: Orthophoto map production: Zeiss topocart

provided it is pursued to the orthophoto map stage, i.e. with grid values and format information.

Future developments

It is almost certain that the production of coloured orthophoto maps will become a routine production operation within the next few years. To the technical expert they provide much more visual information than a line map and therefore provide a very useful base for delineating the map position of topographic and scientific detail that has been identified on air photographs or by field investigation.

It seems most likely that the future requirements of technically oriented maps users will be met by a basic coverage of orthophoto maps, possibly coloured, and supplemented by special-purpose transport overlays that will be plotted, on demand, from computer storage.

Orthophoto maps have the advantage that they can be produced quickly and can therefore readily provide an answer to the map revision problem. However, it should not be necessary to stereoscopically scan models for revision purposes. Some practical technique will need to be evolved whereby the photo limits and scanning lines are set out on a contoured map and the contour information are converted into a form that can be used to automatically drive a differential rectifier.

It is extremely difficult to assess the likely trend in the use of digitally recorded evaluation data. Air photographs plus identified survey control in themselves constitute a data bank from which digital terrain data can be extracted. However, the Division of National Mapping is already producing contour plots from digital terrain data obtained from the stereomat and, with refinements to the processing, this approach will be used particularly in areas where difficulty is experienced in extracting contour information by other methods. Other users have shown an interest in digital terrain data obtained in this way, but the potential for its use is yet to be fully realized.

In the light of these trends, critical management decisions will be necessary from time to time on the extent of production of normal line maps, lithographically printed copies of orthophoto maps and/or contact orthophoto map prints supplemented by computer stored information. In the meantime, the 1:80,000 orthophoto maps to be produced by the Division of National Mapping will afford a valuable aid to users in the various disciplines concerned.

PHOTOGRAMMETRIC NETWORKS OF LARGE-SCALE MAPS

Paper presented by the Republic of Viet-Nam[1]

General observations

The programme of pacification and economic development in the Mekong Delta calls for a map of a larger scale than the present basic map at 1:50,000. To meet these urgent needs, the National Geographic Department has had to use the method of aerial triangulation to establish frameworks of control points, with a view to preparing maps of the Delta at 1:1,000 and 1:10,000. This method saves time and results in a considerable saving in costs.

Descriptions of the method

Due to the fact that the Mekong Delta possesses a fairly dense levelling network along the main roads, the altimetric preparation of the photo control points can be done quickly and easily. What is more, in the case of photogrammetric cameras, pointing accuracy is more limited in altimetry than in planimetry. The aerial triangulation method is therefore characterized by separate plotting of the points on two networks:

(*a*) A planimetric network obtained by aerial triangulation from photo coverage at 1:50,000;

(*b*) An altimetric network established by aerial triangulation on a second cover at 1:10,000, which is itself used for plotting detail.

Plotting the planimetric network

A strip of photographs at 1:50,000 is prepared in the field at the rate of one pair in five; in other words, the photogrammetric preparation is done for one pair in four or five, with four control points (the photo control points) at the four corners. This strip of photographs is then fed into a Wild A7 Universal Autograph for aerial triangulation. Corrections for systematic errors (X, Y, azimuth, tilt) are determined and adjusted graphically with the help of a fibreglass rod.

When the pairs have been provided with aerial triangulation points, they are again located in the Wild A8 Autograph in order to plot a planimetric network of control points on photographs at 1:10,000 by the "double photographing" or "overflight" method. This consists of finding the co-ordinates of the location points on photographs taken at a low altitude (1:10,000) from photographs taken at a higher altitude (1:50,000). In spite of the fact that the aerial triangulation points do not have any altitudes, complete orientation can be roughly achieved with the help of the overlapping hydrographic networks of the area.

Plotting the altimetric network

The altimetric preparation is done in a manner similar to that described above (one pair in four or five), but is carried out directly from the photographic mission at 1:10,000. The mission data are fed into a Wild A7 Universal Autograph for aerial triangulation. The altimetric corrections of systematic errors (longitudinal and transversal inclinations) are also adjusted by the graphic method.

Accuracy

The large-scale maps thus produced are not as yet rechecked in the field to assess the accuracy of the method. However, the calculations and adjustments give an idea of its accuracy:

Estimated average quadratic error in planimetry ± 1.2 m;

Estimated average quadratic error in altimetry: ± 0.25 m.

[1] The original text of this paper appeared as document E/CONF. 57/L. 83.

PREPARATION OF LONGITUDINAL PROFILES OF HIGH-VOLTAGE LINES BY DIGITAL PHOTOGRAMMETRY

Paper presented by Iran[1]

It was during the preparation of the longitudinal profiles of the Karadj Dam–Karadj, Mendjii Dam–Ghazvin–Tehran and Gonbad–Kavous–Gorgan–Tehran high-voltage lines that the procedure in which the tacheometric method is replaced by digital photogrammetry was developed. This procedure was first applied on the Tehran–Firouze Kouh line over a mountainous, rugged terrain, and thereafter over a stretch of 1,500 km of the Dez–Tehran high-voltage line and its secondary lines. By using this procedure we succeeded not only in increasing the accuracy of the ground surveys, but also in reducing considerably the amount of surveying that had to be done. It has been found that after electronic computation of the aerial triangulation and the profiles, the results obtained are almost free from error.

In the earlier method, the longitudinal profiles were prepared by tacheometry and the cross-profiles by measuring the transverse gradient. The required accuracy is:

For length, in flat terrain: 2 cm$\sqrt{D}$;

For length, in hilly country: 4 cm $\sqrt{D}$;

For altimetry: 0.5 cm $\sqrt{D}$;

For alignment discrepancy: $\left(\frac{D}{500}+5\right)$ cm.

Such accuracy is rarely achieved by this method, particularly in the case of hilly country, and measurement of the transverse gradient scarcely helps to make the results satisfactory.

We therefore studied the various possible procedures and, since a mean error of 30 cm per control point was allowed by the consulting engineers, a scale of 1:10,000 was selected for the photographs to be used in the preparation of longitudinal profiles by the method of digital photogrammetry.

To prove the accuracy of this method, a test, in which the longitudinal profiles are marked out and surveyed by the ordinary geometrical method, is carried out over a distance of 20 km in rugged terrain. These profiles are then compared with those obtained by the digital photogrammetry method with photographs at 1:10,000.

Point-by-point comparison (1,400 points) has shown us that the quadratic mean of the discrepancies does not exceed 19 cm and that in 97 per cent of all cases it is less than 30 cm.

DESCRIPTION

A preliminary sketch is made on the 1:50,000 photographs. A team consisting of a line expert and a surveyor checks it in the field and correct it if necessary. The summits are indicated by beacons. The survey teams set up markers situated at 300 to 500 m intervals along straight lines connecting the summits and identified by chalk circles 70 cm in diameter. After it is corrected, the sketch is transferred to a mosaic of 1:50,000 photographs for the purpose of preparing the 1:10,000 photographs.

The planimetric field work consists of forming closed polygons whose summits are some of the markers referred to above. The length of the sides of the polygon is not more than 4 km and depends on the nature of the terrain and the length of the aerial photo strips. In selecting the length, care is taken to ensure that there will be no less than three control points on each strip of photographs. The other points required for control calculations are furnished by the summits of the polygons.

The sides of the polygon are measured with a DI-50 distomat or a model 6 geodimeter. The angles are determined by a Wild T2 theodolite. In flat terrain, the altitude of the markers is obtained by geometric levelling by using the "round-trip" method. In hilly country, trigonometric levelling is used. In this method, distances are measured with a DI-50 distomat and vertical angles are measured simultaneously and reciprocally by a Wild T2.

The altimetric accuracy of the control points obtained by the method described above is comparable to that of geometric levelling.

The altitude of the control points required for calculating the aerial triangulation of the strip is obtained from the points along the axis. A minimum of three rows of altimetric points is required on each strip (see figure I). On strips longer than ten models, one row of altimetric points and one planimetric point are added for every additional five models.

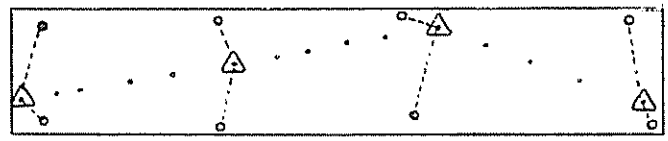


Figure I

RESECTION OF PROFILES

Aerial triangulation is done with an A7 device. After recording the co-ordinates of each model's pass-points and of the control points, we record the X, Y and Z co-ordinates of each profile point and of the cross-profiles. For this purpose, straight lines parallel to the distance of the profiles and cross-profiles are traced on a rigid sheet.

After each aerial triangulation model has been reciprocally oriented and the pass-points have been read, the sheet is fixed to the A7's tracing table so as to superimpose the identified points of the aerial photographs on the profile line. The profile scanning head is guided onto this straight line and the co-ordinates of the change of gradient points are punched on IBM cards and plotted on a sheet. For the parallel lines (of the cross-profiles) the change of gradient points is plotted in the same way, without changing the position of the model or the sheet of paper.

The aerial triangulation calculations are carried out by the strip-by-strip method by using the CORA 1 computer. This method is based on the solution of second- or third-degree polynomials. The instrument's co-ordinates are corrected by using the following polynomials:

$$\Delta X = ax - b_1 y - c_2 z$$
$$\Delta Y = bx + a_1 y - d_2 z$$
$$\Delta Z = cx - d_1 y + a_2 z$$

[1] The original text of this paper, prepared by N. Ghazali, Rassad Surveyors, Inc., Tehran, appeared as document E/CONF.57/L.134.

in which the parameters a, b. . . and d_2 . . . are first-degree data for y and z, and second- or third-degree data for x.

As the memory store of the CORA 1 is limited, we have to carry out our operations in four stages:

(*a*) The models are joined to obtain a series of X, Y and Z co-ordinates for each point;

(*b*) An observation equation is constructed for linear conversion and solved by the method of least squares to establish the scale for the entire strip and to eliminate inaccurate control points by calculating first-degree residual errors;

(*c*) Observation equations are constructed for second- or third-degree conversion and solved by the method of least squares; the conversion coefficient is extracted and second-degree residual errors are calculated;

(*d*) All the points are converted and an exhaustive list of the converted co-ordinates of the points is drawn up.

In connexion with the aerial triangulation of each model, at least five points are calculated on each straight line section of each profile. From those points the other points of the profile can be calculated.

PROFILE CALCULATIONS AND ADJUSTMENT

These calculations are also carried out by the CORA 1 computer. Using the five known points and linear conversion by the least-squares method, we obtain the co-ordinates of the other points:

$$X = Ax - By + C$$
$$Y = Bx + Ay + D$$
$$Z = Z_0 + Ex + (z - z_0)S$$

S is the real scale of the model, obtained from the points established by aerial triangulation. This stage comprises the calculation and adjustment of the co-ordinates of the points of the profile and the calculation of residual errors. The latter reveal the consistency and accuracy of the measurements. Longitudinal sections of less than 1 km make it possible to use this linear formula and so speed up the calculations.

At the end of this programme, with one rotation about the z axis, the X, Y and Z co-ordinates are converted into distance d and height h. If a basic shift is introduced, the distances change in such a way that the various profiles calculated by the same programme are interrelated.

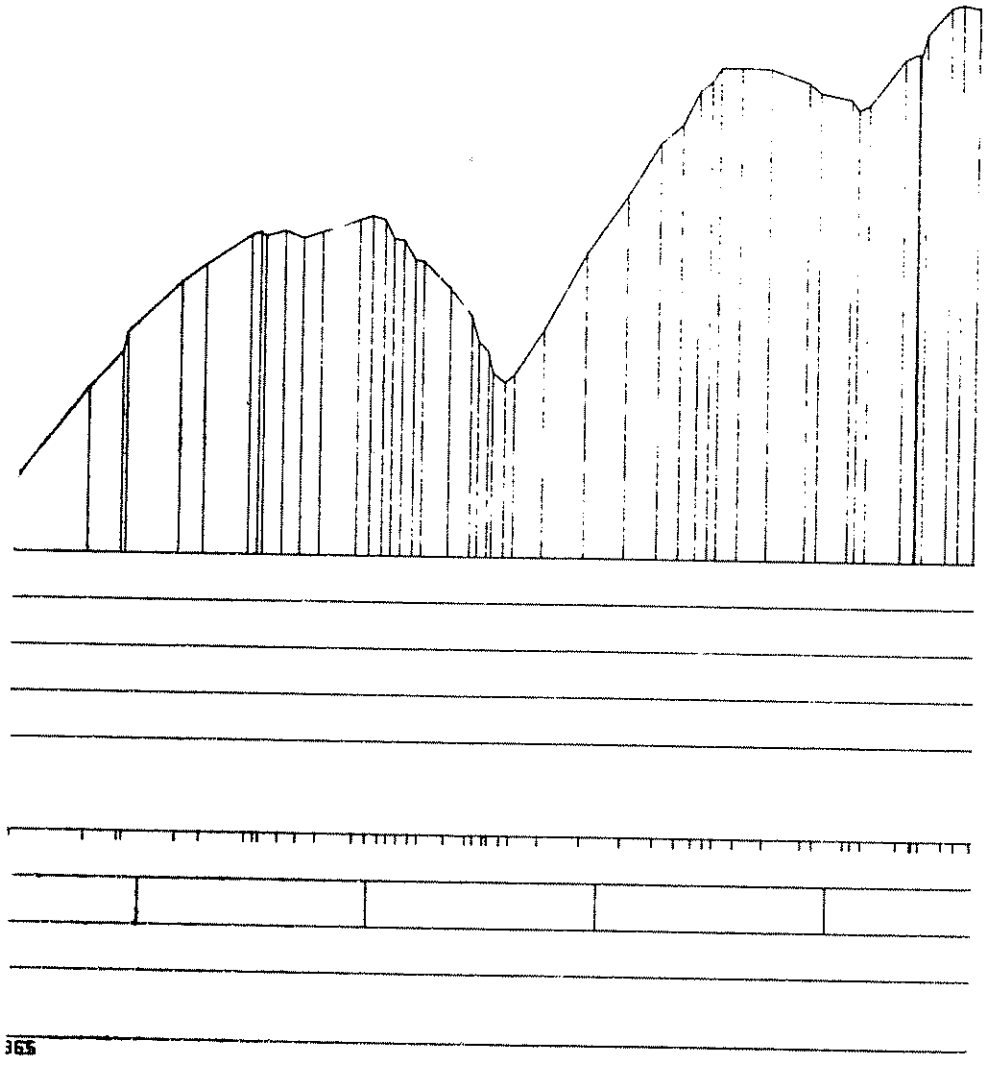


Figure II

The results of the calculations are listed (see the annex) and put on punched tape. This tape is fed into a Coragraph for drawing the longitudinal profile.

AUTOMATIC PROFILE DRAWING

The profile is drawn automatically by the Coragraph to an accuracy of 0.06 mm. This instrument can draw continuous ink lines, scribe on film or prick out points. Ink drawing was chosen for these profiles.

The constant features of a profile or plot are fed into the instrument on cards and the variable profile data on punched tape. The cards carry information on number and spacing of lines below the profile, planimetric and altimetric scale of the profile, length of line-up, thickness of certain profile lines, height of profile on the sheet of paper, length of profile and number of profiles on each sheet.

The roll of paper unwinds automatically on to the tracing table so that tens of kilometres of profile can be drawn without changing the control settings on the instrument. As these profiles are 2 km long, the cards are programmed so that three sections of 2-km profile (1 m of diagram at the scale of 1:2,000) are drawn in three rows. The roll of paper then unwinds 1.30 m for the next drawing. Annotations are added by drafters as desired. The profile and cross-profile plotting rate is about 70 to 80 points an hour.

The speed of calculation by the Coragraph is three minutes for 50 to 60 points per kilometre. The drawing time for the same amount of work is ten minutes. In spite of the small number of points obtained in the field, the preparation of profiles by digital photogrammetry combines a high degree of accuracy and the possibility of control at all levels of the operation with speedy execution of work in the field and in the drawing office. This method costs less than the conventional method.

ANNEX

R =	9		
3157	00−	00−	03+
31571	04−	00−	03−
3158	12−	02−	00−
3159	08−	11−	03+
3160	07+	10+	00−
3157	1056411.96	00	1616.33
48883	1056428.45	16.49	1616.34
48884	1056451.97	23.52	1616.64
48885	1056454.73	2.76	1617 04
48886	1056456.59	1.86	1616.64
48888	1056518.98	62.39	1617.56
48889	1056545.74	26.76	1617.66
31571	1056580.83	35.09	1617.66
48890	1056588.64	7.81	1618 06
48891	1056634.18	45.54	1618.37
48892	1056645.70	11.52	1618.37
48893	1056653.37	7.67	1618.57
48894	1056661.60	8.23	1618.18
48895	1056669.70	8.10	1618.58
48896	1056702.93	33.23	1618.78
3158	1056749.67	46.74	1619 09
48899	1056812.43	62.76	1619.41
48900	1056814.35	1.92	1619.51
48901	1056824.49	10.14	1619.51
48902	1056851.01	26.52	1619.81
48903	1056873.69	22.68	1620.12
48904	1056906.03	32.34	1620.33
48905	1056934.95	28.92	1620.13
48906	1056959.13	24.18	1620 24
48908	1057000.71	41.58	1620 34
48909	1057027.05	26.34	1620 35
48910	1057038.03	10.98	1620 55
48911	1057056.02	17.99	1620 26
3159	1057065.63	9.61	1620 06
48912	1057070.67	5.04	1620 06
48913	1057075.11	4.44	1620 06
48914	1057079.54	4.43	1619.56
48915	1057094.85	15.31	1620 06
48916	1057133.48	38.63	1620 87
48918	1057142.78	9.30	1620.57
48919	1057144.28	1.50	1620 87
48920	1057162.58	18.30	1620 78
48921	1057165.46	2.88	1621.18
48922	1057173.33	7.87	1620 98
48923	1057179.68	6.35	1620.18
48924	1057182.03	2.35	1619.68
48926	1057190.18	8.15	1619.78
48928	1057202.42	12.24	1621 09
48929	1057208.72	6.30	1621 09
48930	1057213.29	4.57	1621 59
48931	1057228.17	14.88	1621 59
48932	1057241.73	13.56	1621 99
48935	1057280.01	38.28	1622.20
48936	1057310.30	30.29	1622.51
48938	1057355.96	45.66	1622.62
48939	1057382.42	26.46	1622 72
48940	1057402.88	20.46	1622 73
3160	1057417.58	14.70	1622.93

(b) *Topographic mapping*

THE CASE FOR UNIVERSAL MAPPING

Paper presented by the United States of America[1]

BACKGROUND

Small sections of the earth's surface approach a plane and can be independently mapped as if the earth were a plane. Such mapping requires no geodetic control as long as it remains localized, and numerous city and cadastral maps are made in this mode. Larger areas which cover countries or a continent require a reference surface based on a sphere or preferably an ellipsoid. Such a reference surface need not be Earth-centred but should provide a reasonable fit at sea level of the area involved. Most current maps are based on such reference surfaces, each of which is uniquely fitted to the Earth's surface at a single

[1] The original text of this paper, prepared by A. P. Colvocoresses, United States Geological Survey, Washington, D.C., appeared as document E/CONF.57/L.19.

specific point known as the datum. These reference surfaces are discontinuous, with the discontinuity generally occurring in the oceans between land masses. As long as one's field of interest is limited to the area covered by the particular reference surface, the discontinuity is of no real concern. Today, however, there is a great deal of interest in relating points which are *not* on the same land mass, and thus the need for a universal control system has already developed. This need is evidenced by the fact that all serious considerations of a change in datum and the corresponding adjustment of control assume that the change will be towards a uniform geocentric reference figure. The geodetic community, as represented by the Coast and Geodetic Survey in the United States of America, is taking appropriate steps on this matter. A system of universal mapping based on such a geocentric reference figure is the subject of this paper.

Need for a universal system of reference

Cited references indicate fields of application such as space operations, geophysics, glaciology, oceanography, navigation and communications which require well-distributed geodetic positions of high precision in an Earth-centred (universal) system. Ongoing geodetic programmes based on satellite observations provide a limited number of such positions, but the only way by which any large number of points can be described in an Earth-centred system is through universal mapping. Enormous sums are currently being spent on mapping throughout the world, but the mapping is not "universal" and will not be so until a concerted effort is made to define and utilize a universal reference system on an international basis.

To the local user it makes no difference whether a reference surface is Earth-centred or merely fitted to a local datum. There is, however, an ever-growing list of requirements for accurate positions in an Earth-centred system; some of the more obvious are:

(*a*) Tracking stations which control earth-orbital and deep-space satellite operations (1, 4);
(*b*) Reference points for navigation and traffic-control systems involving satellites (1);
(*c*) Reference points for directional-beam communications systems involving satellites (1, 4);
(*d*) Off-shore points such as oil wells or buoys which may be located by satellite tracking (5);
(*e*) Control for oceanographic mapping from continent to continent (1, 4, 6);
(*f*) A basis for repeated precise measurements over a period of time for scientific studies of the structure and dynamics of the Earth (2, 3, 6);
(*g*) Control for astronomic mapping of celestial phenomena and the motion of the Earth with respect to other bodies (2).

The above list will undoubtedly expand during the next twenty years, and since mapping is such a slow and costly operation, the time to commence or at least plan universal mapping appears to be now. For the first time man is able to measure the size and shape of the Earth with real precision.

Twenty years ago it would have been difficult to justify universal mapping even if it were technically feasible. Today it can be justified, and sometime in the near future it will be a necessity for effective application of the Earth sciences. President Nixon has stated that we intend to launch satellites for Earth-resource surveys in the early 1970s. These satellites can provide detailed information of the Earth's surface on a global basis. The orbits of all Earth satellites are governed by the Earth's mass. The centre of this mass thus becomes the key point or "universal datum" for Earth-oriented space systems. (The Earth's centre of mass and geometric centre are considered herein as one and the same.) Earth satellites may provide data for mapping the entire Earth's surface and the delineation of the Earth's gravity field (which determines the geoid), both in an Earth-centred system.

As satellite positioning is practical only in an Earth-centred system, it logically follows that the data produced by the satellites should be applied in the same system. If we accept the assumption that maps can be compiled and revised from satellite imagery, we should, if possible, use the same Earth-centred reference system for mapping as well as for the geodetic control network.

Topographic maps are usually compiled to meet defined accuracy standards. For example, on a 1:10,000-scale city map which meets the horizontal requirements of the United States National Map Accuracy Standards, 90 per cent of the well-defined points are within 5 m of true position. At 1:50,000 scale the equivalent figure is 25 m and at 1:25,000 scale, 127 m. If all topographic maps were compiled on an accepted universal reference system, the interrelationship of a nearly infinite number of points on the Earth's surface would be established to the accuracy of the compilation. (The errors in positioning basic control stations, which may be in the order of 10 to 20 m for widely separated points, would also affect the accuracy of the map points.)

To map the Earth on anything less than a surface which closely approximates the entire true shape of the Earth appears to be a self-defeating process. The correct spatial relationship of various points on the Earth's surface is fundamental knowledge related to many of man's activities. If we are able to look at the Earth as an entity we should also be able to map it as an entity.

Selection and orientation of a reference figure

A specified system of three-dimensional Cartesian co-ordinates will uniquely define a point without reference to any mathematical model or surface. However, the undisturbed sea-level surface of the Earth, which is known as the geoid, closely approaches a simple mathematical figure, and it is the basis for elevation determination throughout the world. Thus the use of a reference figure which approximates the geoid is considered essential.

The geoid has been described as triaxial, pear-shaped and having numerous minor deviations from any simple mathematical model. An ellipsoid of revolution is commonly used as the model, although triaxial ellipsoids have been proposed. Through the use of spherical harmonics, far more complicated mathematical figures can be defined to better approach the real Earth figure, but to be of practical use the ellipsoid of revolution appears to be as complicated a figure as is warranted. However, the geoid is somewhat dynamic and is apparently changing shape on a long-term basis in addition to the ephemeral tidal effects of the sun and moon.

In current and planned geodetic programmes, it should be possible to determine the position of major land masses with respect to the centre of mass of the Earth and to each other to an accuracy of ± 10 m (1, 6). Local variations (undulations) of the geoid from the elliptical model may

be as large as 80 or 90 m, but even so a model elliptical Earth figure can be defined which will fit to within 100 m of the actual geoid. It can be argued that, by fitting a model to sections of the Earth's surface, a reference figure within 50 m of all undulations can be achieved. This is true, but a different model must then be used for other land masses, and the undesirable discontinuities we have in present control and mapping systems are introduced.

How important is it to have a model which fits the geoid to within 50 rather than 100 m? If the model were the one frame of reference used, both conditions would be unacceptable because we could then not define an elevation to within 50 or 100 m respectively without knowledge of local geoidal undulations. Fortunately, we use the geoid itself for elevation determinations and the reference surface for horizontal positioning only. Comparing 100 m with the more than 6,000,000 m radius of the Earth could introduce horizontal errors only in the order of one part in 64,000, as shown in the figure. One part in 64,000 is an unacceptable error for high-order geodetic work, and for such purposes the undulation of the geoid must be determined and accounted for. One part in 128,000, which results from 50 m of separation in continental (locally) fitted ellipsoids, is also unacceptable for very precise work, so the problem remains in either case. For other than high-order geodetic work, the 100 m undulation of the geoid may be neglected. It is interesting to note that existing ellipsoids, which have been locally defined, involve separations from the geoid of more than *1,000 m* and are applied without this factor being considered.

Evolution of universal mapping

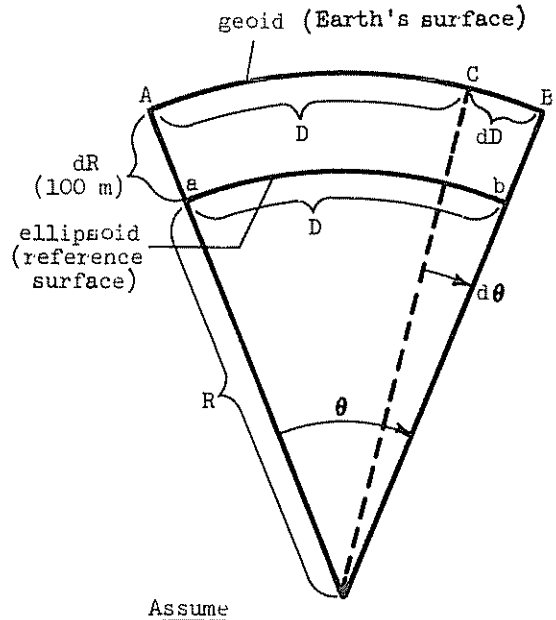
Once the concept of universal mapping is accepted, its successful implementation must follow a logical sequence. Today there are on-going geodetic satellite programmes that must be completed to verify the precise Earth figure and to provide a well-distributed network of primary control points on which mapping can be based. The actual conversion of existing maps to a universal system should be programmed well in advance and should coincide with any required internal geodetic adjustment and possible changes in map projection, scale, series, format etc. Existing maps will generally not require recompilation, but recasting of sheet lines or co-ordinate values would be involved.

Prior to any internal changes, certain steps on an international basis are required. First, a well-distributed world-wide network of geodetic satellite-tracking stations must be mutually tied together in a common geocentric system (XYZ) through satellite observations. Second, a single reference figure (ellipsoid) must be defined and internationally accepted. Third, the reference figure must be fitted (geocentrically) to the network of tracking stations. Subsequent to the above steps, the problem of converting existing geodetic systems to the universal system should be attacked on a continental and country-wide basis.

Applying universal mapping to the United States

Although this discussion is concerned primarily with applying a universal mapping system in the United States, the same problems and solutions would apply in varying degrees to other countries.

Several conditions relative to the current status of mapping of the United States must be considered in any map conversion programme; the more important ones are as follows:



Assume

that the Earth's surface of the concerned area is at or near sea level.

that the reference figure and the curvature of the geoid are both Earth-centred.

The given distance D on the ellipsoid extends from a to b; but when D is measured on the Earth's surface beginning at A, it ends at C rather than the correct position B. The error involved is dD.

Since $D = R \cdot \theta$, by differentiation $dD = dR \cdot \theta$,

and $\frac{dD}{D} = \frac{dR \cdot \theta}{R \cdot \theta}$.

If $dR = 100$ m

and $R = 6{,}370{,}000$ m, then the error

$$dD = \frac{100}{6{,}370{,}000} \cdot D \approx \frac{1}{64{,}000} \cdot D$$

Similarly, the angular error $d\theta \approx \frac{1}{64{,}000} \cdot \theta$

Error due to geoid undulation of 100 m

Control status

Control throughout the United States varies both in accuracy and density. Modern geodetic surveys indicate that considerable error (30 m or more) exists within our basic control. The means and data necessary to readjust the control of the entire country are rapidly becoming

available. This readjustment should be done in conjunction with any datum changes.

Mapping status

Considering its population, industrial development and general wealth, the United States is not a well-mapped area. It is logical to assume that the economy will demand and support programmes that will provide maps of scale, accuracy and currentness commensurate with land values and use.

Standards of measure

The United States of America is one of the few countries of the world that has not adopted the metric system. When any sizeable new mapping programme is planned, the adoption of the metric system should be considered at the same time.

Projection and referencing system

Since the Earth's surface is curved, some projection system must be used to depict this surface on a plane. In the United States of America over 120 different zones are now used for large-scale mapping and plane-co-ordinate referencing (State Plane Co-ordinate Systems). The adoption of a single uniform system of projection and plane-co-ordinate referencing that could be applied in cadastral surveys (property description) as well as in engineering and mapping projects certainly deserves consideration. By changing from the Clarke 1866 ellipsoid to one that would be Earth-centred and internationally acceptable and by utilizing a universal projection, the United States of America could have a reference system compatible with those of all other countries that take similar steps. Indications are that such steps will be taken by many other countries.

Map scales

Should the metric system be adopted, standard scales such as 1:10,000, 1:25,000 and 1:50,000 would be far more logical and easier to use than the currently used scales of 1:24,000 and 1:62,500. Obviously map scales cannot be changed overnight, but as new maps or reprints are issued the scale could be changed, in many cases by enlarging or reducing existing manuscripts. Metric contours might be developed by interpolation from existing foot contours; this operation would, of course, present a major problem.

IMPLEMENTATION

At this time the most important project relative to universal mapping is the completion of a primary geodetic net throughout the world. Current estimates are that this can be done within two to four years if on-going programmes are adequately supported.

In the United States of America additional internal geodetic ties of very high order are required. The United States Coast and Geodetic Survey plans to complete such ties within the next three years.

It is suggested that leaders in the mapping profession initiate dialogue on universal mapping both internally and on an international basis. Following a period of dialogue, specifications, cost estimates, and a proposed time-table for implementation should be drawn up which would include the following steps within the United States:

(*a*) Completion of primary geodetic net;

(*b*) Densification of basic control to include second-order nets of appropriate spacing;

(*c*) Acceptance of a universal Earth-centred ellipsoid with defined reference points in the United States;

(*d*) General adjustment and conversion of all control to the universal datum;

(*e*) Programmed recasting of maps on a standardized system of scale and projection, preferably based on the metric system.

REFERENCES

(1) NASA, "Potential Applications of Satellite Geodetic Techniques to Geosciences", NASA SP-158-1968.

(2) Barnett, Alan H., "Radio Signals from Hydroxyl Radicals", *Scientific American*, December 1968

(3) Heirtzler, J. R., "Sea Floor Spreading", *Scientific American*, December 1968.

(4) NAS/NRC, "Useful Applications of Earth-Oriented Satellites (No. 13), Geodesy-Cartography", National Academy of Sciences, Washington, D.C., 1969.

(5) Moody, A. B., "The Tying of Coordinate Systems Used in the Petroleum World", paper presented at the Off-shore Technology Conference, Houston, Texas, April 22–24, 1970.

(6) Schmid, Hellmut, "A World Survey Control System and its Implications for National Control Networks", paper presented at the 63rd Annual Meeting of the Canadian Institute of Surveying, Halifax, N.S., April 14–18, 1970.

AUTOMATION IN TOPOGRAPHIC MAPPING

Paper presented by the United States of America[1]

In the last decade, the flow of new procedures for automation in topographic mapping has grown from a slight trickle to an ever-increasing flood. Advances in technology—in the use of electronics, multispectral sensors, lasers, microwave phenomena and computer science—have opened the flood-gates so that we are engulfed in a tide of automation efforts in virtually every phase of the mapping operation. In one mapping phase alone, the photogrammetry phase, a well-informed bibliographer lists 142 titles of recent articles under the heading of "Automation" (1). It is time to take stock of what is happening so that we can gain a proper perspective of the current trends and try to put them in some kind of logical order.

At first glance, the view may seem reminiscent of the proverbial rider who jumped on his horse and galloped off in all directions. This impression is really not too wild an exaggeration of the actual situation when we consider current automation activities in topographic mapping, but the circumstances are not as alarming as the metaphor would seem to make it. The fact is that we do need to gallop off in many, if not all, directions because there is

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scarcely an avenue in the network of mapping procedures that could not be improved through automation. What we need to do now is to determine what directions are profitable, what efforts need to be consolidated and what new directions we need to take in spite of the fact that we have apparently pre-empted virtually all directions.

Not only do we need to explore what the effect of automation is, or can be, on each individual phase of mapping, but we need also to determine whether automation points the way to new types of map products or new ways to present conventional map products. Moreover, we need to determine whether the classical operational phases have become obsolete in the light of automated procedures and whether we need to develop entirely new systems for mapping.

Automation of conventional mapping procedures

Let us consider first what are the major phases in conventional topographic mapping, and then we can examine what is happening and what is being explored in each phase. These major phases can be set down in the following categories: (*a*) aerial surveys; (*b*) field surveys; (*c*) photogrammetric control extension; (*d*) photogrammetric compilation; and (*e*) map finishing.

Aerial surveys

In conventional topographic mapping operations, the term "aerial surveys" has signified the obtaining of aerial photographs at flight heights under 50,000 ft with a precision camera having a lens rigidly mounted so as to have a fixed relationship to the film plane. The aircraft is guided by a human pilot, and a human photographer governs the picture-taking (generally with the aid of a semi-automated view-finder). Now there are several new trends towards automating aerial surveys.

A promising automated solution to the perennial problem of camera tilt is based on a radically new type of optical system. This system includes a prism arrangement which changes the configuration of its elements to compensate for tilt; thus, all ground objects in the field of view are imaged in the same positions on the film that they would have if there were no tilt. The relative movement of the prism elements, which are encased in a fluid-filled cylinder placed in front of the lens, is actuated by a small but powerful gyro-servo system (2). If a tilt-free photographic system can actually be developed, the beneficial ramifications in mapping would be revolutionary.

The information gained from conventional aerial photographs can now be augmented by specialized information obtained from multisensing equipment operating from the aircraft simultaneously with the conventional cameras. The sensing techniques available include multispectral photography, infrared imagery and spectroscopy, radar imagery, microwave radiometry and imagery, ultraviolet spectrometry and absorption spectroscopy. The next step is to develop a system such that the sensor data obtained can be automatically correlated with the conventional mapping photographs, to produce information useful to such disciplines as agriculture, forestry, geology, hydrology, oceanography and geography.

Another automated facet of aerial surveys—perhaps the most spectacular of all—is the replacement of the man-operated survey aircraft by space vehicles in orbit around the Earth (or other celestial body). Here we have a possibility for automation to be carried to the ultimate in sophistication. Not as a dream for the remote future, but on today's drawing boards, there are plans in which an unmanned vehicle travels in a precisely predetermined orbit with automated cameras and other sensing devices gathering data of precision-mapping quality and with radio or vidicon equipment returning the data to Earth. Perhaps the most promising effort in this direction is the proposed Earth Resources Observation Satellite (EROS) which has a cartographic output as one of its principal objectives (3).

Once the information obtained from aerial surveys is in the hands of the users, a new phase of automation is involved: processing the data to make it suitable for map compilation. Automatic film-processing machines for mass production of positive photographs are now well known and widely used. Likewise, electronic dodging instruments for automatic contrast control of diapositives and other prints are standard equipment in up-to-date photogrammetric laboratories. A new departure, however, is the ability to perform a wide variety of photographic processing operations by computer.

The potential power and scope of the computer as a picture-processing tool have been well reported in the literature (4). Here is a published description of a typical arrangement for transforming a photograph into digital terms and vice-versa:

> "Some real-world picture, typically a 35 mm film transparency, is scanned by a machine similar to a television camera. The resultant electrical signals, representing the brightness of successive picture elements, are changed by an analog-to-digital converter into numerical representations on magnetic tape. This provides a digital version of the input picture for computer processing.
>
> "A general-purpose, high-speed digital computer is programmed to process the picture according to one or more algorithms. When the processed picture is completed (still in discrete numerical form), the computer instructs a microfilm printer (through tape) to generate the new product. This is done in a manner which is the inverse of the original scanning: a television-like tube paints the picture with a moving spot of light, and a camera records it on microfilm to provide a photographic end-product.
>
> "Within the computer, pictorial information may be represented as a large two-dimensional array of numbers signifying light values, or as listings of co-ordinates in a two- or three-dimensional space of significant points which define lines, surfaces and other relations. The operations which may be performed within the computer include smoothing, edge detection, edge sharpening, abstraction, correlation, searching for matches with patterns, distortion, re-arrangement and the addition of pseudo-random noise."

A well-known example of pictures processed by computer is the series of photographs taken in the Mars fly-by of Mariner IV. In that case, relatively weak original signals were converted, by a series of successive enhancements of imagery represented in digital form, to acceptable photographic renditions.

Field surveys

It can be argued that when field surveys for topographic mapping becomes fully automated, there no longer will be such an activity as "field surveys". This may someday come to pass and there are indeed some operations

formerly done in the field that are now done nearly automatically by other means (for example, photogrammetric control extension). For the present, however, normal topographic mapping operations require field-work for such purposes as obtaining basic control and completion surveys.

Up to the mid-1950s, one of the most laborious and costly phases of field surveying was the measurement of distances by means of tapes or chains. Not only was this a costly procedure, but it was also a prime source of error. With the advent and wholesale adoption of electronic distance-measurement equipment, the use of tapes in topographic mapping has been relegated to auxiliary operations such as tying in reference points. Lengths of traverse courses or sides of triangles are measured automatically, accurately and speedily by electronic instruments that are becoming available in better and better models, spurred by healthy competition among manufacturers, with each passing year (5).

The automatic determination of elevations is a problem that has not been solved as successfully as the automatic measurement of horizontal distances. To be sure, there are automatic levels which make it easy to maintain a horizontal line of sight. There are also laser devices available for projecting a level line or plane at a fixed elevation. These devices, however, do not eliminate the tedious and costly levelling procedure of taking backsights and foresights on a graduated rod carried and held by a rodman who must physically occupy each point at which a reading is required.

One automated solution to the elevation-determination problem that has met with limited success is the elevation meter. The elevation meter consists of a vehicle bearing a pendulum device mounted in an electromagnetic field; as the vehicle proceeds along the road, changes in slope make the pendulum change its position in the magnetic field, causing electronic impulses which can be integrated with others representing the distance travelled to give changes in elevation between points. The elevation meter is limited in application, however, to areas having good road systems, as it will not operate with sufficient accuracy on rough roads or cross-country routes (6).

Another current approach to automation in elevation determination is the airborne laser altimeter (7), a successor to the airborne radar altimeter. Indications are that the laser altimeter may give a better terrain clearance value than the radar altimeter. Unfortunately, the major problem in airborne altimetry has never been the determination of the terrain clearance value. The real problem has been in obtaining reliable values for aircraft altitude, for the ground elevation must be determined by subtracting terrain clearance from aircraft altitude. To automate elevation determination by airborne methods successfully, a reliable and accurate altimeter is needed; this should be a fruitful field for further research.

A recent development in automation of field surveys which may appear minor at first glance is a hand-carried recording device aimed at eliminating the surveyor's notebook. The surveyor punches bench-mark values, rod readings etc. on to a tape contained in the recording device, instead of writing them in his notebook. The far-reaching implication of this is that the surveyor will not have to perform the necessary computations in his notebook. Instead, the tape can be fed directly to a computer (a small desk-type computer if the programme is simple) for reduction of the notes.

Carrying the automation of field survey instruments one step further still is the appearance of a new generation of instruments that permit a flow of information from the field survey instrument itself directly to the data-processing system. The data-recording system is built into the surveying instrument so that the field engineer need only make the proper sightings and press the proper buttons; the instrument produces a punched tape recording horizontal and vertical angles and the slant distance to the point sighted (8).

The automation of a succession of operations, each one a small part of the whole, can in the aggregate result in important savings of time and money. An example of such an improvement is the recent development of a radio-activated flashing signal light. The easily erected light can be delivered to mountain-top locations by helicopter; it can be seen and identified at distances of 15 miles in daylight and can be operated either as a steady or a blinking light. Conventional two-way radios are used to activate the lamps with a special audio tone of selected frequency. The surveyors set up their instruments at the survey point, point their instruments at the distant flashing lamps and record the required survey data, turning the lamps on or off at will by means of the radio-control device (9).

Base-sheet plotting

Until recently, base sheets for maps had to be prepared by laborious hand plotting. With the development of automated co-ordinate plotting systems, some organizations have already eliminated hand work in base-sheet preparation. In the Autoplot system, input in the form of punched cards bearing the co-ordinates and identification of all points to be plotted is fed to a central computer along with a programme for generating plotter instructions. The computer produces a magnetic tape that causes the Autoplot instrument to scribe and label the projection lines, grid ticks and control points; it also labels the sheet with quadrangle name, sheet numbers and map scale. The three plotting heads of the instrument can scribe, prick or ink points and lines (10).

Photogrammetric control extension

Perhaps the most dramatic recent changes in the technology of any mapping phase have occurred in the application of automatic data processing technology to the photogrammetric extension of control. Analogue systems such as long-bar bridging and stereotemplet triangulation have virtually disappeared from major mapping organizations under the impact of more efficient and accurate fully analytical and semi-analytical systems. In the fully analytical systems photoco-ordinates are measured on glass diapositives mounted in automated comparators; horizontal and vertical control can be extended accurately, by purely mathematical procedures, from points of known position to points whose positions are needed for map control. They key to this operation is the development of highly complex electronic computer programmes for the mathematical solutions (11).

The semi-analytical system of aerotriangulation derives its metric data from stereoplotter models; the plotters are equipped with encoding devices so that the model co-ordinates of points are read out on magnetic tape or punched cards, which can be fed directly into the electronic computer. Semi-analytical systems generally provide horizontal control only, but significant progress is being made towards deriving vertical control from such systems (12).

A key difficulty in all control-extension systems has been the problem of precisely transferring an image from one photograph to the corresponding image in the adjacent, overlapping photograph. A promising solution to this problem is at hand in the form of the automatic image correlator. This device scans an area of a photograph and develops and stores an electrical signal, called a signature, which uniquely defines the scanned area. The signature of a corresponding area on an adjacent photograph can be compared with the stored signature for exact correlation. By this means, pass-points can be carried forward with great accuracy, from one plate to another (13).

Photogrammetric compilation

Progress in the automation of map compilation from aerial photographs is now at a crucial stage. Operable hardware and procedures have been developed, but the new systems have not been reduced to practice on a broad scale. The chief difficulties are the need for a large capital investment for the initial installation and the lack of sufficient experience to establish the acceptability of the product. In spite of these reservations, there is no doubt that remarkable progress has been made in this direction (14).

In general, the automated mapping instruments produce planimetric data in the form of orthophotographs, with hypsographic data added either by profiling or contouring procedures. The earliest instrument which successfully followed a stereo surface automatically has been further developed, and now consists of automation hardware combined with a modified mechanical-projection stereoplotter. It can be used for automatic contouring combined with orthophoto production (15).

Another type of equipment, designed from inception to be a universal, automatic, map-compilation instrument, makes altitude measurements over a dense and uniform grid concurrently with the production of orthophotos. The detailed elevation data are stored in digital form on magnetic tape for the production of contour maps or other use (16).

Still another significant effort consists of a modified analytical plotter to which has been added circuitry for electronic scanning and correlation and an orthophoto print-out unit. This instrument, like that mentioned in the preceding paragraph, solves the projective relationships on a digital basis, providing wide flexibility of application (17).

As the cost of the complex electronic packages required for these instruments is reduced, and as the speed and quality of the output are improved, equipment of this class is bound to become attractive to an increasingly wide group of users. These instruments have a great potential for eliminating the tedious operation of stereocompilation through the medium of human eyes, hands and minds (18).

Scribing

The development of an automatic line-following device carries a potential for eliminating two costly and time-consuming operations in the map-production sequence: initial scribing by the stereocompiler, and final colour-separation scribing. Initial map copy would be provided in pencil only. In the line-following device currently under development, a scanning head optically scans the original copy and relays the line data electronically (by means of amplifier, controller and power units housed in the console) to a co-ordinatograph, which is equipped with servomotors and scribing head. The line-following device has been able to follow (and scribe) contours, roads and drainage from copy equal in quality to a compilation manuscript. In its present stage of development, the instrument cannot follow with predictability lines that intersect; a solution to this problem is now being sought (19).

Editing

The task of map editing, a painstaking and often tedious search for errors in map content, will be lightened significantly if current efforts to automate this operation can be brought to an economical and practical conclusion. In the approach currently being considered, the graphic map data are first digitized and marked with identifiers which relate the transformed co-ordinates of points or lines to a reference grid. Any part of the digitized map can then be called for, through this reference scheme, and regenerated on a cathode-ray tube. A light pen pointed at the image of the segment of line to be changed identifies the feature being edited. Manually keyed instructions then tell the editing programme whether to delete, move or replace the feature in question (20).

This approach to automated data editing has a significance that goes beyond its impact on the editing phase of conventional mapping. It has the potential for being an important key to an entirely new system of mapping and map presentation.

Typesetting

Type for place names and other map data to be represented in type can now be obtained speedily from automatic phototypesetting machines. Only one font is needed for a given style of type; the proper size is obtained by photoprocessing in the machine. The machine is programmed for a given typesetting job by running instructions on magnetic tape through a reader and setting type size and line-spacing controls. Input tapes are then fed to the machine which then puts out the required type for the job on stickup strips (21).

Impact of automation on types of map products

Orthophoto maps

It has already been noted that the planimetric output of automated stereocompilation machines is in the form of orthophotographs. This should by no means be considered as implying that a product is obtained which is intrinsically inferior to a conventional line map. The fact of the matter is that orthophoto-mapping systems were originally developed independently of considerations of automation; the objective of the original effort was to produce a superior map that would add to the conventional line symbols all the infinite wealth of detail provided by the photographs. In practice, a high-quality orthophoto map is produced by adding cartographic enhancement to the orthophoto mosaic. This cartographic enhancement can consist, in optional amounts, of delineation of linear features, addition of names, shading or colouring of special features and colour separation appropriate for the area mapped (22).

The orthophoto product of an automated mapping instrument can likewise be enhanced in quality by providing suitable cartographic treatment. It can be anticipated that such an orthophoto map will eventually come into

wide use; this kind of map will be in no way inferior, and in some ways superior, to the conventional line map.

Numerical maps

The pressures of automation must lead inevitably to what some may consider the ultimate in map presentation: the numerical map (23). The numerical map has no visible resemblance to the graphical map which we are accustomed to. It actually doesn't exist at all in a tangible state until the computer is asked to produce it. Until the map is called for, it exists only in a latent state—in computer programmes and magnetic-tape storage of data.

To produce a numerical map, it is first necessary to have all the needed data stored in the computer memory in digital form—and this problem of input is the primary problem of building a numerical map library. Once the topographical information is stored, it is a relatively simple programming operation to ask the computer any conceivable question about the topographic characteristics of the area of concern, or to produce any portion of the map in graphical form at any desired scale.

Topographical data can be fed to the computer storage from either of two principal sources: (*a*) from existing maps; and (*b*) as a by-product of current mapping operations, such as recording the profiles generated in the production of orthophoto maps. An important step in transforming map data to digital form has been achieved with the development of the automatic contour digitizer (24). With this equipment, contour lines on a map sheet can be read automatically and stored on magnetic tape for use in a computer. The various available devices for transforming map detail to digital data and for plotting maps automatically from digitized graphic files, data banks, symbol dictionaries and display units are well documented in the literature (25).

Another development of significance for storage and retrieval of topographical information is an automatic colour-separation machine (26). This device has a colour-sensitive scanning system which derives from an ordinary multicoloured map printed on paper, separate sheets to depict planimetry, drainage, woodland, contours and so on.

Conclusion

The art of mapping is moving into an automated world (27) and we should welcome the changes, even though we may have some misgivings because some cherished skills and talents will disappear into the realm of lost arts. We may wonder whether maps produced through automation will be better or cheaper, but it is fairly sure that we will get them quicker when we need them (28). In the meantime, the field surveyor need not discard his level rod, nor the photogrammetrist his stereoscope, nor the scriber his road graver. There is some time left before everything is automated—we map-makers may yet live out our lives as human beings working with our hands and eyes as well as our minds. For the future, we can expect robot-like machines to eliminate the need for skilled hands and eyes, but the need for sharp human minds will be greater than ever before.

References

(1) Rosenfield, G. H. *Bibliography for Modern Instrumental Photogrammetry*, available from U.S. Geological Survey, 1968.

(2) "Steadying Images by Bending Light", *Time*, February 7, 1969, p. 57.

(3) *Useful Applications of Earth-Oriented Satellites*, National Research Council, Washington, D.C., 1969.

(4) Harmon, L. D. and K. C. Knowlton. "Picture Processing by Computer", *Science*, vol. 164, No. 3875, April 4, 1969, pp. 19–29.

(5) Tomlinson, R. W. "Operational and Field Problems of Electronic Distance Measuring Equipment", *Papers from the 29th Annual Meeting*, American Congress on Surveying and Mapping, Washington, D.C., 1969, pp. 333–350.

(6) Eckhardt, C. V. *Unconventional Methods for Surveying*, Preprint 645, ASCE National Meeting on Transportation Engineering, San Diego, California, 1968.

(7) Schwieder, W. H. "Laser Terrain Profiler", *Photogrammetric Engineering*, v. 34, No. 7, 1968, pp. 658–664.

(8) *Reg Elta 14 Electronic Recording Tacheometer*, technical brochure of Carl Zeiss/Oberkochen, 1969.

(9) Dando, T. O. "Flashing Signal Light", *Papers from the 29th Annual Meeting*, American Congress on Surveying and Mapping, Washington, D.C., 1969, pp. 419–425.

(10) Mullen, R. R. *Automatic Plotter for Map Base Preparation*, U.S. Geological Survey Professional Paper 575 D, pp. D289–D291, 1967.

(11) Doyle, F. J., et al. "Analytical Photogrammetry", *Manual of Photogrammetry*, 3rd ed., pp. 461–513, American Society of Photogrammetry, Falls Church, Va. 1966.

(12) Altenhofen, R. E. "Semianalytical Aerotriangulation in Quadrangle Mapping", *Papers from the 35th Annual Meeting*, American Society of Photogrammetry, 1969, pp. 5–27.

(13) Crabtree, J. S. and J. D. McLaurin. *Investigations of the BAI Area Image Correlator*, paper presented to XI International Congress of Photogrammetry, Lausanne, Switzerland, 1968.

(14) Lorenz, G. G. "Automation in Photogrammetry", *Technical Note 68–4*, U.S. Army Engineer Topographic Laboratories, Wright-Patterson Air Force Base, Ohio, 1968.

(15) Lawrence, C. H. "Stereomat IV, Automatic Plotter", *Photogrammetric Engineering*, v. 33, No. 4, April 1967, pp. 394–402.

(16) Bertram, Sidney. "The Universal Automatic Map Compilation Equipment", *Photogrammetric Engineering*, v. 31, No. 2, March 1965, pp. 244–260.

(17) Helava, U. V., A. E. Whiteside and C. W. Matherly. "New Automatic Analytical Stereoplotter", *Bendix Technical Journal*, v. 1, No. 2, pp. 72–75, Bendix Corp., Detroit, Michigan, 1968.

(18) Bertram, Sidney. "Automation of Stereocompilation", *Photogrammetric Engineering*, v. 34, No. 9, Sept. 1968, pp. 950–952.

(19) Pilonero, J. T. *An Automatic Line Follower*, paper presented to XI International Congress of Photogrammetry, Lausanne, Switzerland, 1968.

(20) Edson, D. T. *Experimental Cartography at the Royal College of Art and the U.S. Geological Survey: A Survey of Equipment and Techniques*, in-house paper, U.S. Geological Survey, 1969.

(21) Moravetz, R. L. "Production of Type for the Mapping Program of the Geological Survey", *Papers from the 28th Annual Meeting*, American Congress on Surveying and Mapping, 1968, pp. 244–248.

(22) Radlinski, W. A., 1967, "Orthophotomapping", presented at Commonwealth Survey Officers' Conference, Cambridge, England, August 1967.

(23) Aumen, W. C. "Mapping in the Computer Age", *Papers from 1968 National Fall Convention*, American Congress on Surveying and Mapping, Washington, D.C., 1968.

(24) Shepherd, W. H. "Automatic Contour Digitizer", *Photogrammetric Engineering*, vol. 34, No. 1, 1968, pp. 75–82.

(25) Gigas, E. F. O., *Automated Cartography*, paper presented at Third General Assembly of the International Cartographic Association, New Delhi, India, 1968. Available from U.S. Coast and Geodetic Survey.

(26) Diello, J., K. Kirk and J. Callander, *The Evolution of Automation in Cartography at Rome Air Development Center*, Air Force Systems Command, Griffiss Air Force Base, New York, 1969.

(27) Thompson, M. M., 1970, *Automation in Cartography*, 1970, report of Commission III, International Cartographic Association, presented at Fifth International Conference on Cartography, Stresa, Italy, May 1970.

(28) *Proceedings of the Symposium on Map and Chart Digitizing*, Geological Survey computer contribution No. 5, Washington, D.C., 1969.

A SIMPLIFIED METHOD OF RELIEF DRAWING TO SUPPLEMENT CONTOURS

Paper presented by Australia[1]

During production of the 1:250,000 series which was completed in 1968 the Division of National Mapping built up considerable experience in relief drawing. The maps in the series were not generally contoured, and relief was shown by conventional methods of airbrush and pencil drawing from air photographs. A degree of uniformity of presentation was achieved by standard drawing techniques and stages production, subject to rigorous checks at each stage, but drawing from air photos is subjective and the normal difficulties of training in photo interpretation, use of airbrush, and light and shade techniques continued to be a problem throughout the production.

Although a great deal of success was achieved in the 1:250,000 series in which there are 541 maps covering Australia, the decision to include relief shading to supplement contours on the 1:100,000 series presented a production problem since the number of sheets to be published at 1:100,000 scale is 1,500. Furthermore the series was likely to be produced by a number of mapping agencies and by private contract. It was necessary therefore to devise a system of drawing requiring a minimum of skill and training, which would produce a very uniform result when carried out by mapping organizations widely separated geographically.

Unlike relief shown on the 1:250,000 series, which depended entirely on light-and-shade rendering to depict the terrain, relief on the 1:100,000 series is aimed at supplementing 20 m contours in such a way as to provide the user with a quick appreciation of the terrain characteristics of the whole area and to show small but important features lying between contours in areas of low relief.

The technique adopted utilizes block colour in black and two shades of grey painted on a white ground as shadows from a north-west light source, with black for the steepest slopes, dark grey for medium slopes and light grey for gentle slopes. Slopes of less than one in ten are left white. Black and the two shades of grey were selected to give maximum contrast in reproduction, and the whitest possible medium was selected as a background.

In the first place, a highlight and shadow plan is prepared in pencil on matte plastic material over a combined positive of the drainage and contours (see figure I). The three grades of hachuring represent the areas to be coloured black, medium and light grey on the final drawing.

The criteria applied by the cartographer in the preparation of the plan are:

(*a*) For slopes steeper than 1 in 3, shadows directly opposing the light source are generally coloured black, or predominantly black, with dark grey highlights;

(*b*) Slopes between 1 in 3 and 1 in 5 are treated so that areas of shadow on the shadow sides of features appear in dark grey, with light grey highlights;

(*c*) On slopes between 1 in 5 and 1 in 10, shadow areas are generally coloured light grey, with uncoloured highlight areas;

(*d*) Generally for slopes less than 1 in 10 no colour is used. However, in certain areas it may be considered necessary to extend the lower limit of 1 in 10 in order to emphasize important small features, or to add character to the terrain. Areas where the draftsman consider such treatment is necessary are referred for direction.

To add character and lift to the white highlight areas, fingers of colour are inserted in the gullies. These fingers are generally light grey and are stopped short of the ridge top.

Preparation of the final drawing is carried out on white translucent "Astralon", stud registered over the highlight and shadow plan, by painting blocks of "Filmograph" colour over the selected areas. The light grey areas are coloured first, followed by dark grey and black (see figure II).

When blocking-in has been completed the drawing is stud-registered with the composite positive of drainage and contours, and colour is airbrushed on hard edges where the land forms make "rounding" necessary. Constant reference is made to the drainage and contours to determine the degree of softening required. Because final printing is in a light grey colour, softening can be restricted mainly to where black and dark grey edges join white areas.

Drawings are photographed using a 150-line half-tone screen and the desired percentages in the resulting negative are:

Black areas	80 per cent
Dark grey areas	25 to 30 per cent
Light grey areas	10 to 15 per cent
White areas	3 per cent or less

Part of a map with relief drawing done in this way is shown in figure III.

It has been necessary to establish a system of training in basic light-and-shade drawing and to devise suitable exercises for trainees, but the system is now well established and junior draftsmen without previous experience can be productive after three weeks' training.

The problem of producing a uniform result between individuals and different mapping organizations has been largely overcome with the new technique because interpretation of terrain has been replaced by an almost mathematical approach to contour reading and interpretation, and the necessity for highly developed drawing skills has been minimized by the use of areas painted with block colours.

The necessity to use the airbrush still exists in the "softening off" stage, but the amount is small compared with that needed in traditional methods, and the degree of skill necessary is reduced.

Time taken to produce a finished drawing varies from fifteen working days for map sheets completely covered by hilly terrain to one or two days for sheets where only a small area needs shading. The technique itself is a standardized approach and lends itself to staged checking and supervision.

[1] The original text of this paper appeared as document E/CONF. 57/L.47.



Figure I. Highlight and shadow plan



 Figure II. Final drawing (this half-tone reproduction in black represents the original drawing in black, dark grey and light grey solid inks)

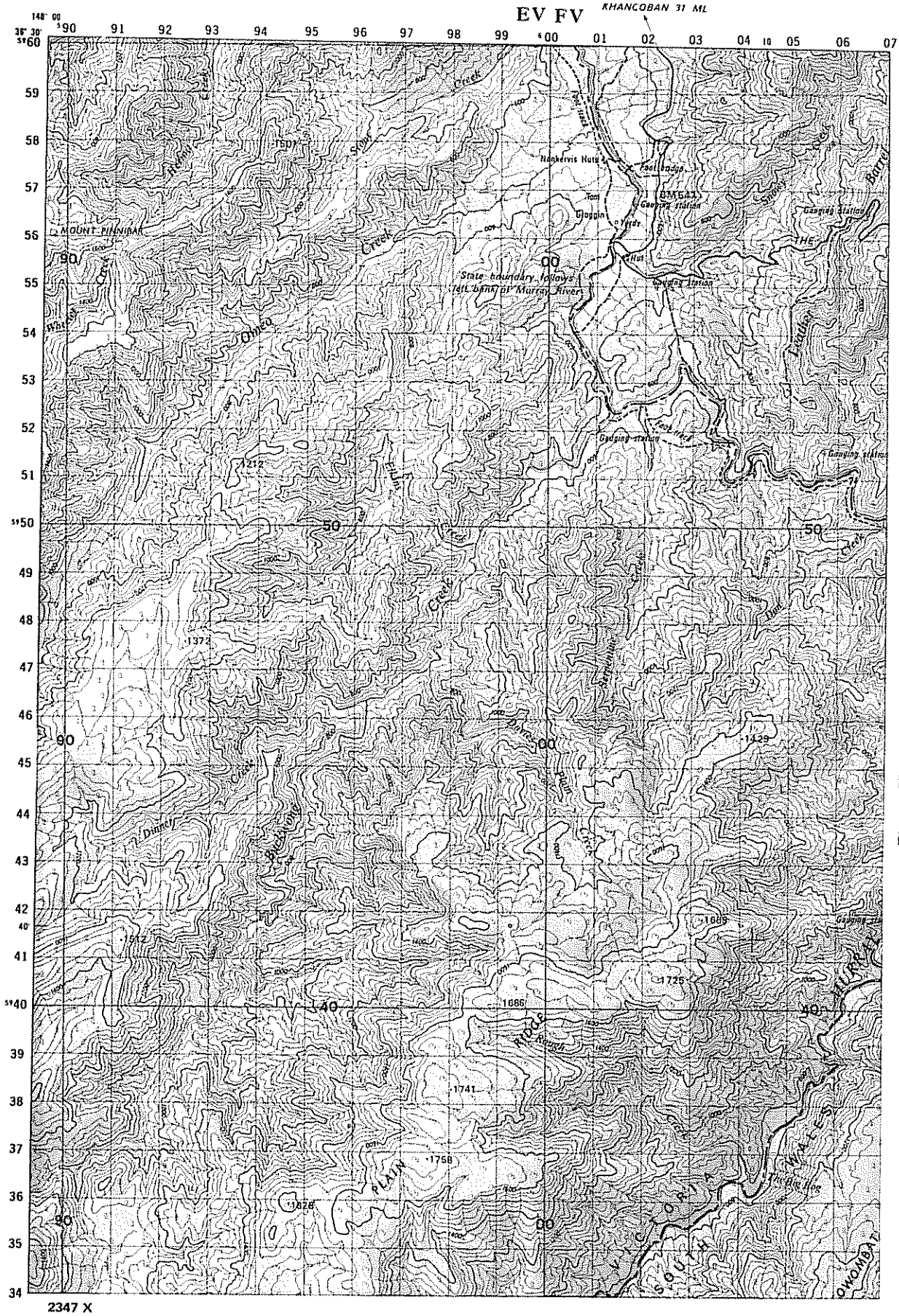


Figure III. Part of a map with relief drawing

DEVELOPMENTS IN AIRBORNE PROFILING: LASER TERRAIN PROFILING EQUIPMENT

Paper presented by Australia[1]

Introduction to Australian requirements

Airborne profile recording has proved to be an efficient means of providing vertical control for medium-scale mapping. For a country such as Australia, with its vast remote areas, the method is both economic and practical, producing suitably accurate results.

The unit for area coverage is the 1:250,000 map sheet, and the standard air photography flight pattern used for relatively flat areas is shown in figure I. Other standard flight plans exist for terrain where larger variations in altitude exist.

All medium-scale mapping is carried out with a super-wide-angle lens camera and the profiles are flown in the 20 per cent side-lap area. In addition to the east–west profiles, north–south profiles, termed tie lines are flown at intervals of either 60 or 30 minutes of longitude, and it is a requirement of the flight pattern that each east–west flight should be continuous between tie runs. Comparison of the profiles at these intersection points provides a basis for assessment of the profile accuracy, and the results may be used for an adjustment, if required.

Principles of profiling and reason for development of specialized equipment

The principle of this method of heighting requires the aircraft to fly along an isobaric surface, at a pre-selected altitude, while the profiler records the distance to the ground. Deviations above or below the selected isobaric surface are recorded and either automatically corrected for on the profile record or recorded and applied as corrections at each profile point used for control.

The development of airborne profile recording equipment began in the mid 1940s when the National Research Council of Canada experimented with radio altimeters and then radar instruments. These initial experiments proved that specialized equipment was necessary, both for measur-

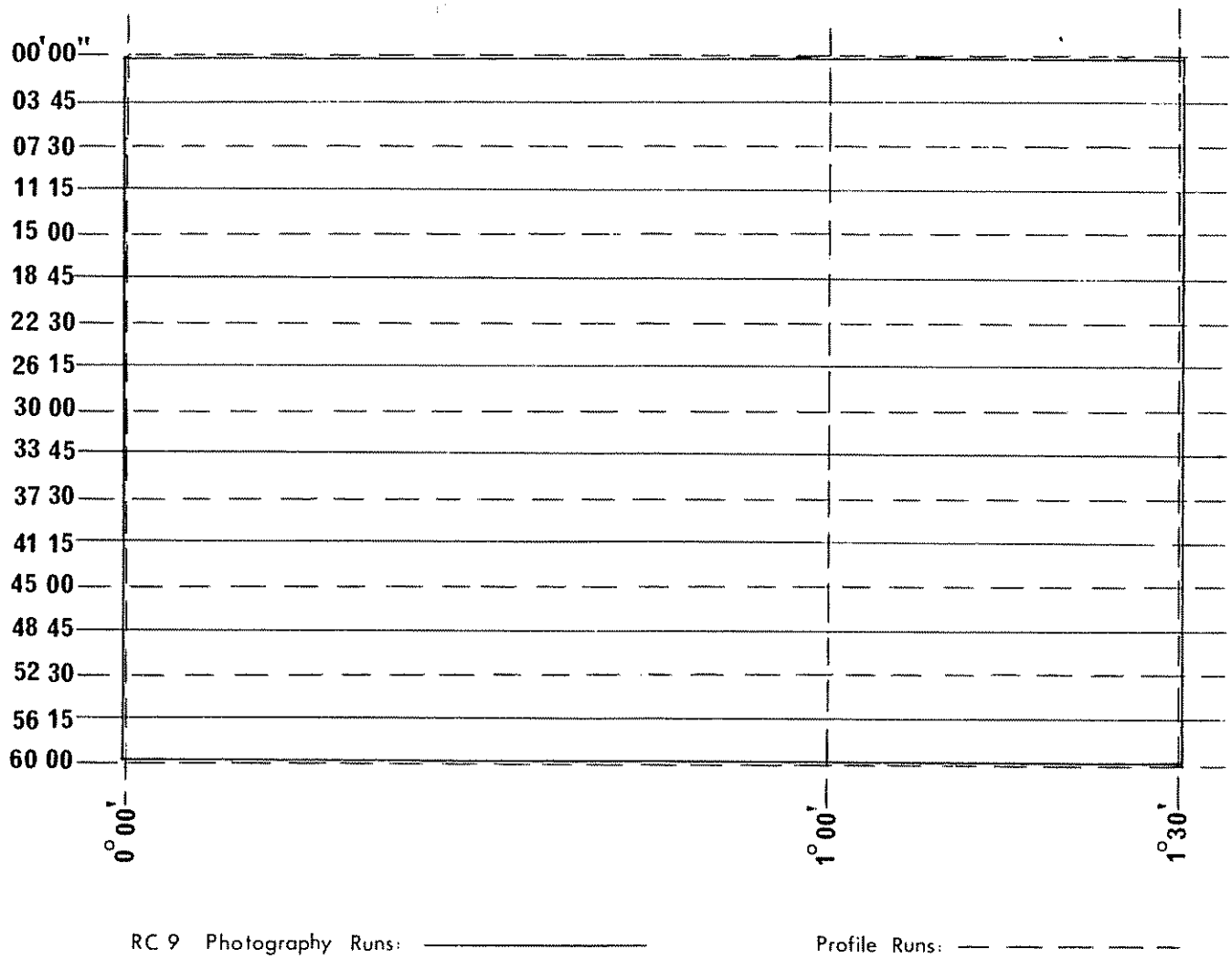


Figure I. 1:250,000 map area: Standard flight line plan

[1] The original text of this paper appeared as document E/CONF. 47/L.64.

ing and the positioning photography. Research proceeded with various systems, and, at the same time, the possible applications of profiling expanded. Commercially available profilers may be divided into two groups on the basis of their measuring systems—either radar or laser.

The accuracy limitations of the radar instruments stem largely from the 1° cone of the transmitted beam. At the operating altitude of 3,000 m, the beam is sampling terrain heights over an area approximately 70 m in diameter. Thus, in areas with steeply sloping terrain, timber coverage, buildings, etc. an accurate height determination is not possible. This limitation cannot practically be overcome, because it would entail an inordinately large increase in diameter of the reflector.

The problem encountered with early laser units was somewhat different. With the frequency and intensity of light used, the aperture diameter was decreased to a few centimetres, but the flying height had to be reduced to approximately 700 m. Thus, the system was capable of measuring to a few parts per million of the height, but the reduced operating height decreases the system accuracy owing to adverse meteorological conditions at low altitudes. This limitation is acceptable for relatively short profiles, but not for extensive mapping control. For Australian conditions, it is generally necessary to operate at a minimum of 2,000 m altitude to avoid thermal turbulence.

With the limitations of existing instruments in mind, the Division of National Mapping of the Department of National Development undertook the sponsorship of the development of a laser terrain profiler specifically for mapping purposes, through the scientific research facilities of the Weapons Research Establishment of the Department of Supply.

The laser terrain profiler and principles of operation

By a judicious selection of flight lines the laser terrain profiler will establish a grid of reference levels within the National Levelling Survey of Australia. The profile levels obtained supplement the existing vertical control and provide the height control necessary for setting up photogrammetric models for contouring. The contour interval for the Australian 1:100,000 mapping programme is 20 m.

The system is currently installed in a Grand Commander aircraft and consists of two main units:

(*a*) *The Profiler Unit* (figure II):

A. Laser and modulator;
B. Receiving telescope;
C. Photomultiplier assembly;
D. Modulator driver;
E. Strip camera and camera control unit.

(*b*) *Equipment Rack* (figure III):

A. Water module;
B. Vacuum module;
C. DC converter;
D. Current regulator;
E. Height computer;
F. Photomultiplier EHT supply;
G. Timing unit;
H. Ultra-violet chart recorder;
I. Cathode ray oscilloscope.

Other units used in the system are the laser cathode heater supply (figure II F), the barometric reference unit (BRU) and a 35 mm frame camera. The latter are not illustrated.

The profiler is an airborne continuous wave argon ion laser unit which transmits to the ground a very narrow, amplitude modulated, laser beam. A small amount of the laser light reflected from the ground is collected through the receiving Cassegrain telescope, and after amplification, it is phase-compared in the height computer with the transmitted signal. The modulation frequency selected is such that a full 360° phase change equates to a distance change of 100 m. Allowing for the transmitted and return paths, this represents an aircraft to ground distance change of 50 m. Resolution of the phase difference is made to an accuracy of one metre.

With the single modulation frequency employed in the present system it is not possible to directly determine the number of multiples of 50 m of aircraft to ground distance, but while the system is in operation each 50 m change of distance is recorded as a phase step on the profile chart. This means that if the height of at least one point on each profile line is known to within 25 m, there is no ambiguity in the profile heights. In practice, these points of known height can be conveniently located vertical control stations near the start or finish of profile lines or anywhere along it.

Power for the laser is obtained from a 28 volt DC supply to a 250 volt DC converter and an adjustable current regulator to allow for deterioration of the laser power efficiency conversion which should be a nominal 100 milliwatts.

The chart recorder is a six-channel, three-speed, ultra-violet recorder with channels used for the laser trace indicating terrain clearance, BRU, frame camera event, height computer half-scale shift and two channels for a timing code.

The timing unit generates coded lapsed time pulses for the recorder and strip camera. This simultaneous event recording is one of the good features of the system. Loss of correlation of data is to be avoided at all times in a surveying operation.

The strip camera, a cassette-loading 70 mm unit, provides photographic imagery of the track traced out by the laser spot on the ground. The camera incorporates a 7 inch focal length Kodak Aero Ektar lens with a fixed aperture of 2.5 giving a scale of photography of approximately 1:15,000 from an altitude of 2,000 m. An internal window set at 45° to the lens axis reflects the incoming rays to the film which is situated at the focal plane behind a slit. Since the window is partially transparent, the ground is imaged on the screen and is viewed by the operator through a rotating disc engraved with a spiral. This disc is driven by the film transport motor which can be regulated to remove relative motion between the ground and the spiral thus ensuring equal longitudinal and transverse film scales.

The camera and navigation sight body can be rotated relative to the axis of the aircraft as with a conventional aerial survey camera to align the film with the track covered on the ground when drift necessitates crabbing to maintain a selected track. This alignment of the camera with the track provides a measure of the drift angle, which is one of the factors used in the computation of the inclination of the pressure plane along which the aircraft is flying.

To facilitate easier identification of terrain on the superwide-angle photography used for map compilation,

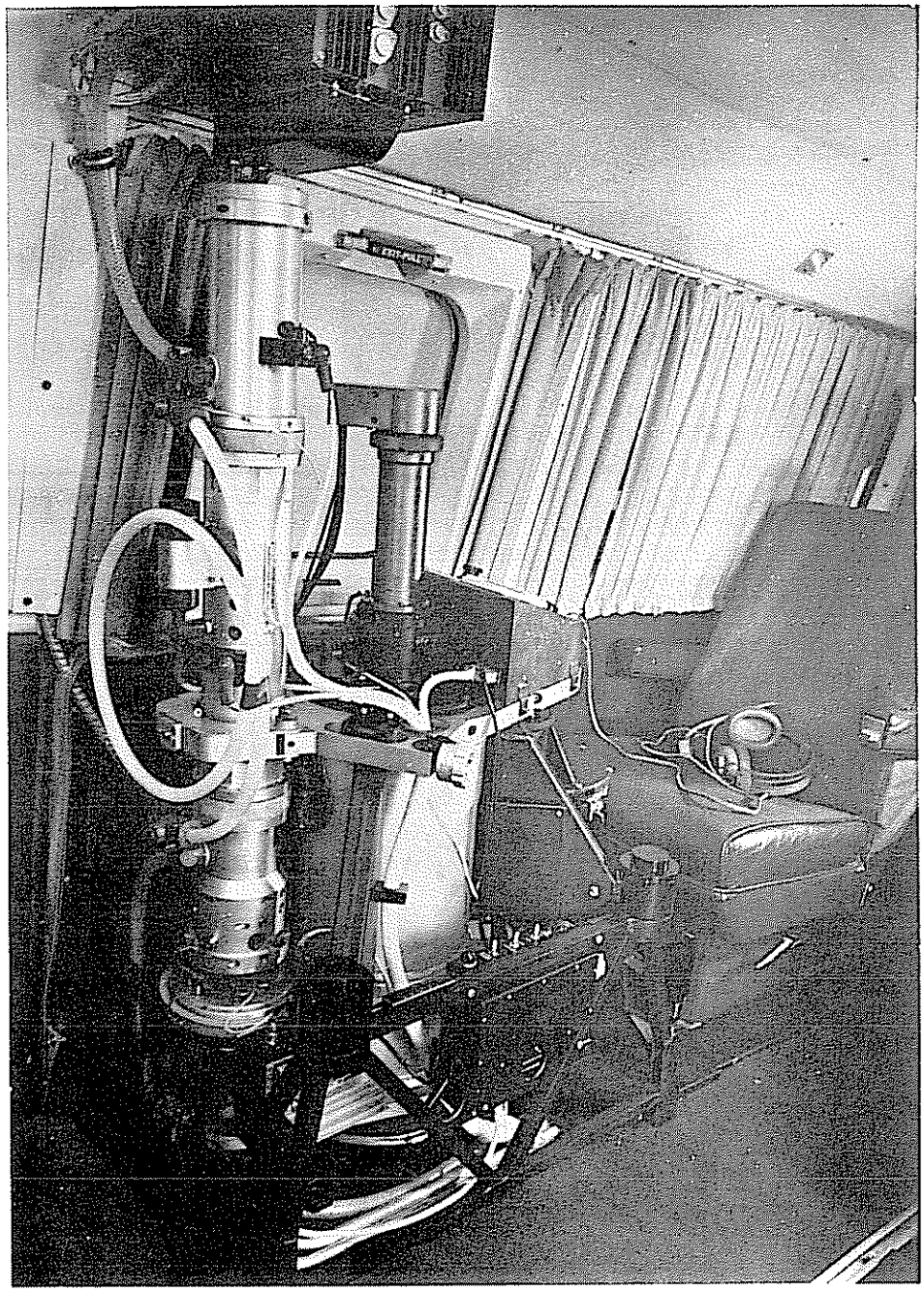
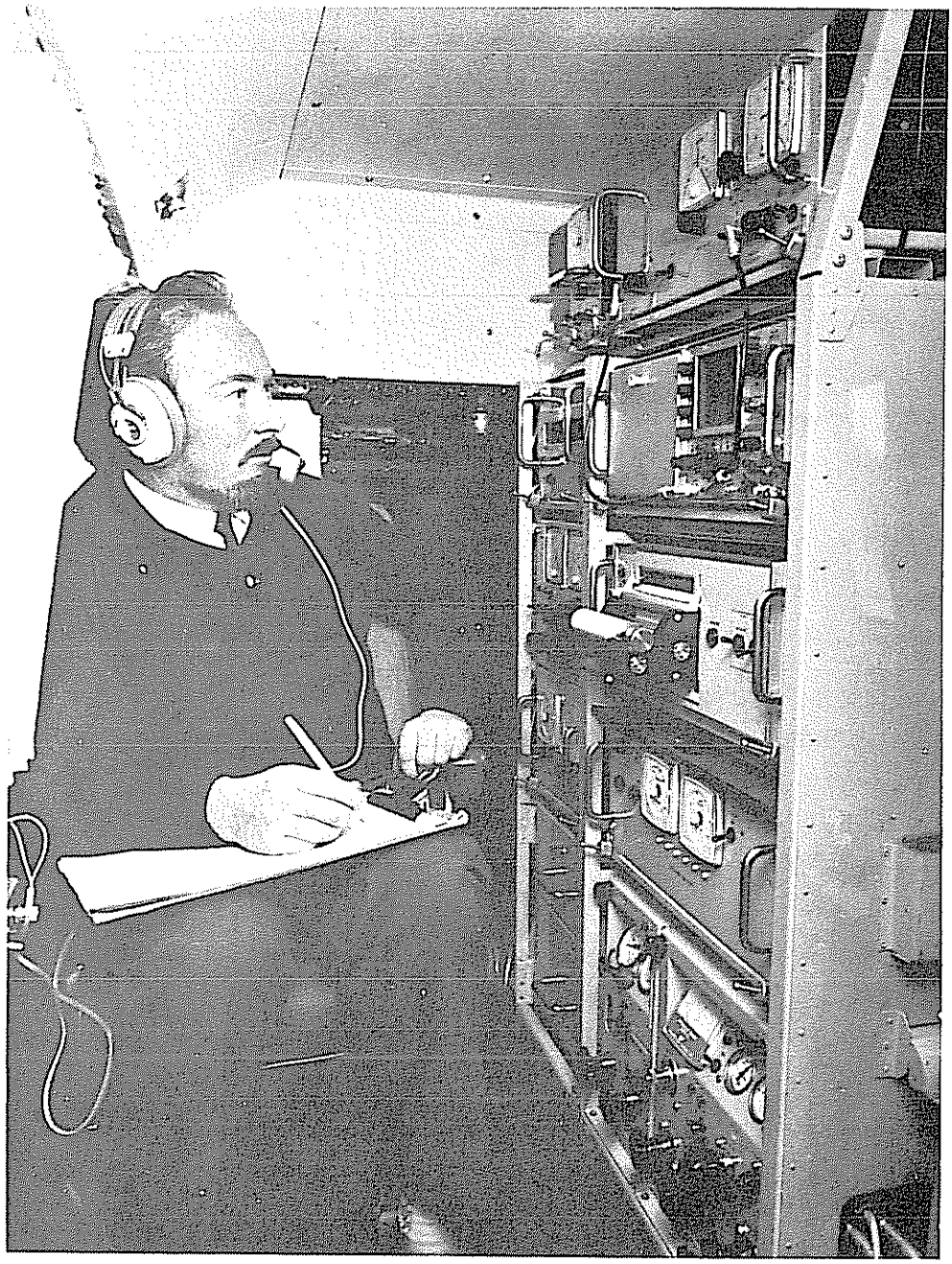


Figure II. The profiler unit



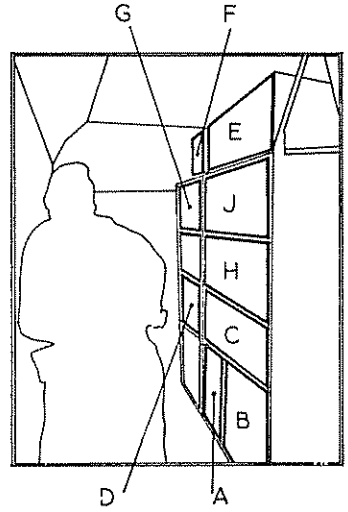


Figure III. Equipment rack

a motorized frame camera with a 50 mm focal length has been installed and can be activated by the profiler operator at any required instant. When this is done the paper chart of the data recorder is event-marked. It should be noted that in some areas of Australia, the area of terrain exposed on the strip camera does not include sufficient terrain patterns to enable cross-identification of the profile positions to the mapping photography to be made with certainty. In these circumstances, the frame-positioning camera, which photographs at a much smaller scale than the strip camera, is used to obtain supplementary photo coverage.

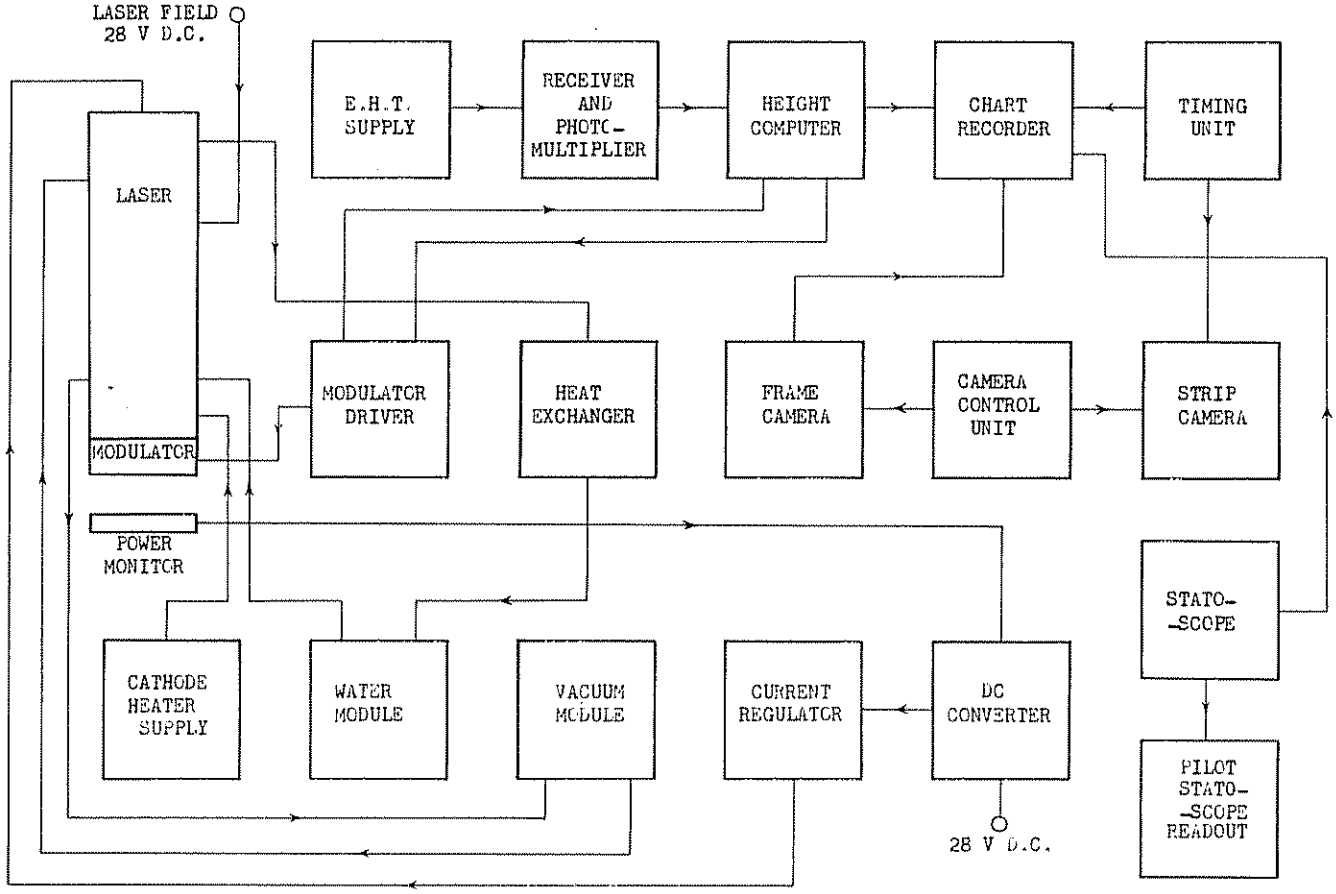


Figure IV. Laser terrain profiler

A brief description of the measuring process is as follows. The laser beam emerges from the bottom mirror of the laser with a diameter of approximately 3 mm and passes through the modulator unit, where it is intensity-modulated with a 3 mHz sine wave. The modulated beam is then passed through a diverging telescope and produces a 30 cm diameter spot on the ground when the aircraft is at 2,000 m. The receiving telescope, which has a field of view of about 60 cm diameter at 2,000 m, is aligned to the laser-illuminated spot on the ground and receives reflected laser light from this area. The received signal is passed through a field stop and an adjustable interference filter set to 4880 A, on to the photomultiplier cathode. The output from the photomultiplier consists of a small amount of 3 mHz signal and random noise, the result of reflected sunlight. The equipment has been designed with narrow bandwidths, both electrically and optically, to reduce this noise content. The received 3 mHz signal is amplified by a head amplifier on the photomultiplier and fed into the signal channel of the computer. A reference signal, which is a small sample of the transmitted signal, is taken from the modulator driver and applied to the reference channel of the computer. Both these signals are then amplified, limited and compared in phase, the phase difference appearing as a DC output suitable for driving a galvanometer head in the U/V recorder.

Operational Techniques

When a 1:250,000 map area has been selected for laser profiling, the superwide-angle mapping photographs at a scale of approximately 1:84,000 are obtained and prepared for field use. This preparation consists of marking the lateral overlap on each photo run, and plotting the proposed flight path along the centre of this overlap. The photographs are then used in conjunction with similarly prepared 1:250,000 map sheets for in-flight navigation. The standard flight plan for superwide-angle photography is always used for profiling operations, irrespective of whether superwide-angle photography is immediately available. If this photography is not available, the existing 153 mm photography is premarked and used for navigation. To provide suitable profiles the flight track should not deviate by more than 700 m from its planned position.

The normal field operation for laser profiling employs a party of four men under the control of a surveyor. This group is based, of necessity, at an air strip which is suitably located in relation to the area to be profiled. On days when the weather is suitable, two missions are normally flown, each yielding a measurement of two profile lines.

In accordance with previously accepted APR procedures, each mission is flown between initial and terminal datum surfaces which form part of the National Levelling Survey. This procedure enables evaluation of a misclosure correction and relatively frequent controls on the profiling operation.

measured drift, indicated air speed and outside air temperature are recorded against time by the profiler operator between successive datums. Along the lines to be profiled, the navigator is responsible for keeping the aircraft above the planned flight path, and he maintains voice contact with the pilot and other crew members by means of an aircraft intercommunication system. The laser equipment is fired, maintained and shut down by the operator in the rear seat.

It is expected that all maintenance and repairs, except those involving specialized equipment, such as for some of the optics, will be carried out in the field. The repairs



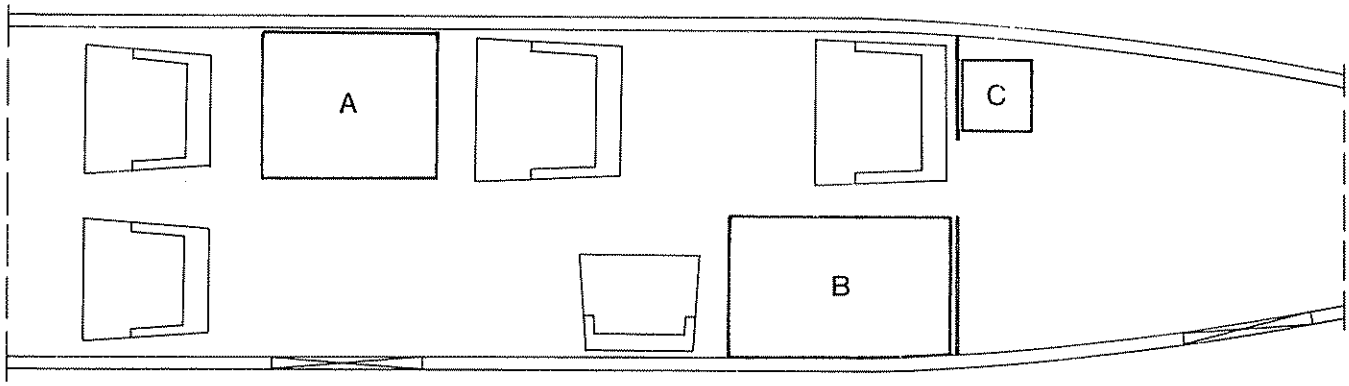


Figure V. Grand Commander aircraft and equipment layout

The basic air crew for a profiling mission comprises the aircraft pilot and the survey crew of navigator, profiler operator and equipment technician. (Figure V shows the Grand Commander aircraft employed and a layout of the equipment in the aircraft. The laser profiler, equipment rack and barometric reference unit are designated *A*, *B* and *C* on the diagram.) The pilot maintains a constant pressure altitude at the selected altitude throughout the flight, with the aid of a remote read-out from the barometric reference unit indicator mounted on his control panel. Regular readings of aircraft heading,

will be carried out in a specially fitted-out workshop, with electric power generator and pump for ground testing of the laser equipment and dark-room facilities, built onto the tray of a four-wheel-drive vehicle. A comprehensive range of spares will be carried in the workshop and space has been provided for field office work. Four lasers have been manufactured for this project; two are held by headquarters and one is carried in the field as a spare.

At the conclusion of each mission all collected data is assessed for acceptability of the traces on the recorder

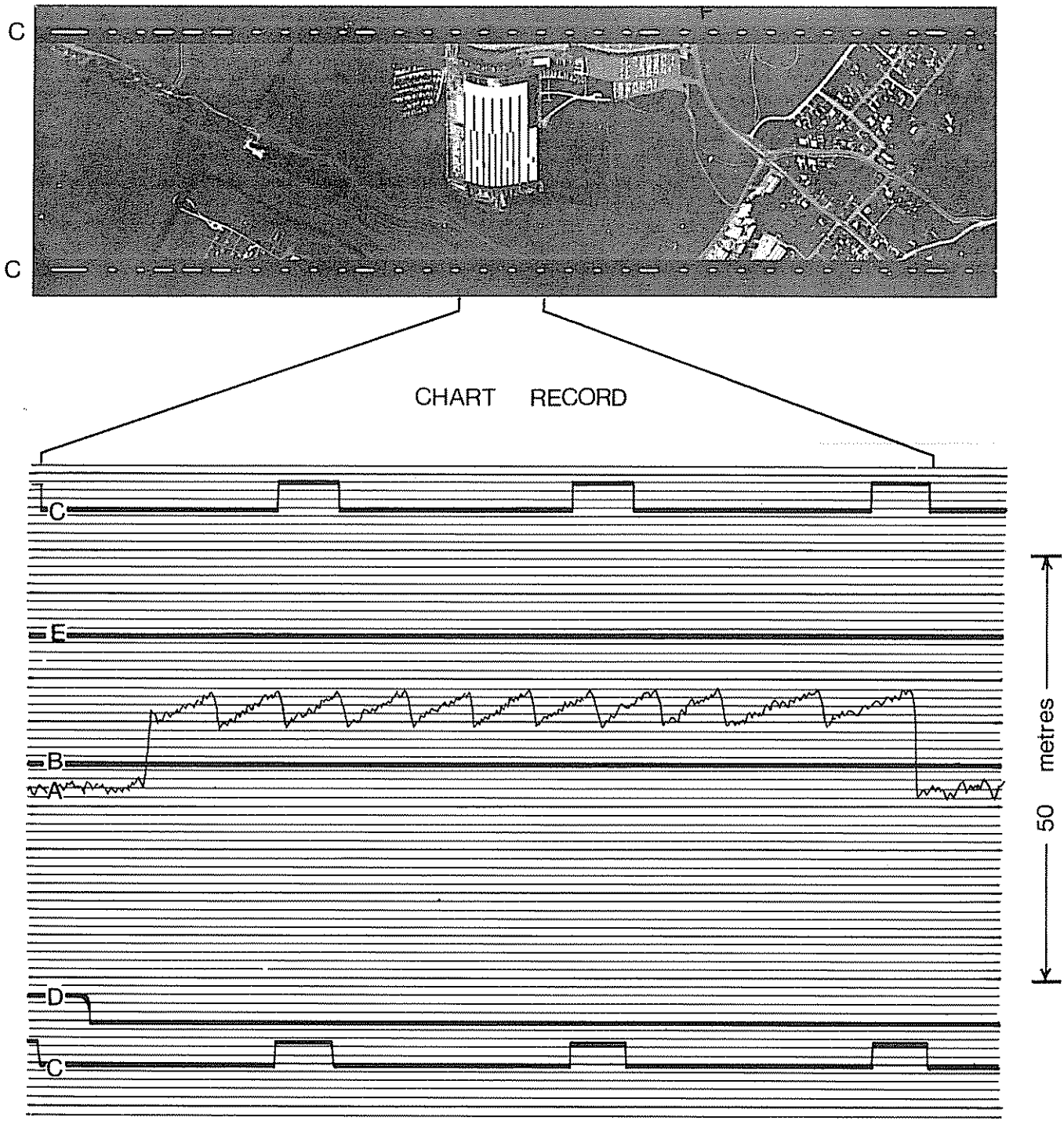


Figure VI

chart to ensure that trace density has been maintained and the signal-to-noise ratio is acceptable. When an area has been completed, the chart rolls, films and flight records are annotated and sent to headquarters for processing, reduction and evaluation.

Here the extraction of height values for control points, while not simply a matter of reading values off the chart, does not require any lengthy computations. The timing code for the point selected is read off the film and the same point is located on the chart. The readings on both the laser height and the barometric reference unit traces are measured and converted to metres by applying previously determined scale factors. The scales of both traces are determined by calibration procedures carried out prior to the initial datum crossing. An orientation constant, determined by obtaining the difference between the chart height and known height of the initial datum surface, plus the misclosure correction are applied, giving the reduced level of the selected point.

Further modifications

Prior to operations, it was recognized that a sealed laser unit which does not require a continuous replenishment of gas would be advantageous. This innovation would not require the vacuum and argon supply module at present in the system, and this, together with work on a field replaceable cathode heater, are now being developed.

With the present single modulation frequency a circumstance could arise where laser reflection from an isolated cloud patch below the aircraft could lead to loss of resolution of the 50 m ambiguity for a short period. In most terrain this would not be a serious problem, but in an area of rapid ground height changes parts of the profile trace could be difficult to use because of uncertainty of ground height to within 25 m.

A modification of the system to include a second modulation frequency coinciding with a full-scale deflection of 300 m, to be switched in if required, is being designed. This modification will overcome any possible problems of loss of ground reference and also make the profiles independent of any necessity to carry ground heights forward from datum points to the beginning of each profile.

Further modifications in hand include a vertical gyro to give read-out of aircraft tilt, and an improved barometric reference unit built around a transducer. This latter will obviate the rather long warm-up time of the present unit and will provide greater sensitivity.

Uses other than topographic mapping

Although the present laser system has been specifically developed for topographic mapping, it is sufficiently versatile in its altitude operating range, which can vary from a few hundred metres to 3,000 m, to be a very useful tool for other purposes.

Already projects have been outlined where this equipment can effect very large savings over the cost of ground surveys, particularly where contour information is nonexistent or existing contours are at very large vertical intervals. These include profiles to serve as a trial survey for the examination of gradients for a new railway, checking line-of-sight problems connected with the cross-country transmission of television frequencies and some of the mensuration problems associated with forestry activity.

These are but a few of the potential applications of laser profiling, which although developed for the provision of height control for the compilation of maps, also has a use in testing the accuracy of the end-product map compiled by photogrammetric methods. This is a quick and reliable solution to an otherwise tedious and expensive problem.

Technical description

A detailed description of the equipment is given in *Technical Note OSD 116* published by the Australian Defence Scientific Service, Weapons Research Establishment, Department of Supply.

(c) *Cadastral and urban surveying and mapping*

BASIC URBAN MAPPING

Paper presented by the United States of America[1]

Urban growth

Control of urban environments is one of the biggest problems facing Federal and local governments. In the United States of America, in 1900, 40 per cent of the population lived in cities; by 1960, that figure had risen to 70 per cent. By the year 2000 it is estimated that 80 per cent of a rapidly growing population will reside and be employed in cities of over 50,000 population. Also in the year 2000, over 300,000 square miles will be dominated by urban activities—nearly 10 per cent of the total United States land area. The intense concentration of population in these large cities will require extensive construction of streets, roads, water supply facilities, sanitary systems, houses, stores, shopping centres and recreational facilities. Problems of air and water pollution, solid-waste disposal, erosion, drainage, transportation and countless others will require a comprehensive understanding of the urban environment on the part of planners, engineers and managers.

Need for urban maps

A basic requirement for this comprehensive understanding is a system of good urban maps, structured to meet a variety of needs. Such a co-ordinated system of urban maps can make a direct contribution to four general types of urban activities:

(*a*) As source data for *planning* decisions on the regional,

[1] The original text of this paper, prepared by R. B. Southard, United States Geological Survey, Washington, D.C., appeared as document E/CONF 57/L.22.

municipal or neighbourhood level, appraising alternative land uses to meet over-all urban needs;

(*b*) In the *management* of urban matters, permitting orderly implementation of planning decisions, and the establishment and maintenance of environmental standards, such as building codes and zoning regulations;

(*c*) As a tool for *engineering* uses, necessary for location and design of construction—buildings, transportation systems, water facilities etc.;

(*d*) For *operations* use in the continuing management of facilities and services—water and sewage plants, streets and highways, crime prevention, fire control etc.

It is clear that no one map can meet all these needs efficiently. Many different types and scales are required, with varied treatment of content. Original surveys can be cartographically presented at one or more basic scales, with accuracy and content compatible with those scales. These basic maps can be reduced or enlarged, generalized or detailed where necessary and made the media for many specialized urban uses. If the requirements for these uses are understood, it is possible to co-ordinate the production of an interdependent "family of maps" that will efficiently meet urban needs. Updating of the different maps can vary from continuous revision for the largest scale coverage to a 5 to 10 year cycle for the regional planning maps. Above all, information on the existence of these maps and how to get them should be available at a central point in the metropolitan complex. Also, in order to achieve a systematic approach to the needed mapping, effective communication must be established and maintained among the Federal, regional and municipal agencies involved in making or procuring maps for the city.

Urban mapping co-ordination

The need for a planned approach to the production of urban maps has been well known for some time. Many United States cities have effective programmes for producing the base maps they need, including Cleveland and Cincinnati, Ohio; Phoenix, Arizona; and New Haven, Connecticut, and many others. In general, however, the situation in most cities is one of a proliferation of map types and scales of uncertain accuracy often prepared in a hurry to achieve a single purpose. Frequently a planner or engineer who needs a reliable, up-to-date map for a special project goes through the process of procuring such a map even though there may be a satisfactory map for his purpose elsewhere in the city, carefully stored in a file drawer, but temporarily forgotten. The production of maps for a variety of single uses by a large number of agencies is a very expensive and not wholly satisfactory situation. A major factor in this problem is the number of Federal programmes designed to help the cities—planning assistance, community renewal, recreation, resource utilization, open space and many others. Two or three Federal agencies may be involved in producing or procuring mapping products, each unaware of the other's activity. Many Federal agencies realize that their helpful efforts are diluted by this lack of co-ordination. Acting on this premise, five United States agencies sponsored an Urban Mapping Panel[2] in June 1965 to seek answers to the following questions:

(*a*) *What uniform mapping standards can be established* to ensure that maps developed under one programme can be of greater value to other programmes?

(*b*) *What actions by the Federal government and by other groups* would most effectively promote the development of better mapping in the Nation's cities?

The deliberations of the Panel developed the following conclusions:

(*a*) *Map series.* The most uniform and widely available maps useful in urban planning are the United States Geological Survey (USGS) standard quadrangle maps in the 7½-minute and 15-minute series (1:24,000 and 1:62,500) and the USGS metropolitan area maps (1:24,000). Additional coverage is provided by the county general highway maps (1:62,500 and 1:125,000) and the Bureau of the Census planimetric metropolitan series (1 inch = 800 to 880 ft);

(*b*) *Scales.* Scales of urban mapping vary widely depending on the intended use. The general range is from 1 inch = 40 ft for engineering or construction surveys to 1 inch = 4 miles for regional planning or display. There are many scales in between for various purposes, but comprehensive urban planning seems to require at least the following basic scales: 1 inch = 2,000 ft; 1 inch = 800 or 1,000 ft; 1 inch = 400 ft.

(*c*) *Co-ordinate systems.* Many urban programmes require the location and identification of certain features and facilities by means of computer-receptive co-ordinate systems. Many standard systems and a number of local systems are now in use. The USGS standard quadrangle maps show latitude and longitude, State plane co-ordinates, Universal Transverse Mercator grid ticks, and township-range systems where they exist. Any co-ordinate system used should be mathematically relatable to either latitude and longitude or State plane co-ordinates, if it is to have universal application;

(*d*) *Control.* Maps and ground-survey control for urban use must be tied into the national horizontal and vertical control network established by the United States Coast and Geodetic Survey;

(*e*) *Accuracy.* The need for accuracy in a map depends on proposed use. Preparation of the map in accordance with National Map Accuracy Standards is considered necessary in some cases and is a desirable over-all goal. Many users believe that the USGS standard quadrangle maps prepared to National Map Accuracy Standards at 1:24,000 can be enlarged considerably and still meet accuracy requirements for many levels of urban planning. Maps that have been produced by enlarging or reducing maps at other scales should include a note to that effect;

(*f*) *Need for updating maps.* Nearly 7,000 of 21,000 available United States 7½-minute quadrangle maps currently need updating; more than 2,000 of these are in urban areas. An expanded programme of revision is needed to meet minimum requirements. A substantial continuous revision programme is needed in urban areas if a 3-year updating cycle is considered an optimum period and a 5-year cycle a maximum;

(*g*) *Suggested new planimetric series.* There seems to be a need for a planimetric map series in urban areas at a scale of about 1 inch = 800 ft or 1 inch = 1,000 ft.

Following the original meeting, a subcommittee was appointed to investigate specific requirements for various types of urban mapping. In addition to its primary

[2] Urban Mapping Panel Highlights, Bureau of Public Roads, June 1965. The sponsoring agencies were the Bureau of the Census, the Bureau of Public Roads, the Coast and Geodetic Survey, the Geological Survey and the Urban Renewal Administration.

deliberations, the subcommittee decided upon an exploration of local area map resources and requirements through interviews held with metropolitan officials.

The subcommittee conducted a series of interviews and held several meetings to develop its recommendations. During the period of its work the parent group came to be called the Urban Mapping Co-ordination Group, made up of members from Bureau of Public Roads, Bureau of the Census, Coast and Geodetic Survey, Department of Housing and Urban Development and the Geological Survey. In December 1967, the final Report of the Urban Mapping Co-ordination Group was distributed to the Bureau of the Budget, the General Accounting Office and the agencies involved. The recommendations of the Group made in that final Report have significant bearing on this subject and accordingly are summarized below.

New series at 1:12,000 scale

Sufficient interest has been shown in a new series of maps at or near 1:12,000 scale (1 inch = 1,000 ft), and its implementation should be further investigated. Among questions to be answered are those of accuracy, content, extent of coverage, format and financing.

Geodetic control

The requirements for geodetic control need to be fully determined and analysed. To meet the requirements set forth for establishing a co-ordinate system, to assure accuracy in urban maps and to promote co-ordination of all mapping efforts, it is essential that adequate control, tied to the national network (1927 North American Datum) be available. Establishment of this control should be a co-operative effort between the various levels of government to assure that an optimum number of requirements are met in the most economical manner.

Revision

The Geological Survey should continue its efforts to develop ways of revising many more of the outdated $7\frac{1}{2}$-minute maps in urban areas.

Implementation

Effect recommendations and co-ordinate actions, especially with respect to scale, accuracy and content, through the control afforded when funds are granted by Federal agencies to State or local jurisdictions.

Metric–decimal systems

Because of the world-wide trend toward adoption of the metric–decimal system and the rapid increase in the use of automated techniques in mapping, the Group strongly urged that an in-depth study should be made to determine the possible effect of this trend on the present United States numerical designations for scale and geographic co-ordinate values, as opposed to decimal designations such as scale 1:10,000 and co-ordinate values such as 39.2165 degrees.

Co-ordination

Federal, State and local agencies should co-ordinate surveying and mapping efforts with the Geological Survey and Coast and Geodetic Survey so that there can be an exchange of information for mutual benefit.

The Urban Mapping Co-ordination Group also suggested that the following subjects should be given further investigation and evaluation.

Co-ordinate system—geographic coding

The task of providing computer-receptive co-ordinate systems to provide for a sound mathematical relationship of group survey and map positions should be actively explored. Also, consideration should be given to providing guidance and maintaining control of the co-ordinate systems that will be used. A reduction of the total number of possibilities would be in order.

Accuracy

The Group recognized the need for tailoring accuracy requirements to proposed uses. Preparation of maps to National Map Accuracy Standards is a desirable goal. Determination of accuracy required for proposed use is a major problem.

New products and techniques

The applications of various new products such as orthophoto maps and automated plotter graphics should be investigated.

Use of USGS general-purpose quadrangle mapping

Geological Survey $7\frac{1}{2}$-minute quadrangle maps are used at publication scale or frequently enlarged to serve special purposes. The circumstances under which USGS $7\frac{1}{2}$-minute maps are appropriate to meet mapping requirements of cities should be ascertained and recorded as part of the urban mapping picture. It appears that if these maps completely covered the United States and were updated on a current basis they would satisfy most of the mapping needs for general planning. For example, the county general highway map series prepared by the State highway departments and most of the mapping programmes under the Bureau of the Census could be curtailed if these maps were available on a current basis. Until funds are available for such an extensive mapping programme, priorities must take account of mapping and updating needed in the highly developed and rapidly changing areas as well as any urgent requirements in less developed areas.

Need for data-bank mapping at 1 inch = 200 ft

Data banks are a growing topic of discussion. There were some recommendations from local agencies for mapping at 1 inch = 200 ft to make up a data bank. This aspect needs further study.

Standard specifications

There are a multitude of specifications dealing with each of the mapping scales; many are informal or unrecorded. At the earliest possible time, after the related problems have been resolved, specifications and mapping standards for each scale and type of mapping must be developed. These will serve as a guide for all map producers at any level of government, especially where Federal funds are involved.

Education

Education in the use of base maps and survey control is needed. A "primer" or other explanatory brochure should be devised for study.

CURRENT ACTIVITY

The urban Mapping Co-ordination Group has only begun to explore the problem of improved co-ordination to produce better urban maps, but an important beginning

has been made. During the period of the Group's activity some real progress has been made, some of it directly responsive to the dialogue of the Group. A few of these items are highlighted.

Geodetic control. The Coast and Geodetic Survey has recognized the needs of rapidly developing areas and in its current programmes is emphasizing the densification of very precise control in urban regions.

Revision. Recognizing that the standard quadrangle maps of the Geological Survey are useful for general urban planning when they are up to date, the Survey has developed a system of rapid updating called interim revision. It is being applied primarily to urban areas. In this process, maps are culturally revised by photogrammetric means; no new field work is done, and the contours are not revised. All changed features are shown in a single distinctive colour—purple. These maps can be rapidly and cheaply produced requiring about one year and approximately one-fourth to one-third the cost of normal revision. This new product has been well received by map users and is enabling the Survey to reduce the growing backlog of maps needing revision.

Larger-scale mapping. The Geological Survey is actively investigating the nature of urban needs for standard urban maps at scales larger than 1:24,000. Scales from 1:7,200 to 1:12,000 are being investigated along with various means of presentation.

Metropolitan Map Series. Another development has been production of the excellent Metropolitan Map Series of the Bureau of the Census. These maps are line planimetric maps prepared at basic scale of 1:9,600 (1:10,000 in Puerto Rico) and 1:10,560, with publication planned at 1:24,000. They are available for most of the country's major cities and were prepared for use in the 1970 census.

ACSM Urban and Regional Planning Committee. The American Congress on Surveying and Mapping has formed an Inter-Divisional Committee on Urban and Regional Planning. The Committee is charged with the development of a pilot programme for continuing education of surveyors and mappers in the several planning disciplines, and with the preparation of a set of broad specifications for maps to be used in planning projects.

The foregoing are but a few of the activities that indicate the extent to which responsible officials have realized the urgency of doing something about the national aspects of the urban mapping problem. Recognizing the problem is a big step toward solution. Much can be accomplished by continued communication among Federal agencies whose activities bear on the mapping problem. Even more can be accomplished when that dialogue actively includes knowledgeable officials from the cities where the mapping situation needs improvement.

Improvement programme

Before urban managers can establish a programme to assure the most effective production and use of maps, there must be an awareness that improvement is needed and is possible. This awareness must exist at the highest possible level of city responsibility. Steps that can be taken to evaluate the degree of need and the availability of solution to the problem include:

1. *Secure the services of a knowledgeable cartographic adviser.* There may already be such expertise in the city government. If not, contractual consultants or part-time advisers from responsible government agencies involved in surveying and mapping could be contacted. The activity of this adviser must be co-ordinated with those who are furnishing other surveying and cartographic services to the city.

2. *Determine what mapping already exists.* The investigation of existing mapping should include all products, whether made by the city (in-house or under contract) or by State, regional of Federal agencies. All mapping should be catalogued as to format, scale, contour interval, accuracy, need for updating, cost to procure, availability of stock, type and location of reproducible materials.

3. *Investigate map-use patterns in the city.* This can be done by conferring with a large group of major map users or by a careful office-to-office check of uses and needed products. A combination of the two would take longer but would promise most success.

4. *Design a proposed programme to upgrade the cities' map resources.* Such a programme should include information on the nature of the map products needed to fill short- and long-term needs, alternative funding and time-phased production schedules, as well as availability of funding and technical support from Federal and other agencies.

5. *Provide continued funding support* commensurate with available funds and degree of urgency.

6. *Identify the responsible city agency* which will implement the mapping programme and will function as a central clearing-house for information.

The advice contained in the foregoing suggestions is not complete in detail, but is meant to be indicative of actions that can solve mapping problems noted in many cities. For any plan to be effective, there must be expert knowledge—there must be co-ordination—and there must be funds available to do the needed work. All three factors are necessary and interdependent if the urban mapping problem is to be solved.

SUMMARY OF THE URBAN SURVEY OF TAIPEI CITY, 1967–1969

*Paper presented by China** [1]

In order to meet the urban development needs of Taipei City, the Government of China directed the China Topographic Service in July 1968 to conduct an aerial survey of the city. This project was completed in February 1970. The details of the project are as follows:

1. Area of coverage: 280 km² (plane area, 150 km²; hilly area, 130 km²);

2. Number of map sheets: (*a*) 968 sheets at 1:1,200; (*b*) 8 sheets at 1:10,000;

* See introductory note at beginning of volume.

[1] The original text of this paper appeared as document E/CONF. 57/L.39.

3. Surveying method:

(*a*) Aerial photography: Aerial photographs were taken with a 6 inch focal length aerial camera at a scale of 1:3,000, with a 60 per cent side lap and a 30 per cent forward lap;

(*b*) Control survey:

(i) on the basis of known triangulation stations, 140 third-order triangulation were established with a Wild T2 theodolite, with a closing error for the triangle not exceeding 20″, and a base-line error not greater than 1/4,000; all stations were marked by concrete marks;

(ii) 1,300 control points were established from triangulation stations, with an error of closure for the triangl not greater than 60″;

(iii) 2,400 horizontal control points were established from known triangulation stations. 20″ theodolites were used in this survey, with the error of closure not exceeding 1/3,000 and the error of closure in azimuth not greater than $20\sqrt{N}$″, N being the number of points. These points were marked on the aerial photos for identification;

(*c*) Levelling:

(i) Second-order levelling: 25 second-order benchmarks were established in the plane areas of the city. The results of the two traverses over a section differed by no more than 8 mm $\sqrt{K}$, K being the length of the section in kilometres. The accidental error per kilometre did not exceed 25 mm;

(ii) Third-order levelling: third-order levelling was performed for triangulations and control points in the plane areas, with the error of closure not greater than 12 mm $\sqrt{K}$, K being the length of the levelling line in kilometres;

(iii) Indirect elevation: Indirect elevations were computed from known points for the low-order triangulations and controls in the hilly areas;

(*d*) Stereo-mapping: Multiplex compilation was used for mapping the hilly areas with 2 m contour intervals. The photo rectification method was used for the mapping of the plane areas with 0.5 m contour interval. The horizontal displacement of the features did not exceed 0.8 mm and the error of elevation did not exceed half the interval;

(*e*) Field edit: Field edits were made to obtain more information about geographical names, features, permanent constructions, floors of the buildings and the details not shown on the aerial photographs. Building over five floors high were checked against known reference points for the rectification of displacement;

(*f*) Tying the surveying to the pre-fixed marks: The urban survey was tied to the results of the pre-fixed city planning concrete marks which number 1,500;

(*g*) Reduction: The manuscripts at 1:1,200 were also reduced in scale and published as topographic maps at 1:10,000, with a contour interval of 5 m;

(*h*) Drafting: Drafting was done for the 1:1,200 and 1:10,000 topographic maps.

4. Owing to the shortage of sufficient autograph and Kelsh plotters, these maps were compiled with multiplex instruments, but their accuracy is reliable.

INVESTIGATION FOR THE ISSUANCE OF TITLE-DEEDS IN THAILAND

Paper presented by Thailand[1]

The Document Division and the Mapping Division of the Bureau of Cadastral Surveys are responsible for the investigation and mapping which precede the issuance of title-deeds. The Document Division investigates land rights and the Mapping Division prepares cadastral maps.

In Thailand investigations relating to the issuance of title-deeds began in 1901, and lasted 68 years. The number of parcels of land for which title-deeds were issued does not exceed 1,462,579 parcels, or about 14,596,000 rais.[2] The following data show that large cultivated areas still remain for which the State can still issue title-deeds:

(*a*) The area of Thailand measures some 321,250,000 rais;

(*b*) Cultivable areas suitable for the issuance of title-deeds measure 83,085,589 rais;

(*c*) From 1901 to 1969 we issued title-deeds for some 1,462,597 parcels of land, or about 14,596,006 rais;

(*d*) The areas devoid of title-deeds comprise approximately 68,487,583 rais;

(*e*) We have issued title-deeds for about 20 per cent of the cultivable areas.

The Department of Lands of the Ministry of Interior has decided to speed up the issuance of title-deeds and deliver them to the holders of land rights as quickly as possible. Intellectual and material progress and agricultural development have reached a point where holders of land rights demand to have title-deeds. The road and highway network has expanded considerably and made travelling easy. The development of irrigation has led to increased production and benefits from farming and gardening, and has conferred value to the most barren lands. As a result, the interested parties try to obtain their title-deeds, which entails conflicts over property rights and boundaries. About 40 per cent of all court cases have to do with title-deeds. The issuance of title-deeds is essential if the economy as a whole is to benefit from the action of the administrative services and social conditions. This will enable us to raise the standard of living of the population, which is the policy of the Ministry of the Interior. The investigations which necessarily precede the issuance of title-deeds represent an investment that will enable the Government to increase its receipts owing to registration of the land rights and subsequent procedures.

Development of land investigation for the issuance of title-deeds

In the past, there were two methods for the issuance of title-deeds: (*a*) ground-survey mapping; and (*b*) survey of specific parcels by provincial land offices. Then in 1960 we adopted a new method involving the issuance of title-deeds by local survey of isolated areas; in 1962 we started

[1] The original text of this paper appeared as document E/CONF.57/L.70.

[2] 625 rais = 1 km².

Conclusion

A feasibility study should be conducted to determine whether cadastral work would be economically feasible in Indonesia. It would be useful to draw a comparison with other developing countries, especially with regard to mapping techniques and the system of land registration that should finally be applied in Indonesia.

It must be realized that land registration is very important in a country where population is increasing and arable land is limited. The landowner or the land itself must be assured of legal protection and a compensatory tax can be levied so that land registration work will not represent a budgetary loss. Cadastral work is expensive, but the guarantee which the deeds give the landowners justified the expense.

A comprehensive report should be prepared concerning the problem of land registration in Indonesia. Comparative data relating to cadastral work in other countries should lead to a solution of cadastral problems in Indonesia.

LARGE- AND MEDIUM-SCALE SURVEYS IN HUNGARY

Paper presented by Hungary[1]

In Hungary surveys were undertaken in the eighteenth century—though not everywhere and not systematically—for the purpose of large-scale mapping. A uniform "cadastral" survey, covering the entire country, was started only in 1856; its purpose was to establish a basis for the levying of a land tax. These maps were prepared by the graphical surveying method, generally at 1:2,880. There are maps from this period at 1:1,440 and 1:720 having to do with interior territories and important municipal areas.

There was a rapid growth in the demand for maps for land-tax, land registration and technical purposes. As a result, the numerical method and scales at 1:2,000 and 1:1,000 were introduced in 1928. Since then, new surveys were undertaken by that method and at those scales to replace the old maps. After the Second World War, during the economic development period of the 1950s, it became apparent that a detailed, large-scale map of the entire country was inadequate, since it did not meet the requirements of economic life: about 90 per cent of the maps were prepared at 1:2,880 and 1:1,400 (old scales), and only about 10 per cent were prepared in the so-called "metric system" scale. New problems arose from the fact that some pages had been prepared several decades ago, and during their continuous registration, they had undergone many changes. A large-scale renovation was started in 1957, in the course of which new surveys were undertaken on the territories surveyed earlier, and a detailed revision was completed in the other areas. This has been one of the main tasks of the Hungarian surveyors ever since, and many of them are still working on it now. During the past twelve years we managed to prepare maps at 1:2,000 and 1:1,000 in the metric system for 35 per cent of the cadastral maps and to make available carefully updated maps for the other territories. The same situation prevails with regard to the surveys of towns and municipal areas to be developed. A new survey has been undertaken and 30.5 per cent of the old maps have been replaced.

Much work remains to be done by Hungarian surveyors in the future in this area. So far we have made rapid progress, thanks to the application of up-to-date procedures and the use of modern instruments. We need only mention here the increasing use being made of photogrammetry, especially in small and medium scales, which have long been traditional in Hungary. Some changes and developments were necessary, however, in order to use photogrammetry at 1:1,000. As a result, the following work was completed through the application of the photogrammetric method in the past ten years: 85 per cent of new surveys of municipal areas; 90 per cent of new surveys of village areas; 40 per cent of village area renovations; and 100 per cent of new land surveys. Incidentally, surveys by the photogrammetric method are 30 per cent less costly than those carried out by the classical method.

In addition to the large-scale maps, medium-scale topographic maps are also used in Hungary; these include maps at 1:5,000, 1:10,000 and 1:25,000. Preparation of relief, vegetation and technical maps at 1:5,000 and 1:10,000 began in 1953. About 65 per cent of these maps have been completed. The contents of these topographic maps at 1:25,000 for civil engineering uses were selected to suit general planning and administrative purposes. Forty-five per cent of these map sheets have been issued to date.

[1] The original text of this paper, prepared by F. L. Raum, Technical Director, Hungarian Geodetic and Mapping Company, Budapest, appeared as document E/CONF.57/L.90.

using aerial photogrammetric mapping which many countries are now using to advantage. We are currently using four methods for the issuance of title-deeds: (*a*) ground-survey mapping; (*b*) aerial photogrammetric mapping; (*c*) local surveys of isolated areas; and (*d*) surveys of particular parcels.

The issuance of title-deeds has progressed rather slowly and interested parties are continuing to ask questions about it.

Record of distribution of title-deeds in Thailand:

1967: Issuance of title-deeds for 20,792 parcels covering an area of 137,641 rais;

1968: Issuance of title-deeds for 36,410 parcels covering an area of 284,795 rais;

1969: Issuance of title-deeds for 68,336 parcels covering an area of 137,068 rais.

CADASTRAL ACTIVITIES IN INDONESIA

Paper presented by Indonesia[1]

Cadastral surveys before and after 1961

The cadastral system inherited from the Netherlands Government is a "quasi positive" system, which means that the landowner and the location and size of the property must be registered in the office of the Cadastral Surveys Management, but all such registrations are still subject to intervention by the Court of Justice.

Since western land titles were limited to urban land (mostly big cities) and to plantation areas, the cadastral services was also limited to those areas. The main purpose was clearly to protect the Westerners and those few Indonesians who had the same status as the Westerners and thus the same legal rights on land. The native inhabitants were not allowed at all to register their own lands, which were subjected to custom law; instead, they were harmed by the regulations based on the colonial agrarian law. Since the purpose of land registration was merely to serve a small number of urban landowners, the number of offices and field personnel for cadastral surveys was very small.

With the proclamation of the Basic Agrarian Law on 24 September 1960, the scope of land registration was changed. This law protects land titles in all areas of Indonesia, and not only the legal rights of Westerners. The transition from the colonial law to the new agrarian law, which benefits the entire population, has had a marked impact on the work required to carry out cadastral surveys and land registration throughout Indonesia, an area of about 1,984,127 km^2. The number of staff and the amount of equipment have not been increased to the extent required by the task.

In order to overcome the shortage of personnel, training courses for technicians and refresher courses for the existing staff must be organized. On the other hand, a simpler land registration system has been introduced to meet the current requirements of land title registration.

Offices, personnel and equipment

The following table describes the organization and capacity of the cadastral service; it indicates the number of offices, the total strength of technical and administrative staff and the equipment owned by the Cadastral Management Service before and since 1961, as well as the strength that would be desirable to cope with current needs.

Organization of the cadastral service in Indonesia

	Before 1961	*After 1961*	*Desirable strength*
Head office	1	1	1
Inspectors	—	9	26
Regional offices	12	139	241
Technical staff	240	1,790	2,158
Administrative staff	150	896	1,079
and equipment	70	695	2,410
Photogrammetric equipment	—	3 units	29 units

One year's work

Every office in Indonesia is expected to survey two villages per year by the terrestrial method. These villages are selected in accordance with their social and economic conditions, i.e. where land transactions involve at least 400 ha. This method should make it possible to prepare a cadastral map of 20,000 ha per year. However, the Service cannot achieve this target because of insufficient personnel and equipment.

Since 1968 Indonesia has prepared base maps at 1:5,000 scale by the photogrammetric method covering an area of 450,000 ha, as well as cadastral maps of six villages at 1:1,000 scale by the same method. Production should increase when rectifiers become available.

Accuracy achieved

For large- and medium-size cities, the instruments used vary according to the desired accuracy. When a high degree of accuracy is desired, the time factor plays an important role in survey work. To establish a first-order traverse connected to the national triangulation system, much time and money are needed. High degrees of accuracy are not necessary for surveying rice fields and other arable land.

Since national geodetic control is not available in some areas, a suitable system must be adopted for each such area.

When mapping is carried out by the photogrammetric method, sufficient accuracy is achieved for second- and third-order areas.

[1] The original text of this paper, prepared by the Cadastral Management Service, Indonesia, and submitted under agenda items 6 and 9 (*c*), appeared as document E/CONF.57/L.80.

RESOURCES INVENTORY FOR DEVELOPMENT PLANNING OF CITY REGIONS IN THE PHILIPPINES

Paper presented by the Philippines[1]

INTRODUCTION

Concentration of wealth

In an article in the *Sunday Times* of 30 June 1968, Mr. Alejandro A. Lichauco, Chairman of the Economic Committee of the Movement for the Advancement of Nationalism (MAN) stated that 2.6 per cent of all Filipino families enjoy an annual income of *P*10,000 or more; 6.9 per cent earn from *P*5,000 to *P*10,000; 21.1 per cent earn from *P*2,500 to *P*5,000; and 69.4 per cent earn *P*2,500 or less. The article also quoted him as having stated to Congress that considering the high and rising prices, it was evident that 90.5 per cent of all Filipino families were literally starving and living in squalor and massive poverty.

According to figures released by the NEC, our gross national product, which in 1965 amounted to *P*20.28 billion, is increasing at the rate of 4 to 6 per cent per annum. Moreover, it would appear that most of the nation's wealth is concentrated in metropolitan Manila.

Where are we investing our resources?

In January 1968, Mr. Bernard Wagner, Chief of the Housing and Urban Development Division, USAID, Manila, stated in his report that based on the statistics issued by the NEC for the 1960–1965 period the ratio of investment in the housing industry ranged from 1 to 1.7 per cent of the gross national product; only 2.6 per cent of building costs were defrayed by government funds and the balance was paid by the private sector. In the United States and Europe the funds allocated for housing construction usually account for 4 to 5 per cent of the gross national product.

In the 1968–1969 fiscal year, a professor stated in a class in environmental planning at the University of the Philippines that *P*1.2 billion of the nation's resources was allocated to the production of "miracle" rice varieties. Moreover, on 17 September 1969, the *Manila Times* stated that *P*30 million had been released for irrigation purposes. Funds are therefore available for development, but they are channelled to the agricultural sector without making equivalent investments in the industrial sector of the economy, which means that the urban sector is neglected.

Census data and population projections

According to the census, aside from metropolitan Manila, there are twenty-one cities whose population is 100,000 or over. These towns and/or cities are the potential growth points of twenty-one regions. These cities are centres of culture, education, government, commerce, industry and transportation facilities, and they are called city regions. They have been growing at a faster rate than the other areas of the country, and if no plans are made for them, they will experience a growth similar to Manila's, which has become a city of squatters, inadequate housing, deteriorating peace and order and badly managed development resources.

The movement from rural to urban areas is taking place in the Philippines as well as in more developed nations, as indicated in table 1.

Table 1. Percentages of urban and rural population in 1960[a]

Area	*Urban population*	*Rural population*
United States	70	30
Japan	80	20
Australia	80	20
Denmark	70	30
Russia	48	52
Philippines	30	70
India	18	82
Africa	13	87

[a] Taken from lecture notes of W. G. Faithful, United Nations project manager on regional planning, Institute of Planning, U.P.

Table 2 is a list of twenty-one cities and/or towns with their corresponding population growth, as per data provided by the Bureau of the Census and Statistics.

Planning attempts

In recent years an attempt was made to implement a series of economic improvement programmes in our country. Much has been accomplished, but much still remains to be done in the areas of infrastructure and facilities. These programmes required a high degree of planning. Since the Government adopted formal planning procedures, the pace of development has quickened and specific goals are more easily attained. The aim of national planning is to make efficient use of resources, meet urgent development needs and reduce duplication of effort.

Equally important in national planning, but unfortunately often overlooked, is the need for adequate knowledge of the physical and human resources. The collection and evaluation of comprehensive information on the people concerned and on the land and natural resources available to them are essential for the efficient use of development capital.

The Philippines are fortunate to have qualified individuals among their population who can participate in the execution of development projects. However, these human resources have not been taken into account in the over-all evaluation and allocation of the country's physical resources. Many special purpose surveys have been undertaken, but they are too fragmentary. In order to set up a sound economic programme, our planners must be provided with all the basic data on the nature, location and possibilities for exploitation of our resources, which calls for a well-integrated survey.

ANALYSIS OF THE PROBLEM

The Board of Technical Surveys and Maps was created in 1960 to co-ordinate and supervise the surveying and mapping activities of the country. One of these activities

[1] The original text of this paper, prepared by Cmdr. M. S. Tabin, Vice-Chairman and Executive Director, Board of Technical Surveys and Maps, Office of the President, Manila, and submitted under items 9 (*c*) and 11, appeared as document E/CONF.57/L.98.

Table 2. Twenty-one centres of population including metropolitan Manila

	Centre	*1960*	*1970*	*Area (ha)*	*Density (ha)*	*Percentage growth*
1	Butuan City	82,485	140,288	54,378[a]	2.58	7.00
2	Batangas, Batangas	82,627	109,479	28,296[a]	3.86	3.24
3	Lipa City	69,036	101,335	23,444[a]	4.45	4.65
4	Iriga, Camarines Sur	75,439	100,256	11,963[a]	8.42	3.30
5	Cebu City	251,146	346,926	28,091[a]	12.35	3.80
6	Gen. Santos City	84,988	118,300	115,300[b]	1.03	4.36
7	Davao City	225,712	347,595	221,125[a, b]	1.57	5.40
8	Iloilo City	151,266	209,410	5,600[a, b]	37.20	3.86
9	San Pablo City	70,680	105,867	21,404[a, b]	4.91	5.00
10	Cagayan de Oro City	68,274	132,858	41,278[a, b]	3.23	9.40
11	Cadiz, Negros Occidental	88,542	124,958	51,650[a]	2.42	4.00
12	San Carlos, Negros Occ.	124,756	100,680	45,130[a]	2.23	(−1.93)
13	Bacolod City	119,315	187,685	15,606[a, b]	12.00	5.71
14	Guihulñgan, Negros Oriental	92,993	126,200	33,767	3.74	3.97
15	Cabanatuan City	69,580	100,892	19,278[b]	5.22	4.50
16	Angeles City	75,900	136,534	6,027[b]	22.70	8.00
17	San Carlos City	73,900	84,243	16,903[b]	4.98	1.40
18	Calbayog City	77,832	94,386	90,304[a]	1.03	2.12
19	Tarlac, Tarlac	98,285	134,800	93,602[b]	1.44	4.13
20	Zamboaga City	131,489	203,323	141,469[a]	1.42	5.48
21	Basilan City	155,712	144,951	132,723[a]	1.09	(−0.69)
	Sub-total	2,269,957	3,151,067	1,197,338		4.13 average
	Metropolitan Manila					
	Manila	1,138,611	1,310,502	3,828[a, b]	343.00	1.52
	Quezon City	397,990	678,500	16,615[a, b]	40.70	7.05
	Pasay City	132,673	204,662	1,397[a, b]	146.00	5.40
	Caloocan City	145,523	274,630	5,581[a, b]	49.00	8.90
	Sub-total	1,814,797	2,468,394	27,421		5.71 average
						Percentage of the total Philippine
	(Sub) total of 21 cities	2,269,957	3,151,067	1,197,338		4
	Total of metropolitan Manila	1,814,797	2,468,394	27,421		0.09 (Manila)
	TOTAL	4,084,754	5,619,641	1,224,759		4.08
	Total for the country as a whole	27,410,000	37,008,419	30,000,000		
	Urban population as a percentage of the Philippine total				15.18	

[a] Geodetic control points are available.

[b] Fully covered by 1966 serial photographs. For additional information, all of the Philippines are covered by 1947–1953 aerial photographs.

While this table was being compiled, there was a request to include within Albay, Baguio City, Surigao, Surigao del Norte, Locsin and Legaspi City which are only 4 km apart. The statistics for these are as follows:

22	Baguio City	50,436	83,952	4,893[a, b]	17.00	6.65
23	Surigao	37,439	51,100	24,534[a]	1.53	4.05
24	Locsin–Legaspi City	102,814	142,200	27,229[a]	5.28	3.85

Since the average population growth is about 3.4 per cent, it may be concluded that if the population growth of the twenty-one cities is about 4.13 per cent, 0.73 per cent or 23,002 persons are immigrating to these cities annually, and 57,020 persons are also immigrating to metropolitan Manila annually.

Butuan City, Gen. Santos City, Davao City, Cagayan de Oro City, Zamboanga City and Basilan City belong to the Mindanao Development Authority; Angeles City, San Carlos City, Cabanatuan City and Tarlac, Tarlac to the Central Luzon–Cagayan Valley Development Authority; Iriga, Camarines Sur to the Bicol Development Company; Iloilo City to the Panay Development Authority; and Calbayog City to the Northern Samar Development Authority. The cities within metropolitan Manila, except Manila itself and San Pablo City, belong to the Laguna Lake Development Authority.

Batangas, Lipa City, Cebu City, Bacolod City and Guilhulñgan, Negros Oriental and Cadiz and San Carlos of Negros Occidental do not belong to any development authority.

The following development authorities have no towns or cities with a population of 100,000 which would serve as growth points: Hundred Islands Conservation and Development Authority, San Juanico Strait Tourist Development Authority, Mountain Province Development Authority, Mindoro Development Board, Catanduanes Development Authority, Mariveles Free Port Authority and Sulu Development Authority.

pertains to topical and economic maps and data for economic development (see annex I). The importance of economic maps to national planning cannot be overlooked. The compilation of data and preparation of these maps would be facilitated if a selected resources inventory and mapping were undertaken. Identification, location and quantification of the natural and physical resources are needed, as well as an evaluation of the social, psychological, cultural and political characteristics of the people in order to determine their ability and willingness to support this development plan.

It is therefore necessary to prepare as soon as possible an inventory and a map of the potential resources of the country. The integrated survey approach for resources inventory as practised by the Commonwealth Scientific and Industrial Research Organization of Australia (CSIRO) and the UNESCO–ITC Centre for Integrated Surveys at Delft, the Netherlands, would be most appropriate. This project proposal calls for a national resource inventory by the Board of Technical Surveys and Maps (in co-operation with its related agencies[2]) of the main city regions listed in table 2. At the present time, most of the areas planned for development are under a regional development authority.[3] Congress has so far created thirteen regional development authorities, but none of them is progressing at a satisfactory rate of development. There is a need to make development plans more effective.

For a change of strategy

Before undertaking a nation-wide resources inventory, we propose to establish a pilot project in one of the city regions, to be selected on a priority request by the city officials concerned. A research operation will be undertaken to test the applicability of the integrated survey approach (annex II). If this method and these techniques prove effective, they will be applied to the other city regions according to order of priority (table 2).

Statement of the problem

The problem of growth in big cities is well known. It is associated with the growth of slums and squatter areas, traffic congestion, inadequacy of waterworks and sewerage services, inadequacy of schools to accommodate a rapidly increasing school population, inadequate housing facilities, increasing rate of crime and unemployment (the latter is estimated to be about 10 per cent of the manpower), inadequate health facilities and growing criticism by students of living conditions and the Government. In general, there is a pressing demand for more and better government services to eliminate or at least minimize graft and corruption.

The basic root or cause of all these problems is economic. Most of our development programmes were based on a lack of adequate information on the resources needed for growth. Data were gathered in a haphazard and uncoordinated way and time has not always been on our side. There is a need to identify regional centres of growth which have the greatest potential for development and to correlate the development of city regions with that of our rural areas, as well as to allocate wisely our scarce resources.

Purpose of the project

The purpose of the project is to gather reliable data on natural and human resources of city regions in order to implement development plans. Basic data will be collected on the economic situation, social structure, demography, physical characteristics (such as soil, vegetation, geology, land form and hydrology) and their future development.

In particular, the project will serve to:

(*a*) Establish a pilot scheme to determine the suitability of the integrated survey methods and techniques to the mapping and assessment of the resources for potential development;

(*b*) Execute the necessary surveys with aerial photographs to produce a selection of maps[4] for each city region. This map collection should portray the exact present status of environmental resources and conditions so as to establish a rational plan for the future development of a region;

(*c*) Prepare reports with recommendations to serve as investment guides and ultimately aid in the development planning of a city or region;

(*d*) Make a framework development plan;

(*e*) Establish co-ordination with the regional planning body.

Suggested procedures

This project is expected to last five years. It will cover the following phases:

(*a*) Preparatory phase: organization of the project, collection and collation of existing data, preparation of base maps,[4] photo interpretation and other administrative work in preparation for the field surveys;

(*b*) Field work phase: this includes the actual field

[2] The agencies co-ordinated by the BTSM are as follows: (1) Bureau of Coast & Geodetic Survey, (2) Philippine Air Force, (4) Research and Development Center, GHQ, APP, (5) Bureau of Public Works, (6) Bureau of Public Highways, (7) Civil Aeronautics Administration, (8) National Waterworks & Sewerage Authority, (9) National Irrigation Administration, (10) Bureau of Agricultural Economics, (11) Bureau of Lands, (12) Bureau of Forestry, (13) Bureau of Mines, (14) Philippine Fisheries Commission, (15) Bureau of Soils, (16) Parks and Wildlife Office, (17) Reforestation Administration, (18) Bureau of the Census and Statistics, (19) Weather Bureau, (20) Land Registration Commission, (21) National Planning Commission, (22) National Economic Council, (23) Electrification Administration, (24) Land Authority, (25) National Institute of Science and Technology, (26) Training Centre for Applied Geodesy and Photogrammetry, (27) Forest Products Research Institute, (28) Phillippine National Railways, (29) National Power Corporation, (30) Board of Travel and Tourist Industry and (31) People's Homesite and Housing Corporation.

[3] At present we have thirteen regional development authorities created by law: (1) Mindanao Development Authority—RA 3034, (2) Central Luzon–Cagayan Valley Authority RA 3054, (3) Hundred Islands Conservation and Development Authority—RA 3655, (4) Panay Development Authority—RA 3856, (5) San Juanico Strait Tourist Development Authority—RA 3961, (6) Mountain Province Development Authority—RA 4071, (7) Northern Samar Development Authority—RA 4132, (8) Mindoro Development Board—RA 4188, (9) Catanduanes Development Authority—RA4412, (10) Bicol Development Company—RA 4690, (11) Laguna Lake Development Authority—4850, (12) Free Port Authority—Mariveles and (13) Sulu Development Authority.

[4] The suggested size of folio is 17×22 inches. The scales are 1:10,000 for built-up areas; 1 :25,000 for metropolitan areas and 1:50,000 or 1:250,000 for regional areas. However, if the area covered is larger than the folio size, a larger map will have to be drawn up to include both built-up and metropolitan areas. Preliminary base maps will have to be prepared from the existing city maps ranging from 1:10,000 to 1:25,000 and based on the 1:50,000 national topographic series.

surveys, checking and gathering of additional information, evaluation of data and other field activities;

(*c*) Report writing phase: preparation of technical and general reports and compilation of accompanying maps and folios;

(*d*) Final phase: publication of reports and map collections and preparation of a framework development plan.

The Board of Technical Surveys and Maps will be the co-ordinator of the project. Aerial photographs will be used extensively. In the preparatory phase, the photos will be interpreted, and each specialist will draw up a preliminary map of the spots where all the field operations can be co-ordinated. Teams of experts will then carry out field surveys. The observation of the group will be integrated as efficiently as possible from the start. The other data and samples to be collected in the field will be analysed and identified in the laboratory. Simultaneously, the field notes and other information derived from the rechecking of photos will be transferred onto maps. In the final stage, each specialist will prepare a technical report. This work will be co-ordinated by the project manager, who will make sure that each team leader writes the final general report indicating the team's evaluation of the resources of the region and recommendations for their use.

Composition of the teams of experts

The teams of experts will consist of technicians of various backgrounds who will have the following responsibilities:

1. Civil engineer	Transportation and infrastructures, including water supply, irrigation and sewerage systems
2. Cartographic engineer/ Geodetic engineer	Surveying and mapping, preparation of base maps, drainage and engineering surveys
3. Economist	Commerce, trade and finance, labour and government regulations
4. Sociologist or psychologist	Demography, social welfare, health, education and social attitudes towards change
5. Geologist or geo-morphologist	Geology, geomorphology and mineral resources
6. Soil technologist	Soil surveys and classification
7. Urban and regional planner	Preparation of framework development plans
8. Agriculturist/Agricultural engineer	Agricultural surveys and vegetation
9. Architect	Buildings and structures
10. Lawyer with training in planning	Administrative and zoning regulations
11. Engineer	Electrification and industry

The project will be entrusted to a project manager, who will form one research party for the first six months, then four teams in the first year, an additional five parties in the second year, and retain only five parties in the third year. The necessary staff will be recruited from the agencies co-ordinated by the Board, from other agencies willing to participate in the work and from local officials of the cities concerned. Consultants will be engaged from the Institute of Planning, University of the Philippines, the National Economic Council, the Agency for International Development and the United Nations Development Programme if necessary. A resources inventory and five reports relating to city regions are expected to be completed in the first year; ten reports in the second year; and six reports in the third year. The teams will be phased out in the fourth year.

Sources of staff for the project

Qualifications of personnel for the project. The project director, assistant project director and all group leaders must be technicians with a Master's degree in environmental planning, or its equivalent. The team leader for the research phase must be the assistant project director. For the other groups, he must be a technician with appropriate training and experience obtained either locally or abroad.

Personnel requirements for one party:

Position	*Agency*
1. One civil engineer	NWSA, BPW, BPH, NIA, development authority concerned
2. Cartographic engineer/ Geodetic engineer	BTSM, BC and GS, BL
3. One economist	PES, NEC, LA, BCS, development authority concerned
4. One sociologist and psychologist	DSW, NEC, PHHC, BCS
5. One geologist geo-morphologist	BM, Volcanology Commission
6. One soil technologist	BS, LA, development authority concerned
7. One urban and regional planner	NPIC, NEC, development authority concerned
8. One agriculturist/ Agricultural engineer	Any agency under DANR and development authority concerned
9. One architect	BPW, PHHC
10. One lawyer with training in planning	LRC, BWP, NPC, LA, development authority concerned
11. One industrial engineer	NPC, NIA, BPW, development authority concerned

Completion of work

This project will be phased out in the fourth and fifth years. It may take additional time and effort to get the rest of the data desired. In all cases it would be necessary to review data gathered and the project manager may decide to get additional urban and regional planners to help in making the final development plan.

Financing

The operations are expected to be financed by the Special Science Fund of the National Science Development Board, by the local governments concerned and by other sources. Salaries and wages of the staff will come from counterpart contributions of the relevant government agencies.

Development plans

The proposed team can only be expected to prepare a framework development plan. It is expected therefore that in the post-final phase of the project, the city concerned will want to strengthen the team with urban planning consultants and experts who will work with their own planning board which should be established and organized during the duration of the project.

BIBLIOGRAPHY

Chapin, Stuart, F. *Urban Land Use Planning*, University of Illinois Press, Urbana, 1965.

Roxas, Sixto K. "Urban Land Use Problems", *Man and His Environment*, Institute of Planning, U.P., 1969.

——— *Crati River Basin, An Integrated Reconnaissance Survey* (4 *vols*), ITC–UNESCO Centre for Integrated Surveys, Delft, The Netherlands, 1968.

——— *Proceedings of the First International Seminar on Integrated Surveys*, ITC–UNESCO Centre for Integrated Surveys, Delft, The Netherlands, April 1966.

——— *Urban Analysis Quezaltinango*, AID Guatemala, Guatemala, C.A., 1964.

——— *Housing and Urban Development in the Philippines*, USAID, Manila, 1968.

——— *Proceedings of the Fifth United Nations Regional Cartographic Conference for Asia and the Far East*, Canberra, Australia, 1967, United Nations, New York (Sales No. E.68.I.14).

ANNEX I

Resources inventory for development planning of city regions in the Philippines

Legal basis: Republic Act No. 2912 as amended by RA 5710—An Act to create a Board of Technical Surveys and Maps, defining its functions and appropriating funds therefor.

"Sec. 2. Policy . . .

"(3) That economic maps, large scale topographical maps which conform with modern standards, special geological maps needed for economic development, and aeronautical charts be produced in this country and made available for its economic development;

. . .

"Section 3. Board of Technical Surveys and Maps; Powers, Functions and Duties . . .

"(7) To encourage, assist, plan, co-ordinate and direct within its powers and facilities the early publication for public use economic maps, large scale topographical and special geological maps needed for economic development, aeronautical charts, technical and scientific data;

"(8) To promote and encourage research and development among the designated agencies not only for the improvement of production methods but also for utilization of local instruments, machines and materials;

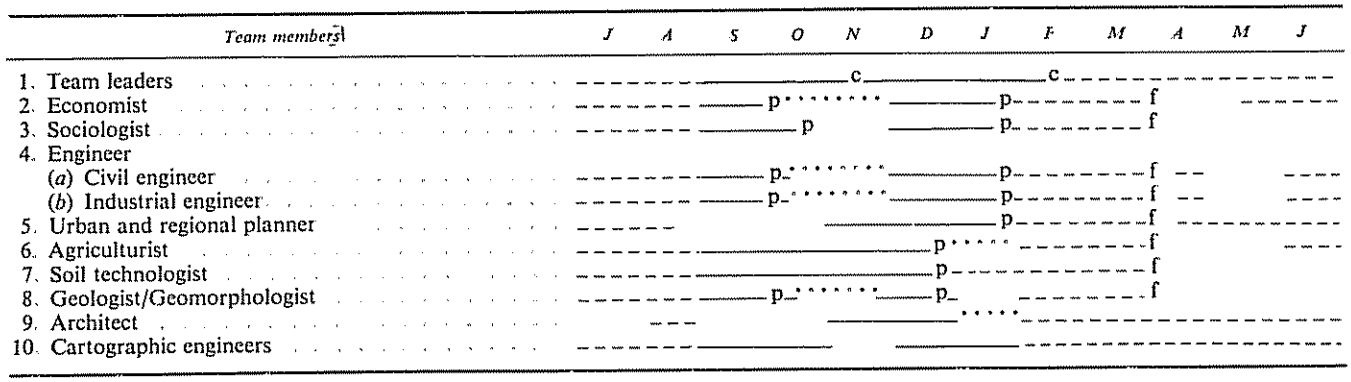
"(9) To initiate and formulate measures designed to promote the early attainment of the objectives of this Act;

"(10) To obtain the necessary data for the compilation, reproduction and publication of any of the maps and charts specified in this Act, unless such function is vested under existing laws to any other government agency."

ANNEX II

(Part 1)

Time schedule of research operation
Integrated survey in the mapping and assessment of city region for potential development



For notes to this table see Part II on p. 294.

(Part 2)

Phase	*J*	*A*	*S*	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*M*	*J*
I. Preparatory	———											
(*a*) Collection and collation of existing data	- - - -											
(*b*) Preparation of base maps	- - - -											
(*c*) Photo-interpretation	- - - - - -											
(*d*) Preparation of a work plan												
II. Field work			———	———	———	———	———					
(*a*) Field survey			- - - - - - - - - - - - - - -									
(*b*) Checking of data				- - - - - - - - - - - - - - -								
(*c*) Gathering of additional information						- - - - - - -						
(*d*) Evaluation of data							- - - -					
(*e*) Rechecking of data							- - - -					
III. Report writing								———	———			
(*a*) Preparation of technical report								- - - -				
(*b*) Preparation of general report									- - - - -			
(*c*) Preparation of maps								- - - - -	- - - - -			
IV. Final phase									———	———	———	———
(*a*) Publication of reports and map folios									- - - - -	- - - - -	- - - - -	- - - - -
(*b*) Framework development plans									- - - - -	- - - - -	- - - - -	- - - - -

Man months in the field 39½
Man months in home office 61
½ time home office 7½
Field: ———
Office: - - - - - - - - - - - - - - -

Part time: . . . . . .
p: preliminary internal report.
f: final report.
c: co-ordination.

ANNEX III

Proposed resources inventory for development planning of city regions in the Philippines

(Proposed budget)

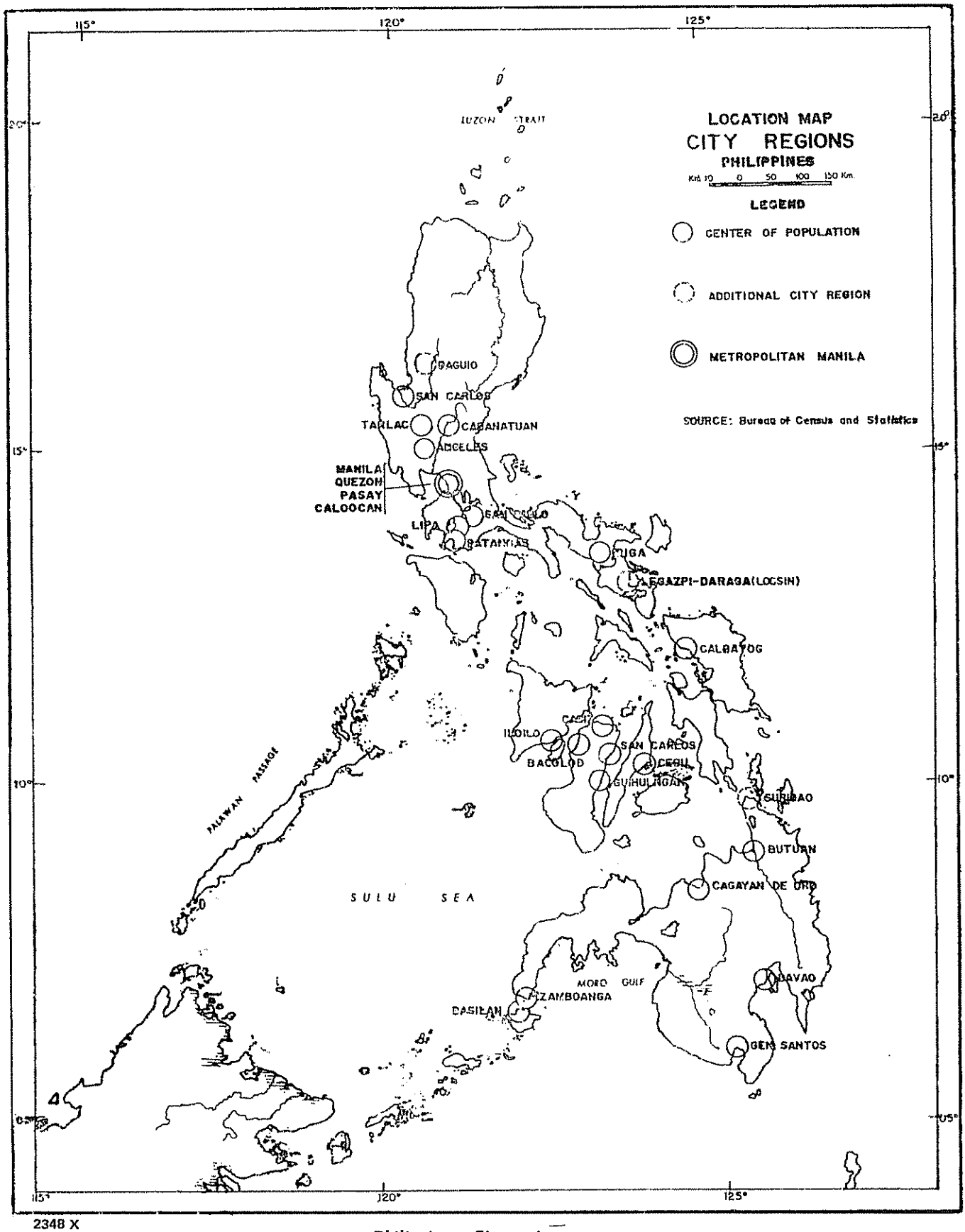
Object classification	*1st year*	*2nd year*	*3rd year*	*4th year*	*Total*
			(In pesos)		
Personal services	Salary of personnel participating to be paid by their respective offices				
Travelling expenses	150,000	300,000	150,000	5,000	605,000
Supplies and materials	35,000	45,000	20,000	10,000	110,000
Sundry expenses	20,000	25,000	20,000	10,000	75,000
Equipment outlay	45,000	—	—	—	45,000
TOTAL	250,000	370,000	190,000	25,000	835,000

List of equipment

	(In pesos)
1 Wild B-9	40,800.00
1 KG-30 (contact printer)	4,200.00
TOTAL	45,000.00

Other equipment needed and available at these agencies

Kind	*Agency*
RC 9 (Wide-angle camera)	Philippine Air Force
SEG-V rectifier	Bureau of Lands and UP Training Centre for Applied Geodesy and Photogrammetry
One plane, Aerocommander or equivalent	Philippine Air Force



2348 X

Philippines: City regions map

AGENDA ITEM 10

Earth-orientated Satellites for Geodesy, Cartography and Earth Resources Studies and Inventory

PROGRESS REPORT ON THE NATIONAL GEODETIC SATELLITE PROGRAMME (WORLD-WIDE GEOMETRIC SATELLITE TRIANGULATION PROGRAMME)

Paper presented by the United States of America[1]

The National Geodetic Satellite Programme (NGSP), better known as the World-wide Geometric Satellite Triangulation Programme, has as its over-all objective the establishment of a precise spatial network of forty-five control stations on the Earth's surface whose positions are defined relative to a Cartesian co-ordinate system in inertial space, having one axis parallel to a specific pole, which will meet the accuracy requirements of ±10 m. This of course depends on the accuracy of the measured scale lines, and they should be of an accuracy of 1 to 500,000, or preferably 1 to 1,000,000.

This programme started with the launch of PAGEOS on 23 June 1966. However, planning began in the late 1950s. The first camera system was purchased by the Coast and Geodetic Survey in 1960. By 1966 we were certain such an operation could be successful, and the camera system had been field-tested in North American field operations from Antigua Island, which is east-south-east of Puerto Rico, to Nord, Greenland, Denmark, in temperatures ranging from 130 °F to −55 °F.

The programme represents the co-operative efforts of NASA, which designed and put the satellite into orbit; the Department of Defense, Topographic Command; and the ESSA/Coast and Geodetic Survey, which is responsible for the technical direction of the field observations, including maintenance of the camera systems, correct time and the furnishing of predictions. The C&GS also has the responsibility for plate-measuring, processing and geodetic computations.

This precise network would provide:

(*a*) A world-wide reference net to which all geodetic, topographic and navigational data can be related. Such a reference system would achieve economy and permanence in the collection and recording of data essential to the development of the Earth sciences;

(*b*) Replacement of the classic, time-consuming, long arc triangulation methods of determining the size and shape of the Earth by a more economical and theoretically superior approach. A knowledge of accurate Earth parameters is necessary for the solution of modern geodetic problems and for meeting the requirements of modern astronomy and space research;

(*c*) Establishment of the necessary geometric fidelity for a world-wide system of satellite-tracking stations for accurate determination of satellite orbits, which will provide data ideally suited for analysing gravimetric and related geophysical parameters. These parameters, in turn, are the necessary prerequisites for determining the position of the centre of mass and the over-all shape of the gravitational field of the Earth.

Because of the unpredictable motion of a satellite, precise direction measurement can be carried out, at present, only by photographing the satellite against the star background and using the photogrammetric method as a tool of interpolating its position against that background.

The reference into which the direction to a satellite can be interpolated is the right ascension–declination system. This reference system is attractive from the geodetic standpoint because one of its axes is by definition parallel to the rotation axis of the Earth. From a quantitative standpoint, a practically unlimited number of fixed stars are available as reference points. Since the stars are for all practical purposes at infinity, it follows that their direction co-ordinates are insensitive to translations and, therefore, cannot be used for any scale determination.

To scale properly the satellite triangulation, the Coast and Geodetic Survey has determined that at least four base lines spaced around the world are essential to obtain the accuracy of 1 to 500,000, as is needed to meet the accuracy requirements of the NGSP.

We are indebted to Norway, Sweden, Denmark and the Federal Republic of Germany for measuring the scale line from 006 Tromsø, Norway, to 065 Hohenpeissenberg, Federal Republic of Germany. This line is completed. Austria and Italy are now extending this line to 016 Catania, Italy, and it will probably be completed within the year. The accuracy of the completed line approaches 1 to 1,000,000.

Australia has measured one line, and is in the process of measuring a second. The one from 032 Perth to 060 Culgoora is completed. The second line, from 060 Culgoora to 023 Thursday Island, will be completed this year.

The section 064 Fort Lamy, Chad, to 063 Dakar, Senegal, of the survey of the 12th parallel, which extends from the Chad–Sudan, border to Dakar, Senegal, will also be used for scale. The survey was made through the efforts of the United States Government. One portion of this section was accomplished through contractual co-operation with

[1] The original text of this paper, prepared by Capt. L. W. Swanson, Coast and Geodetic Survey, Environmental Science Services Administration, Rockville, Md., appeared as document E/CONF.57/L.17.

France's IGN (*Institut Géographique National*); and that portion of the section within Nigeria, by the Federal Survey Department of Nigeria with technical assistance from the United States. A fifth line will be from 002 Beltsville, Maryland, to 003 Moses Lake, Washington. Its accuracy is 1 to 1,000,000.

There would be local benefit to the network to have a scale line measured in South America. It has been suggested that the line from 019 Villa Dolores, Argentina, to 043 Cerro Sombrero, Chile, should be measured; and possibly this will be done.

A maximum of seventeen camera systems were in operation during periods of the programme. Of these, four were operated by the United States Army TOPOCOM, and eight, and sometimes nine, by the Coast Survey. There was at least one C&GS employee attached to each party except TOPOCOM's. The C&GS prepared the operational manual and trained all personnel involved.

Many nations around the world have furnished cooperation and assistance. Special mention should be given to these countries: The Federal Republic of Germany furnished two camera systems and two camera teams; the United Kingdom furnished one camera team throughout the programme; South Africa furnished a camera team for camera operation in South Africa; Australia furnished personnel for two camera teams operating in Australia as well as full support to, from and at their Antarctic stations, Mawson and Wilkes; and the following nations allowed the establishment of from one to seven camera stations within the nation or its territories:

Station No.	*Location*
001	Thule, Greenland, Denmark
002	Beltsville, Maryland, USA
003	Moses Lake, Washington
004	Sheyma, Alaska
011	Maui, Hawaii
012	Wake Island
022	Pago Pago, American Samoa
059	Christmas Island
006	Tromsø, Norway
007	Azores (Lajes AFB), Portugal
008	Paramaribo, Surinam
009	Quito, Ecuador
013	Kanoya, Japan
015	Mashad, Iran
016	Catania, Sicily, Italy
019	Villa Dolores, Argentina
020	Easter Island, Chile
043	Cerro Sombrero
023	Thursday Island, Australia
060	Culgoora
032	Perth
040	Cocos (or Keeling) Island
044	Heard Island
031	Invercargill, New Zealand
038	Isla Socorro, Revilla Gigedo Islands, Mexico
039	Pitcairn Island, United Kingdom
055	Ascension Island
061	South Georgia Island
069	Tristan da Cunha Island
073	Chagos Islands
075	Mahe Island, Seychelles
078	Vila, New Hebrides
059	Christmas Island
042	Addis Ababa, Ethiopia
063	Dakar, Senegal
064	Fort Lamy, Chad
065	Hohenpeissenberg, Federal Republic of Germany
067	Natal, Brazil
068	Johannesburg, South Africa
072	Chieng Mai, Thailand
045	Mauritius, Mascarene Islands
047	Zamboanga, Philippines
050	Palmer Station, Antarctica, USA
051	Mawson Station, Antarctica, Australia
052	Wilkes Station, Antarctica, Australia
053	McMurdo Station, Antarctica, USA

All but two nations permitted two-way radio communication between adjacent stations and Beltsville, Maryland; and this little item is one reason the programme has progressed so smoothly.

Field observations will be completed by 30 June 1970 at all stations with the exception of those at Kanoya, Japan, Chieng Mai, Thailand and Zamboanga, Philippines. The camera teams and camera systems will be returned to their home bases by that date. The three remaining systems will complete observations by the end of July 1970. All field operations on the World-wide Geometric Satellite Triangulation Network will end at this time.

The measuring and processing of photographic plates will continue on a planned schedule which will allow for the completion of this phase of data processing early in 1972. This will give two or three months' leeway for the final computations and analysis. The final computations are to be completed by 30 June 1972.

As of 1 June 1970, there is no plan for publishing or distributing data until the final computations are completed and analysed. We believe the plan is capable of being implemented and that the programme will be completed satisfactorily.

The experience gained from the large amount of work involved in preliminary reductions has enabled us to develop a new generation of computer programmes with a level of sophistication consistent with an ultimate potential accuracy of one part in two million. In addition, this data reduction system yields stepwise statistical information related to all error contributions, and sheds light on the validity of the *a priori* assumed precision of the individual error sources. Based on the limited reductions made thus far with the new programmes, there is little doubt that the final result for all stations in the world net for which no deficiency in observational data exists will have an accuracy of at least one part in 1.2 million. That is, the positional RMS error is somewhat better than ± 6 m, or specifically ± 5.0 m for the horizontal components and at least ± 8.5 m in height.

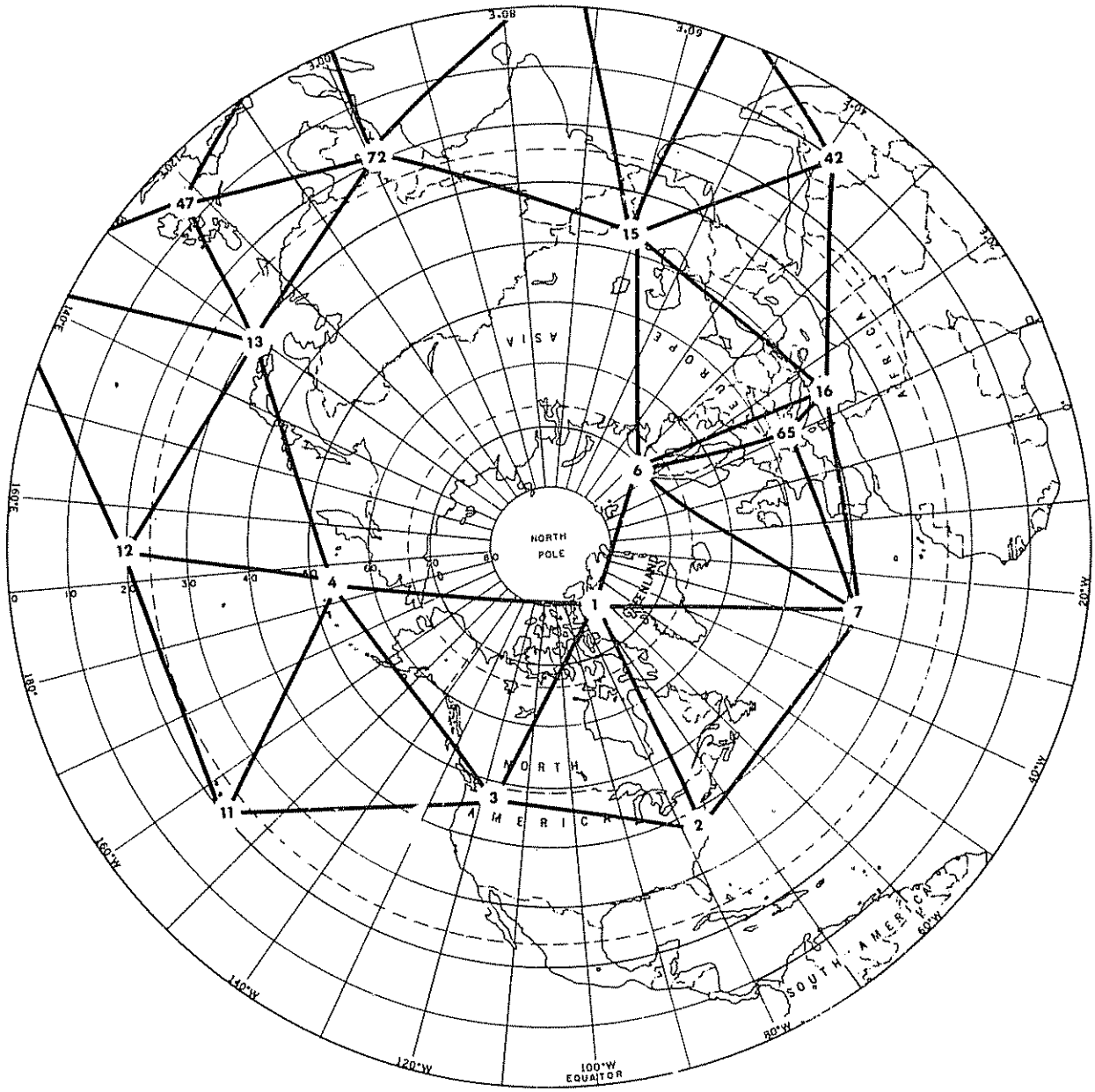


Figure I

2349 X

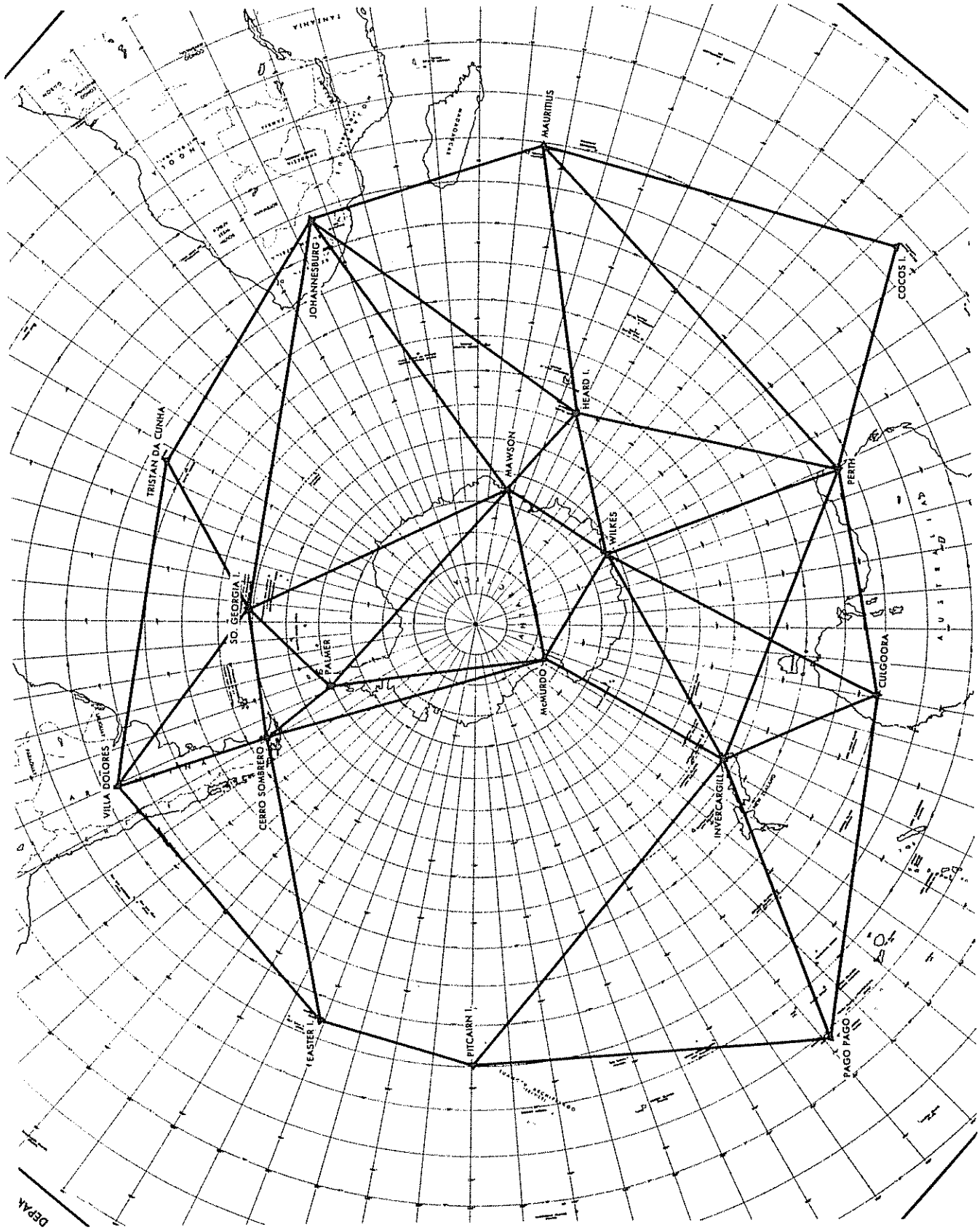

MAURITIUS
JOHANNESBURG
COCOS I.
HEARD I.
TRISTAN DA CUNHA
HAWSON
PERTH
WILKES
SO. GEORGIA I.
PALMER
CULGOORA
McMURDO
VILLA DOLORES
CERRO SOMBRERO
INVERCARGILL
EASTER I.
PITCAIRN I.
PAGO PAGO
AUSTRALIA
DEPAA
2350 X

Figure II

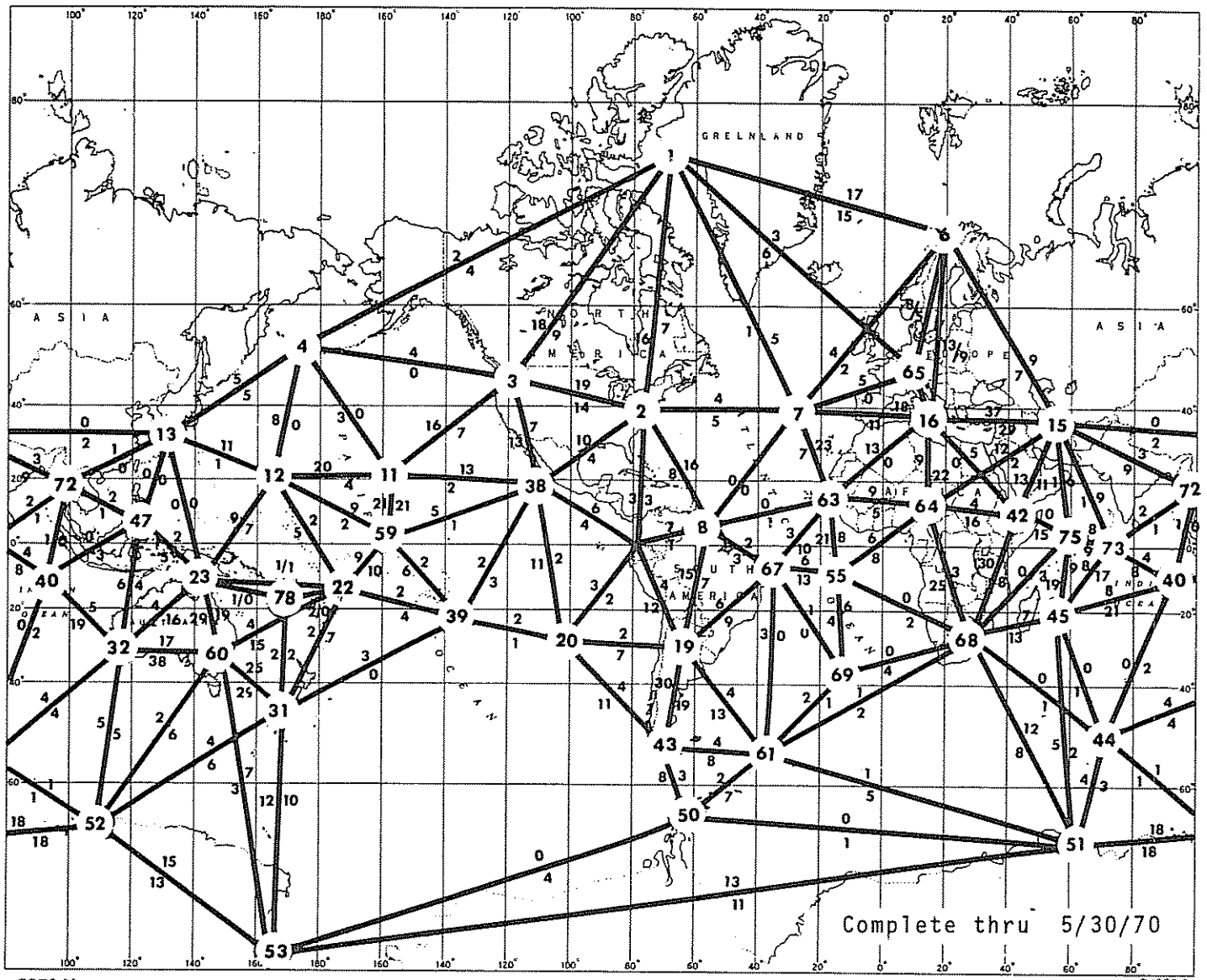


Figure III. Geometric satellite network (number of events available for measurement indicated on each side of observed lines)

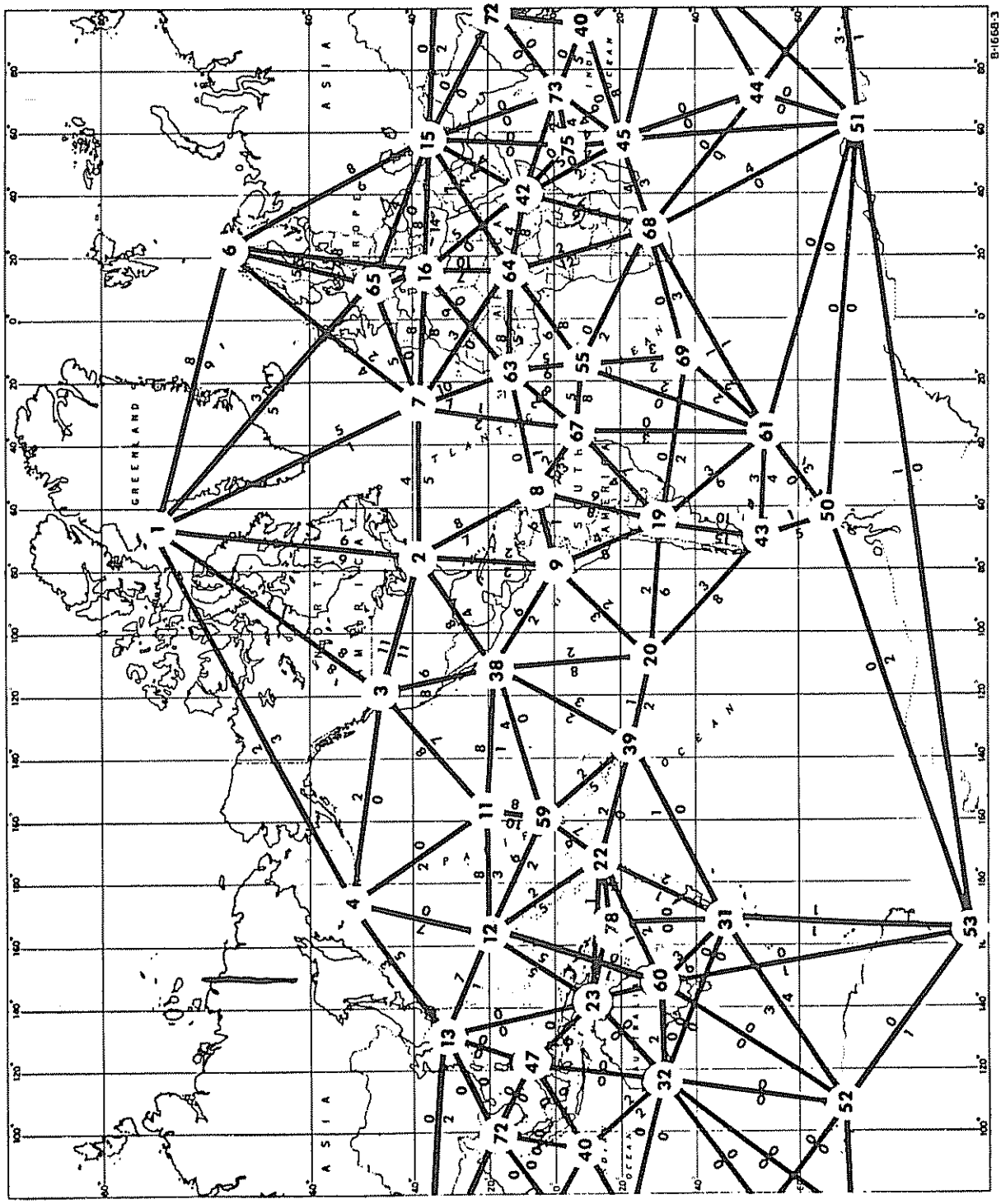


Figure IV. Base map of the world (number of events measured indicated on each side of the line as of 30 May 1970)

USES OF SPACE OBSERVATIONS OF THE EARTH: THE EROS PROGRAMME OF THE DEPARTMENT OF THE INTERIOR

Paper presented by the United States of America[1]

EROS (Earth Resources Observation Satellite) forms part of the programme of the Department of the Interior to acquire, process, utilize and disseminate remote-sensor data collected from aircraft and space craft. The programme is a collaborative one with the Department of Agriculture, NASA and other government agencies, and is supported by the ERTS (Earth Resources Technology Satellite) programme of NASA. Under it NASA is developing experimental satellites to provide data of a type requested by the Department of the Interior. The desired performance characteristics for the first satellite and an abbreviated rationale for the selection of these characteristics are given in table 1.

EROS and NASA's attendant ERTS programmes are a new concept or system of data-gathering and use. Under this concept, timely but gross inventories of the environment are made, and in part substituted for conventional detailed and less timely inventories. These gross inventories will be used to identify areas of change or problems of import and, thence, to guide the acquisition of more precise information by aircraft or ground methods. In effect, the broad overview that can be obtained from space will permit inauguration of an inductive (general to specific) system of environmental and resources survey.

[1] The original text of this paper, prepared by W. A. Fischer, United States Geological Survey, Washington, D.C., appeared as document E/CONF.57/L.20.

ORGANIZATION

The introduction of a unique system of data-gathering and use requires the introduction of innovative organizational methods to assure optimum utilization of the data on a departmental basis. All major bureaus and offices of the Department participate in the programme through five working groups, namely, (1) marine resources and oceanography; (2) human and cultural resources; (3) water resources; (4) mineral and land resources; and (5) mapping requirements.

In practice, the resources working groups identify the research required to accomplish programme objectives and goals; they identify specific elements of information that can be routinely extracted from data to be collected from the first ERTS satellites and those that are sufficiently important to warrant development of specialized processing methods. Once these informational elements are identified, the mapping requirements working group is asked to develop the technology to extract this information from the satellite data in the most cost-effective way. The elements of information thus far identified include (*a*) the distribution of surface water; (*b*) the distribution of snow; (*c*) the distribution of vegetation; (*d*) the distribution of cultural features; and (*e*) the detection of changes in a scene, with time. In addition, it is hoped that it will be possible to distinguish between turbid and non-turbid water and between natural and agricultural vegetation.

Table 1. Desired performance specifications for the initial ERTS

Specification	*Reason for specification and expected benefits*
100 to 200 ft ground resolution	Most features on small-scale maps (1:250,000 or smaller) are 100 to 200 ft in size or larger. Lesser resolution will reduce usefulness of the data; greater resolution will provide too much data for small-scale evaluations and reduce area coverage.
Images 100 by 100 miles (10,000 square miles)	This is the maximum size that can be imaged orthographically and will provide a reasonable size for regional or continental image mosaics.
Three spectral bands imaging simultaneously	
(1) 0.475 to 0.575 μm (blue-green)	For penetration of ocean, bay and lake water to permit mapping of underwater features.
(2) 0.690 to 0.830 μm (IR)	For maximum obscuration by water to permit precise shore-line mapping and estimates of relative moisture distribution and vegetation vigour on the ground.
(3) 0.580 to 0.680 μm (red)	For discrimination of vegetation communities, recognition and identification of agricultural crops, and distribution of cultural features.
Sun-synchronous orbit with 30° sun angle at 50° north latitude at the vernal equinox	Sun-synchronism means that the satellite, Earth and sun maintain a constant angular relation at any given latitude. Repetitive images of the same area have nearly the same angle of the sun illumination and are readily compared for changes in features.
1-year lifetime	Required for repetitive viewing through the four seasons for detecting changes in growth of crops, extent of snow cover and urban construction rates, and to provide a high probability of cloud-free observation of any area several times during a year.

Table 2. EROS data users and their requirements for timeliness of data

User	*Time frame within which data are needed*[a]	*Type and format of data needed*	*Suggested method of dissemination*
Scientists	1 week to 1 year	Raw data, data in map format, specially processed data	Mail
Resource managers and planners	1 day to 2 months	Interpretative data, data in map form, extracted information	Telephone, jet, plane, mail
Policy-makers	1 month to 1 year	Synthesized interpretative data, data in map form	Mail
Resource producers	1 to 2 days	Raw data supplemented by quick interpretations, comparisons of sequential coverages and extracted information	Established media: TV, newspapers, radio, etc.
Educators	1 year	Data in map format and data supplemented in some cases by interpretations and explanations	Mail

[a] It is recognized that variations will exist in delivery requirements; some scientists, for example, may need rapid delivery.

The mapping requirements working group has also been asked to evolve the technology to (*a*) provide a measure of building densities within the urban scene; and (*b*) permit objective classification (as opposed to mapping) of landforms. Spatial filtering techniques will probably be used to satisfy the latter two requirements. Consideration is also being given to development of a method for the automatic mapping of "colour" distributions to aid in interpreting soils and vegetation.

Users

Major emphasis has been placed on identification and classification of users of the data to be derived from ERTS-A, the quantities of data to be received and reproduced and the timing and format requirements of the various classes of users. Basically, five categories of users exist; these are shown in table 2, together with current estimates of their time requirements for delivery of the data.

The users are variously equipped to make effective use of satellite data at this time. A summary follows of the current capability, steps that are being taken and steps that still must be taken to assure good use of the data at time of launch.

Scientists

Significant segments of the scientific communities have been engaged in study of space photography and aircraft data for the past five years. Sufficient information now exists in the scientific literature to enable those not now engaged in these studies to familiarize themselves with the data and their projected scientific uses. Classification systems such as land use and soils classifications that will mesh with the projected information content of the data need to be sharpened and in some cases evolved. Further consideration needs to be given to the scientific uses of the information, such as surface water distribution, that will be routinely provided. Continuation of study at current levels, with focus on classification development and information use, will provide for adequate use of the data by the scientific community at time of launch. A need does exist for specialized interpretative tools that must somehow be fulfilled.

Resources managers and planners

A series of studies of the potential applications of remote-sensing to natural and cultural resources management problems grew out of the basic discipline studies for cartography, geography, geology and hydrology conducted at the Geological Survey, as well as out of studies of applications to forestry and agriculture being conducted by the Department of Agriculture, the University of California and others. Findings in all these disciplines indicated that airborne and spaceborne remote-sensor systems have great potential value for bureaus of the Department of the Interior that have responsibility for management of large and far-flung areas of the country. They need timely data from those areas regarding use of land, seasonal and longer-term changes that affect the ability to sustain various activities, and the results of natural and human pressures. These pressures may be storm damage to coastlines, wind damage to forests, urbanization, land reclamation, mining activities and accidents, such as oil spillages, that have widespread disastrous effects.

Responsibility for design and conduct of the studies rests on the appropriate bureaus of the Department. The goals of current resources management studies are to develop applications of airborne and spaceborne remote sensor systems for:

1. Soils classification;
2. Engineering classification for:
   (*a*) Drainage;
   (*b*) Irrigation;
3. Analysis of conditions of irrigated lands and functioning of irrigation systems by:
   (*a*) Detection of leakages;
   (*b*) Detection of phreatophyte growth;
   (*c*) Detection of damage by natural or human events;
4. Detection and monitoring salinization;
5. Public lands classification;
6. Monitoring of natural and human activities:
   (*a*) Grazing of livestock;
   (*b*) Range and forest conditions in respect to:
      (i) Condition of grass and other forage;
      (ii) Erosion conditions or hazards;
   (*c*) Results of use of public lands as range land, forest and mineral sources;
7. Detection of oil spillages and leakages;
8. Monitoring dispersion of spillages and leakages;
9. Aid in development of plans to counteract spills and leaks and to recover oil where feasible;
10. Assessing, seasonally, the condition of marsh lands, pot holes and seasonally wet areas in respect to:
   (*a*) Nesting conditions;
   (*b*) Feed conditions;
11. Monitoring changes affecting wildlife:
   (*a*) Short range—natural and human induced;
   (*b*) Long range—natural and human induced;

12. Recording conditions of national park environments;
13. Monitoring changes in national park environments;
14. Planning appropriate measures for conservation of:
    (*a*) Shorelines;
    (*b*) Coastal features;
    (*c*) Natural vegetation and wildlife;
15. Detecting effects of surface and sub-surface mining;
16. Detecting modification of environment resulting from treatment and use of mineral products:
    (*a*) Culm banks and spoil piles;
    (*b*) Mine drainage;
17. Monitoring changes in mining areas relative to:
    (*a*) Success of restorative measures;
    (*b*) New hazards.

Progress made to date includes acquisition of airborne sensor (University of Michigan) data for the reclamation–irrigation test site at Moses Lake, Oregon, and preparation of the plan for processing at the University of Michigan facility.

The classification of and monitoring the use of lands for public land management are in progress with data obtained in Apollo 6 and 9 underflight missions and high-altitude NASA missions now being flown. A supporting study contract for analysis of the data is now in effect. This contract also addresses potential applications for management of Indian and Territorial Lands, a very important activity which will benefit from attention to the same type of studies, but applied to specific geographic and management needs.

The wildlife–waterfowl study was begun in FY 1968 with EROS programme funds with which data over the Jamestown, North Dakota, test site were acquired. FY 1969 funding has been dedicated to the processing of that data at the University of Michigan and will be reported on early in 1970.

National Parks applications studies are being conducted in the Everglades in co-operation with United States Geological Survey hydrology applications study programmes and at the Padre Island test site in co-operation with United States Geological Survey geological applications studies.

The Bureau of Mines is studying applications to solid waste inventory and control using Apollo 6 and 9 photography, Apollo underflight data and USGS aerial photography. Findings of a United States Bureau of Mines–United States Geological Survey co-operative study of mine fire occurrence using a thermal infra-red scanning radiometer were reported on at the Sixth Symposium on Remote Sensing of Environment.[2]

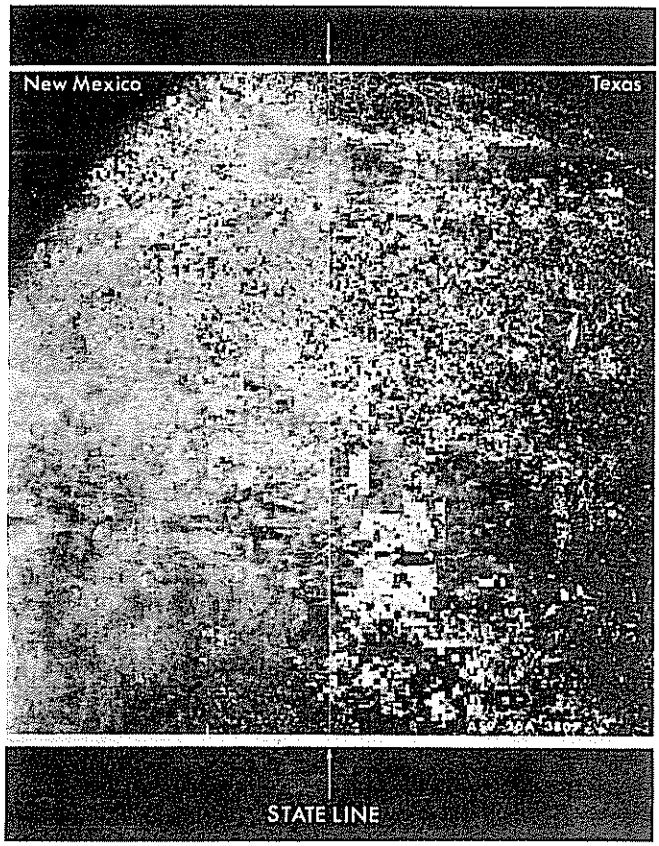
In addition to the studies that consider the Department of the Interior uses of space data for resources management and planning, the following contracts or agreements were reached with organizations to study applications and benefits to State and regional organizations: (1) The State of Washington; (2) The Desert Research Institute (DRI); (3) The Tennessee Valley Authority (TVA); (4) The Delaware River Basin Commission (DRBC); and (5) RCA, assisted by Raytheon/Autometric. Under the terms of these agreements, RCA worked closely with TVA and DRI and to a lesser extent with the State of Washington and DRBC, in analysing their uses of data to be derived from initial Earth resources satellites. Photographs taken from Apollo 9 and colour–infra-red photographs taken by the United States Geological Survey from a high altitude jet aircraft were used in the investigations. The aircraft photographs were degraded and reduced in scale to approximately the resolution and scale of the space photography. The report of RCA's findings is complete; following is an excerpt from the summary of results contained in the report:

"The study of the TVA and DRI activities pointed out clearly that EROS data could be directly applied by these users. Land-use mapping, using up-to-date EROS imagery, was consistently the most obvious application for users within both the TVA and DRI. Forest inventory for the TVA and *playa* inventory for the DRI were also major applications for the data. There were at least eight other potential applications for which EROS imagery seemed likely to be useful for each of the user organizations. Significant among these for both groups is thermal pollution detection, which would require a thermal IR sensor, not planned for ERTS-A but very likely for one of the early following flights.

"The analysis of simulated EROS data by the TVA, DRI and Raytheon/Autometric resulted in specific conclusions about useful data types and formats for user interpretation. Colour–IR composites were generally easiest to interpret and contained the most information, but black-and-white spectral separations, used either separately or in side-by-side comparisons, could be used to extract almost any specific information. The photo-infra-red and the yellow-red separations were the most useful and, indeed, seemed to contain all the information visible in the blue-green band. However, no enhancement was done on the pictures analysed during this study, and other studies have indicated that enhanced versions of the blue-green band make water penetration visible in this band which cannot be seen in the other two separations. The users preferred the larger format and lower distortion of the Apollo SO65 pictures over the pictures simulated from aerial photos. They indicated the desirability of using available collateral data (maps, ground truth etc.) to speed up analysis and reduce errors, and the desirability of images of the same scene at several times during the year for change detection. They also indicated that it would be desirable for them to be able to receive, on request, either mosaics of a larger area or portions of a picture at a larger scale (1:250,000), the latter to simplify the comparisons within existing scale data and to allow for easier annotation of analyses."

Scientists and managers at DRI, TVA and in parts of the Interior Department are now ready, or nearly so, to apply data and derived information to their problems. However, resources managers and planners are a large group of potential users, and most have essentially no familiarity with the data or its applications, and there is a paucity of information in the literature relating to resources management applications. Accordingly, steps are being taken to provide educational assistance and to speed publication of available information in appropriate journals. It is quite likely that many management and planning organizations will require professional assistance in utilizing the data; to this end, we are encouraging organizations that specialize in photo-interpretation to give thought to these problems.

[2] G. W. Greene, R. M. Moxham and A. H. Harvey, "Aerial infra-red surveys and borehole temperature measurements of coal mine fires in Pennsylvania", *Proceedings, Sixth Symposium on Remote-Sensing of the Environment*, October 1969, pp. 517–526.



Apollo photograph showing difference in land use in New Mexico and Texas

Policy-makers

Information of the type that we expect to routinely derive from the ERTS imagery, such as surface water distribution, land classification and urban population growth[3] will be of obvious value in making some regional or national policy determinations. Because the information closely parallels information now used in some policy determinations, we foresee no difficulty in introducing it into the decision process, provided the information is properly qualified as to precision.

In addition, the raw data and interpreted data are believed to have value in assessing the effects of policy determinations. The Apollo photograph is an example of such use. It shows parts of the States of Texas and New Mexico; the marked difference in land use between them results from differences in the laws of the two States relative to extraction and use of ground water.

We believe that the policy community is prepared to use both raw and interpreted data now, provided a full explanation of the data and any interpretations are given.

Resources producers

ERTS-type photographs obtained from high altitude aircraft flights over parts of South Dakota, followed by a symposium held to explain the characteristics and uses of the photographs, revealed that the resource-producing public (ranchers, farmers, fishermen etc.) is surprisingly capable of interpreting images of this type. We attribute this capability to (1) intense interest in information that can bear upon the individual's economy, and (2) the individual's full familiarity with his area of interest. From this experience and similar experience in Texas, we believe that the resource-producing public can be quicly prepared to utilize both the raw data and derived information. We believe this preparation could best be achieved by preparing material for transmission over local and educational television stations just prior to the launch of ERTS-A.

Educators

Images of the Earth, collected from space platforms, have relevance in the educational processes primarily because: (1) their small scale and, hence, large area coverage make possible an inductive (general to specific) approach to Earth sciences, and (2) the high information content of images as compared to small-scale maps suggests their useful substitution for some maps in many curricula. In addition, multispectral data (within and beyond the visible spectrum) may be found useful in teaching introductory physics and radiation physics. It is thought that existing Gemini and Apollo photographs and multispectral images, acquired from aircraft, should be evaluated under curriculum development programmes to ascertain their possible usefulness as educational aids. As a first step, we are currently fostering examination of a photo-image map of Peru, produced from Gemini photography, to determine its value in aiding understanding of the history and the development problems of Peru.

Availability of data

As has been the case with photographs taken from the Mercury, Gemini and Apollo spacecraft, it is anticipated that data collected from ERTS-A will be made readily available to interested scientists throughout the world. NASA expects to issue an experiment opportunity's document in the near future. This document will explain the characteristics of the data that are expected from ERTS-A and invite proposals for experimental use of the data. For those who wish the data but do not wish to propose experiments, it is anticipated that it will be possible to obtain copies of the data, by purchase, from an appropriate agency of the United States Government.

Conclusion

EROS is a new concept in resources and environmental data gathering. The data to be collected from the first ERTS satellite will be of value to a very broad spectrum of users. It is interesting to speculate on the benefits that these users will derive from using a common set of data for the first time. We foresee a greater understanding among the disciplines of one another's problems and needs, a clearer structuring of resources problems, a better understanding of the relative importance of these problems and a greater uniformity of results.

[3] W. R. Tobler, "Satellite confirmation of settlement size coefficients" (Institute of British Geographers), *AREA*, No. 3, 1969, pp. 30–34.

GEODETIC POSITIONING OF AN ISLAND IN THE PACIFIC BY ECHO II

Paper presented by Japan[1]

The programme for determining geodetic positions of islands in the Pacific by optical observations of artificial satellites is now in progress in Japan (Hirose, Harada, Sinzi, 1968).

In December 1968 and August 1969, observation teams of the Hydrographic Department were sent to Titi Sima (Bonin Islands) to determine the geodetic position of this island, located about 1,000 km south of Tokyo. The third determination is scheduled for February 1971, in accordance with the ISAGEX plan (International Satellite Geodesy Experiment). We will outline here the preliminary results of the work carried out in 1968.

For the simultaneous observation of satellites, several stations dependent on the Tokyo Astronomical Observatory and the Hydrographic Department (table 1) were selected as reference points of the Japanese geodetic system. The co-ordinates of these stations are given in the geodetic system (Bessel's ellipsoid) currently being used in Japan.

During the 16-day observation period, five simultaneous observations were obtained for Echo II, as shown in table 2. However, no valid set of observations was obtained for the link between Tosa-Saga and Dodaira. Accordingly, the position of Titi Sima was derived as if the co-ordinates of these two stations were known. The results of the calculation are shown in table 3. The first gives the astronomic position of the observation spot obtained by the Carl Zeiss Ni 2 astrolabe. The second line shows the geodetic co-ordinates derived from the satellite observations in the Japanese geodetic reference system.

In order to integrate the position of Titi Sima in the world-wide geodetic system, the co-ordinates of Dodaira and Tosa-Saga in the current Japanese geodetic system were transposed to the SAO C7 system (Veis, 1967), by means of the Molodenskii transformation formulas (Molodenskii *et al.*, 1960). The calculations were done a second time, introducing this new co-ordinate system. The results are given in the third line of table 3.

Table 4 gives the absolute deflection of the vertical at Titi Sima in relation to the standard Earth C7 (Veis, 1967). The geoidal height of Titi Sima seems to correspond to that obtained from the generalized geoidal map by Veis (1967).

[1] The original text of this paper appeared as document E/CONF. 57/L.52.

REFERENCES

Hirose, H., Y. Harada and A. Sinzi. *Present Status of Researches on Satellite Triangulation in Japan*, United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 1968.

Molodenskii, M. S., V. F. Eremeev and M. I. Yurkina. *Methods for Study of the External Gravitational Field and the Figure of the Earth*, Israel Program for Scientific Translations, Jerusalem, 1962.

Veis, G. *Determination of the Radius of the Earth and Other Geodetic Parameters as Derived from Optical Satellite Data*, Smithsonian Astrophys. Obs. Spec. Rep. No 264, pp. 75–97, 1967.

Table 1. Satellite observation stations

Station	*L(E)*	*B(N)*	*H*	*Camera*	*f*	*Agency*
Dodaira	139° 11′ 43.179″	36° 00′ 08.596″	856 m	Baker-Nunn[b]	50 cm	T.A.O.
Tosa-Saga[a]	133 06 42.215	33 04 29.894	3	Parkin Elmer[b]	100	H.O.
Kurasiki	133 46 15.60	34 35 23.70	6	Parkin Elmer	100	T.A.O.
Taniyama	130 31 49.47	31 31 34.82	17	Star camera	50	T.A.O.
Sapporo	141 21 23.5	43 02 35.0	33	Star camera	50	T.A.O.
Sirahama	138 59 20.64	34 42 46.28	158	Star camera	60	H.O.
Titi Sima	142 11 16	27 05 20	2	Astro Camera	60	H.O.

[a] Temporary observing station.
[b] With precise timing device.

Table 2. Satellite observation data

Date	*UT*	*Satellite*	*Station group*	*Sub-point L*	*Sub-point B*
30 Nov. 1968	08 h 25 m	Echo II	Dodaira, Titi Sima	149°	30°
1 Dec. 1968	08 28	Echo II	Dodaira, Titi Sima	148	34
6 Dec. 1968	08 33	Echo II	Dodaira, Titi Sima	135	30
6 Dec. 1968	19 24	Echo II	Dodaira, Titi Sima	141	34
9 Dec. 1968	19 27	Echo II	Tosa-Saga, Titi Sima	136	26

Table 3. Resulting position of Titi Sima

Observation method	L(E) (p.e.)	B(N) (p.e.)	h(p.e.)
Astronomical	142° 11′ 16.40″	27° 05′ 20.08″	
Satellite (Bessel)	39.29±0.41	15.80±0.81	+84 m±10 m
Satellite (SAO C7)	27.70±0.41	30.81±0.81	+44 ±10

h = Height of the observer above the reference ellipsoid.

Table 4. Absolute deflection of the vertical at Titi Sima

Meridional vertical	Prime vertical	Geoidal height N
−10.7″	−10.1″	+42 m

CONTRIBUTIONS OF SPACE TECHNOLOGY TO GEODESY AND CARTOGRAPHY

Paper presented by Iran[1]

CRITERIA FOR SATELLITE USE

Despite the fact that the capital investment in cartography, surveying, geodesy and geography roughly amounts to $500 million per year, so far less than 50 per cent of the world has been mapped, and inadequately at that. This fact is incompatible with modern technological advances in the fields of aerial photography, astrogeodesy and aerial survey techniques. Cartography is based on the mathematical interpretation of geodesy and, when it is combined with geography, it plays an essential role in so far as it enables man to understand his environment, make better use of his economic resources and contribute to general development. Since geodesy helps to determine the shape and general configuration of the Earth's surface, it enables engineering and development projects such as construction of dams and pipelines, irrigation projects, urban development, tunnel and communications projects to proceed with greater accuracy. The economic benefits of satellite geodesy and surveying do not always follow immediately.

Geodesy, or the science of mapping, deals with the quantitative description of the shape of the Earth and its dimensions. Geodesy makes it possible to determine boundaries for political and legal ownership purposes. Prior to the application of space technology to geodetic problems, survey measurements were effected with optical instruments along lines of sight parallel to the Earth's surface. Since light rays undergo refraction and bending owing to the effect of the gradients of the refractive index of air and consequently follow the Earth's curvature, the radial distances from the centre of the Earth by observation of lines of sight between consecutive points are unreliable. Furthermore the survey methods were confined to small areas, and the triangulation technique could not operate across seas or in large inaccessible areas and when it could, the cost of the operation was prohibitive.

The older methods of triangulation and height measurement provide the surveyor with positions on level surfaces in specific regions or indicate differences in potential between a level surface which passes through a particular point of the topographic surface and that which passes through some other point in the area. If the surveyor can determine the form of level surfaces through some new procedure, he can relate his measurements in one area to those in the next, and in principle he can carry these links from one continent to another, provided that sufficient gravity measurements are available within the region.

The launching of the first sputnik in October 1957 marked the birth of modern space geodesy. Astronomers and geodesists at once grasped the potentialities of the artificial satellites sweeping over the planet and making it possible to calculate the shape of the Earth and its gravitational field and consequently the equipotential surfaces. This also resulted in a perfect solution for the different reference spheroids in various areas of the world. Modern space geodesy offers the first real opportunity to develop a unified international geodetic system through a world network of satellite-tracking stations.

The optical and the electronic tracking systems make it possible, through simultaneous observations and accurate position fixing, to accurately determine the perturbations of the orbit and consequently the variations of the Earth's gravitational field.

Satellites and their orbits provide the best solution to the problem of the geometric form of the Earth and the make-up of its dynamic masses: gravity and the geoid (imaginary level which coincides with the mean sea level).

At first glance, the geoid is an ellipsoid of revolution about the polar axis; one of the earliest results of the observations of the artificial satellites was the calculation of the polar flattening of this ellipsoid—the difference between the polar and equatorial axes. The results of a

[1] The original text of this paper, prepared by H. K. Afshar, representing the Committee on Space Research and the Institute of Geophysics, Tehran University, Tehran, appeared as document E/CONF.57/L.114.

decade of observations and processing of data by the Smithsonian Institution yield much more detailed information about the shape of the geoid and its very slight departure from the rather idealized ellipsoid.

The International Union of Astronomy and the International Union of Geodesy and Geophysics have jointly adopted new parameters conveniently selected to describe the size and shape of the Earth and the variations of gravity over its surface. This system provides the best means to obtain a proper framework for linking one geodetic area to another.

Satellite survey techniques

In connexion with satellite geodetic surveys, the satellite is viewed as a point whose distance and direction from fixed points could be exactly determined. This involves calculation of the following parameters:

(*a*) Measurement of the direction or angular distance of the satellite from the survey point to the fixed stars;

(*b*) Measurement of the distance of the satellite from the survey point;

(*c*) Measurement of the speed of the satellite in relation to the survey point.

Measurement of angles

The angles are measured by accurately photographing a satellite against fixed stars with a large-lens camera which releases the shutter when the anticipated position is given. This requires a synchronized precision clock to take simultaneous photographs of the satellite which must either reflect or carry its own light source. The accuracy depends upon how precisely the position of the stars is known, or about 2 minutes of arc in direction or 20 m on any co-ordinate of a position on Earth. The greater the accuracy of the calculation of the position of the stars, the greater the precision.

The Institut géographique national (IGN) in Paris has achieved accuracy in the order of 1/100,000 by using passive reflecting satellites such as Echo I, Echo II and Pageos, and special ground optical equipment.

In Japan, through the use of more accurate timing devices in the order of a few tenths of a millisecond and simplified satellite triangulation techniques, it has been possible to survey islands and isolated areas which are difficult if not impossible to reach.

It is also of considerable interest to know that the analysis of satellite orbits can also be used in the upper atmosphere to determine variations in air density at heights from 150 to 1,500 km. Orbital analysis also provides the best method for evaluating the average rotational speed of the upper atmosphere at heights from 150 to 400 km. Orbital perturbations of artificial satellites also enable scientists to determine the effects of the distribution of Earth masses.

Measurement of distances

The distances can be measured by radar, but the results are not sufficiently precise. Optical lasers are now being tested; a solid-state laser emits a short light pulse in the direction of the satellite; the reflected light is received by a sensitive detector which measures the time interval between emission and reception. Since the duration of the pulse can be compared with the time needed for light to travel a distance of one metre, the distances can be measured to one metre accuracy. It is necessary to measure distance and direction simultaneously; for this purpose a special satellite is used, which involves solid-state lasers and which can reflect strong signals thanks to a special device which can reflect the light rays along the direction in which they fall on the satellite. This method should make it possible in future to increase the accuracy from 1.5 m to 30 cm and, if money is no object, it should be well suited to solving the current geodetic problems of cartography and topography.

Measurement of relative velocity

The speed of the satellite in relation to the observatory can be found by measuring the frequency of its radio signals. Owing to the Doppler effect, the observed frequency is proportional to the speed of the satellite in relation to the observatory. This relative speed is a complex function of the parameters of the orbit, namely, the position of the station in terms of latitude and longitude and the Earth's rotational speed.

Satellite geodesy makes it unnecessary to refer measurements to the level surface of constant gravitational potential and furthermore eliminates the difficulty of triangulating wide areas that are largely inaccessible or undeveloped.

These advantages have led the United States Academy of Sciences to recommend the use of a special satellite with a low volume-to-mass ratio so as to minimize the air drag and solar radiation effects. This satellite has an almost circular orbit with an inclination of about 50° and an altitude of some 800 km. It is equipped with a powerful strobe flash having the intensity of a fifth magnitude star at a distance of 5,000 km, which makes it possible to recognize it against a star background and to programme it so that it will emit a definite series of light pulses for photography. The Anna 1-B satellite launched by the United States Department of Defense complied with the recommended norms. In France, the Centre d'études spatiales (Space Research Agency) also launched three of these satellites as part of experimental satellite geodesy programmes which used the Doppler effect and laser distance measurements.

A decade of continuous work in twelve tracking stations, including the Shiraz Station, yielded some 46,500 observations which when processed resulted in 80,000 equations, which were solved by modern computers in $5\frac{1}{2}$ hours.

The values obtained for the flattening and equatorial radius of the Earth are:

$$\alpha = \frac{1}{298{,}255}$$

$$a = 6{,}378{,}144.6 \pm 5 \text{ m}$$

Advantages of modern space applications

Modern space technology makes it possible for us to photograph the entire Earth accurately and comparatively quickly; it thus constitutes a new source of environmental knowledge in support of cartographic and geodetic investigations.

For example, a simple Gemini photograph at 1 : 1,200,000 taken at an orbital height of some 260 km covers about

4,000 km²; by comparison, twenty-one conventional aerial photographs taken at a height of 8 to 9 km would be required to cover an equivalent area. Satellite photography enables map compilation techniques to proceed five times faster than current techniques and at greatly reduced costs.

Map revision operations which are of such vital importance for developing and developed countries could be carried out by modern satellite photography techniques with the aid of cartographic cameras at optimum orbital heights. This would make it possible to complete the geographic analysis of environmental conditions in different parts of the world more quickly, more accurately and at lower cost.

Future applications of satellite geodesy

(*a*) It is hoped that, through highly advanced technological instruments, a precise definition of the geoid and the Earth's general gravitational field can be determined, so as to obtain more reliable control points on a world-wide basis. The geocentric co-ordinates used in satellite application programmes could be determined more accurately, and the effect of the forces acting on the satellite could be studied;

(*b*) It should be possible to define not only the surface topographic relief features, but also the geometry of the sea surface with an accuracy in the order of one metre by means of a satellite-borne altimeter;

(*c*) The geocentric location of a satellite as an aid to navigation could be determined with an accuracy in the order of from 1 to 30 m, and this would enable ships to determine their position within 10 to 150 m;

(*d*) The orbital position of satellites could be predicted six weeks in advance with one-minute accuracy;

(*e*) The orbital perturbations will generally have to be in the order of from 5 to 10 m, so that the position of a satellite in space can be determined within 10 m;

(*f*) The secular horizontal and vertical movements at the Earth's surface could be determined; this will yield additional information on the movements of large land masses and islands; it will also be possible to determine more accurately displacements along fault zones (in conjunction with earthquakes and volcanic eruptions), glacial and ice-cap movements, ocean currents and buoys, polar ice-packs and the icebergs, snow and ice accumulations, as well as erosion and land deposits and related phenomena.

Role of geodesy and cartography in development projects

It is not possible to classify man's activities on this planet and deal with matters such as demography and urbanization without accurate maps, the preparation of which presents serious problems depending on the region and the limitations imposed by the nature of the surroundings.

The maps that could be prepared by the remote sensors mounted on the satellites are far more accurate and less costly than those prepared by ordinary cartographic processes. The geodetic nets established in recent years thanks to space techniques are excellent examples of man's ability to make the most accurate scientific measurements ever attained in the measure of distances and angles.

The measurement of distances between the continents of America and Europe has attained a precision in the order of a few centimetres, which is comparable with the tilt measurements that can be carried out by modern tiltmeters, the accuracy of which is in the order of 2/10,000 seconds of arc. Such precision in the measurement of distances and angles has surpassed all expectations.

The advantages of cartographic and geodetic maps prepared by these methods are as follows:

1. In the developed countries there is an urgent need for revising and up-dating the maps of rapidly expanding urban areas and new industrial areas. This need is directly connected with the economic status of the region, and in many parts of the world it is a major problem. In order to cope with these rapid changes and meet the needs of areas which have experienced big upheavals, new techniques must be adopted which are compatible with the requirements of the modern space age and space technology;

2. Aerial mapping photography is a long, tedious, somewhat less precise and even costly undertaking which requires extensive calculations with regard to the observation data; moreover, it is subject to the limitations imposed by flight altitude, range and speed. Routine aerial photography does not yet give a synoptic view since coverage involves successive discontinuous exposures and especially because the technique cannot cover and map inaccessible areas. These problems could be dealt with by systematic and methodical applications of earth-resource detection satellites. The remote-sensing equipment on these satellites would represent as much progress as aerial photography did when it replaced field surveys in mapping techniques;

3. The satellites equipped with photographic sensors can produce topographic maps which meet the required standards and at scales ranging from 1:24,000 to 1:250,000 and even at 1:1,000,000 and more on a global basis. The use of orbital photographic data for revising planimetric details on published maps at 1:24,000 or larger is considered perfectly feasible;

4. The importance and necessity of mapping and aerial photography for developing countries with extensive and mostly inaccessible areas can hardly be ignored. None of the accurate geological investigations so necessary to mineral resource surveys could be undertaken without topographic maps of this kind. These maps are also used for hydrological studies and assessment of underground water resources, land reform and urban development, agricultural surveys and mineralogical investigations. A thorough analysis of all the required data is essential; without such maps, it would be literally impossible to undertake development projects simply because graphic representation and statistical data must be properly plotted. In order to acquire complete and precise knowledge of the land surface, drainage of large areas in developing regions, etc. priority must be given to programmes relating to land survey techniques, since the knowledge thus acquired involves all phases of land-use and resource-development programmes;

5. The advantages to be derived from accurate and up-to-date topographic maps and other data collected by remote-sensor satellites would include the following:

(*a*) More efficient use of landed property, either on a small or large scale;

(*b*) More accurate and detailed evaluation of demographic changes and population movements for very different purposes;

(*c*) More accurate and detailed calculation of statistical data and results of national or international censuses;

(*d*) More efficient and better use of existing transportation networks and collection of the data needed for their development and for the planning of a new communication system for large and small communities;

(*e*) More efficient and accurate means for planning and designing major engineering and industrial projects of high economic value, such as construction of ports and dams, airports, highways, tunnels and other communications, electrification and the like.

THE APPLICATION OF SENSOR SATELLITES TO ENVIRONMENTAL INVESTIGATIONS

Paper presented by Iran[1]

The papers presented by Iran under the titles (1) "Contributions of Space Technology to Geodesy and Cartography", and "Criteria for the Applications of Sensor Satellites to Environmental Investigations" have a dual objective.

The first objective is to emphasize the importance and necessity of modern astrogeodetic measurements and the advantages of this new method over past conventional techniques for carrying out geodetic and cartographic measurements.

The second objective is to emphasize (since a member of the Iranian delegation also represents the International Committee on Space Research established by the International Council of Scientific Unions), the importance and potential of the applications of space technology and sensor satellites for solving our daily environmental, technical and engineering problems and their impact on our economic and social conditions.

On 4 October 1957, when the first *sputnik* was put into orbit, a new era known as the "space innovations era" began with profound revolutionary effects on human communities. This marked the birth not only of the science of astrogeodesy, but also of a whole array of new sciences and disciplines which can have creative applications for our civilized societies.

These new space sciences will facilitate research in geodesy, cartography, geology, geography, oceanography, hydrology, forestry and agriculture, not to mention their contributions to meteorology, telecommunications, navigation, education and earth-resources and environmental investigations.

Up to a few years ago there were many criticisms and public outcries of protest concerning the extensive capital investment in space. Even in the countries actively engaged in space activities some of the top scientists embarked upon a vehement campaign against space research.

The basis for these strong protests is that since there are still so many unresolved problems on our planet, the solution of which would improve the conditions and the standard of living of millions in need by helping to overcome the difficulties raised by the population explosion, the lack of proteins and malnutrition, the crisis in housing and the absence of hygiene, it does not seem wise to embark on projects for conquest of the moon and other planets.

In connexion with the figures released during the space explorations to the effect that in some underdeveloped countries of South-East Asia, Central Africa and Latin America the *per capita* income is in the order of $100 per year, one wonders whether it is morally justifiable to spend $200 per day just to feed one astronaut. Again, considering the fact that 7 out of the 21 children who are born every second are deprived of all the amenities of modern life and are practically without food and shelter, is it morally justifiable to spend $8 million just for the space suit and bodily protection of one astronaut?

Today, after 15 years of space research, human communities are starting to receive dividends from the gross capital investment. It is this capital investment that is today enabling us, owing to the extraordinary properties of infra-red photography, to prepare our cartographic maps more quickly, accurately, and economically by using methods without precedent in the history of science.

For example, in order to map a country the size of the United States of America with infra-red-equipped sensor satellites, a few hundred photos would be adequate, whereas with conventional aerial survey techniques a few million would be needed and at a higher unit cost.

A few of the advantages of the use of satellites are listed below:

1. Sensor satellites now provide us with data the accuracy of which is without precedent in the history of science; at the same time, they are saving us millions of dollars in cartographic, geodetic, geographical and urban surveys;

2. Astrogeodetic measurements have enabled scientists to determine the exact radius of the Earth, as well as the equipotential and geoid characteristics. The radius of the earth has been determined with an accuracy in the order of 5 m. This was the result of a decade of satellite observations from twelve stations, including Shiraz Station in Iran, and the solution of 80,000 equations carried out by modern computers in 5½ hours;

3. One Gemini photograph at an orbital height of 260 km can cover approximately 4,000 km^2 whereas twenty-one conventional photographs taken at a height of 9 km would be required for an equivalent area;

4. Since the geodetic location of satellites for positioning is determined with an accuracy of from 1 to 30 m, it makes it possible to position ships at sea with an accuracy of from 10 to 150 m and, at the same time, to determine the exact position of aircraft—a problem of vital importance in our era of expanding air navigation;

[1] The original text of this paper, prepared by H. K. Afshar, representing the Committee on Space Research and the Institute of Geophysics, Tehran University, Tehran, appeared as document E/CONF.57/L.124.

5. Astrogeodetic measurements of the secular horizontal and vertical movements of the Earth's crust now enable us to forecast earthquakes and volcanic eruptions, as well as glacial movements and related phenomena such as land slides, erosion and formation of deposits;

6. Satellites equipped with infra-red photographic and sensor devices make it possible to produce maps at 1:24,000, 1:250,000 and 1:1,000,000, as well as maps of the world at smaller scales;

7. Geodetic satellites provide geodetic and cartographic maps of areas which are inaccessible to conventional apparatus and which are separated by mountain ranges or large bodies of water;

8. Geodetic satellites provide us, for the measurement of distances between two points in America and Europe, an accuracy in the order of a few centimetres, comparable to that of tilt measurements, i.e., in the order of 2/10,000 seconds of arc.

These are only a few examples of the wide spectrum of advantages to be derived from the application of sensor satellites.

AGENDA ITEM 11

Photo-interpretation; Topical Maps and National Atlases

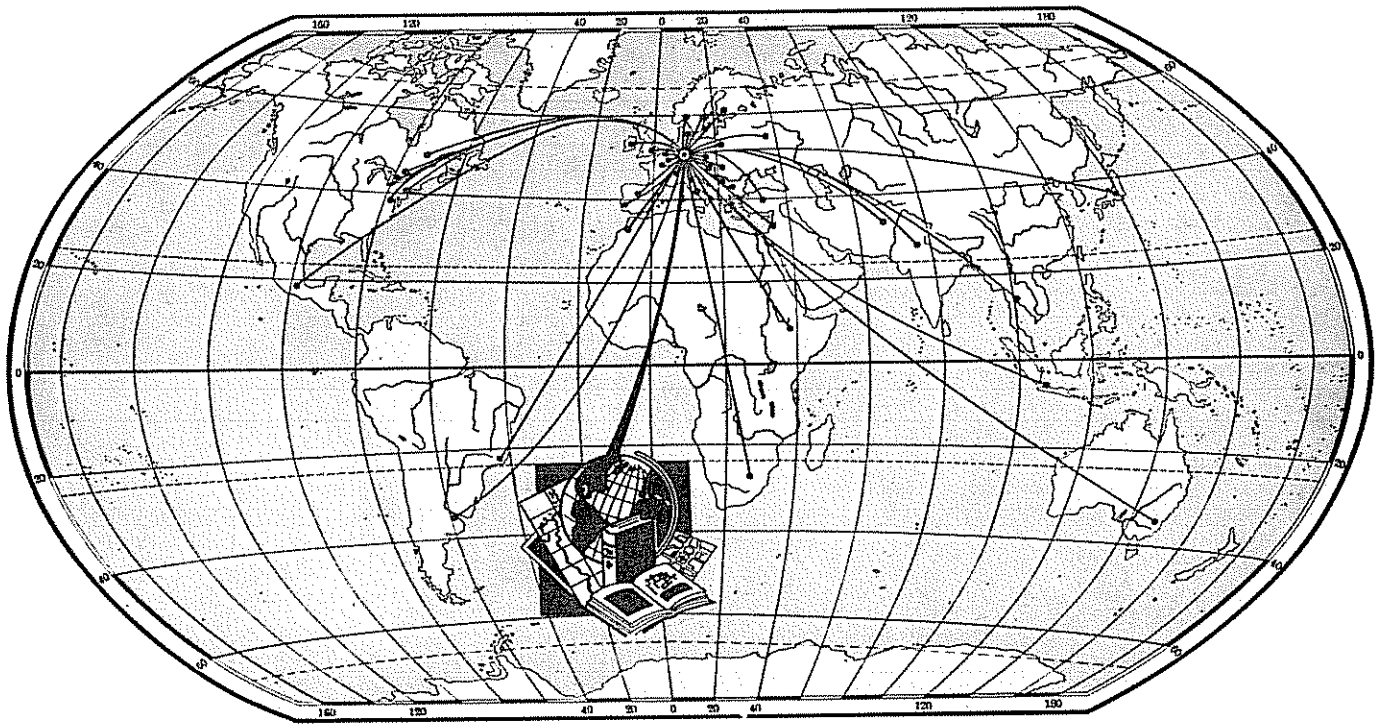
DOCUMENTATION ON THE CARTOGRAPHIC LITERATURE: AN AID IN MAP DESIGN AND MAP PRODUCTION

Paper presented by the Federal Republic of Germany[1]

From a scientific viewpoint, only through the simultaneous study of literature and maps can a fertilizing effect be exerted on the development of any geoscience. The compilation of the literature, the classification, the study of the source material and the presentation of the material for future research results in a comprehensive bibliography which is an essential device to any scientific work. In some countries there were precursors of such working groups; either their work was done on a national basis or it served a clear topical purpose. Furthermore, the valuable *Bibliographie Cartographique Internationale*, published in Paris and inaugurated by M. Foncin at the International Geographical Congress at Amsterdam in 1938, deserves great praise and has been a valuable reference for non-text publications. It led to the consideration that an additional register of literature on maps and their sciences was required.

To this end, the German Society for Cartography established in 1956 a working group to compile a bibliography of cartographic literature. The head of this working group is Dr. Karl-Heinz Meine, the author of this report. Today, fifty-six experts from thirty-four nations and nine organizations (national and international, including the United Nations) are involved in the recording of all relevant titles. The collection of all mapping literature other than cartographic research texts is the basis for all related sciences. These efforts either lead to the production of maps or, by developing new sets of problems by means of maps, they serve to confirm the results achieved. Thus, the work of the group may also

[1] The original text of this paper, prepared by Karl-Heinz Meine, Council for the German Society for Cartography, Rhoendorf-am-Rhein, and submitted under items 11, 12, 13 and 14, appeared as document E/CONF.57/L.6.



Geographical index of the Bibliotheca Cartographica *staff*

be important for fields related to cartography. The scientific problems of cartography have always been closely associated with the preparation and review of atlases, maps, books and articles. Documentation in cartography is an important aid in map design, map reproduction and the entire process of map production. It is very important to know the technical methods that are used in other countries. Moreover, new ideas, statistics and other basic data should be available as soon as possible to cartographic authorities and agencies. Compilation of data for design and production purposes is now more important than in the past. Technical papers and reports on cartographic theory and practice must be read. But owing to the limited time available, it is impossible for the staff of the group to keep up to date with all of the cartographic literature, since this requires specialized documentation with multilingual indexes, detailed classifications and a register of authors and periodicals.

Interested persons wishing to submit titles of cartographic literature should mail them to the chairman of the international working group (Dr. K. H. Meine, D-534, Rhoendorf-on-Rhine, Rhoendorfer Str. 40) twice a year (March and September). The group has the international support of the International Cartographic Association (ICA), the International Association of Geodesy (IAG), the International Society of Photogrammetry (ISP) and the International Federation of Surveyors (FIG). The information obtained is published in *Bibliotheca Cartographica* (a bibliography of cartographic literature), which is issued twice a year. Chapter headings are given in English, French, Russian and German. The geographical index indicates cities throughout the world where the scientific collaborators are located. All States, institutes and scientists are invited to co-operate in this effort in the future. This basic work will help all discussions and detailed examinations in cartography. Scientific and technical progress in cartography has been very marked in the past two decades.

The task of gathering all written materials on cartography can be accomplished only by experts working in close co-operation with one another. More than 20,000 titles have been published since 1957. We hope that the results achieved by the working group will be of interest to all specialists in the various branches of cartography. The results, the contents of the *Bibliotheca Cartographica* and the procedure to be followed for registering titles and supplying bibliographic details follow hereunder. The bibliography of cartographic literature is undoubtedly important for all cartographic activities. The working group therefore proposes that a centre for cartographic literature should also be established for the region of the Economic Commission for Asia and the Far East.

ANNEX I

Contents of *Bibliotheca Cartographica*

I. Bibliography, map collection, documentation
- A. Bibliography and list of maps
- B. Libraries and map collections
- C. Documentation and classification problems

II. General publications
- A. General and comprehensive representation. Manuals (handbooks). Collections
- B. Periodicals
- C. General aids

III. History of cartography
- A. General features
- B. Regional representations
- C. Biography. Personal data

IV. Institutions and organizations of cartography
- A. International, national and private map producers
- B. Training and research institutes. Societies
- C. Congresses and exhibition
- D. Law of cartography. Legal questions (copyright)
- E. Education and training

V. Theoretical cartography
- A. General methodology of cartography. Map reduction. Review of maps. Terminology
- B. Data. Bases (surveying, topography, photogrammetry, air photo interpretation. Projections)
- C. Questions on scale and neat-line systems
- D. Names. Transcription
- E. Graphic elements. Colours
- F. Drafting specifications. Standards. Specifications. Keys of symbols
- G. Keeping up to date. Map revision

VI. Applied cartography
- A. General features
- B. Bases for drafting. Drawing equipment
- C. Drawing techniques. Scribing and engraving techniques
- D. Photographic and copying techniques
- E. Reproduction and printing techniques
- F. Map lettering techniques
- G. Automation

VII. Topographic and landscape cartography
- A. General features
- B. Regional cartography (Earth. Single States)
- C. Preparation of certain scales
- D. Map data
- E. Cartography of celestial bodies. Space cartography

VIII. Thematic maps and cartograms
- A. General features and methods of representation
- B. Keys for representation of subjects and specifications of standardization
- C. Range of topics

IX. Atlas cartography
- A. General features
- B. World and school atlases
- C. Regional atlases

X. Use and application of maps. Special-purpose maps
- A. Range of applications
- B. Auxiliary devices for the use of maps

XI. Reliefs and relief maps. Block diagrams
- A. Relief maps in general and history of relief making
- B. Manufacturing procedures and preparation of reliefs
- C. Block diagrams

XII. Globes
- A. General features
- B. History of globes
- C. Preparation and manufacturing of globes

List of periodicals
List of abbreviations
Index of authors
Concordance of the UDC and of the chapter headings of the BC

ANNEX II

Rules of procedure for detailed bibliographic works

1. Books, booklets and other non-regular publications
   Author (surname, first name in full):
   Main title and subtitle (not abbreviated); name of editing institution and editor, if any. Number of edition, volume number. Place of publication. Publishing agency or firm and date of publication. Number of pages, figures, maps, if any, series title, volume number of current number.

   Example 1
   Bosse, Heinz:
   Kartentechnik II. Vervielfältigungsverfahren. 3. Auflage.- Lahr/Schwarzwald: Astra 1955. 232 S, 20 Abb., 1 Farbskala in 9 Taf.: Kartographische Schriftenreihe Bd. 3.

2. Papers published in periodicals etc.
   Author (surname, first name in full):
   Main title and subtitle (not abbreviated). In: Title of periodical or series. Volume number, date of publication, current number. Number of pages, figures and maps. Summary (if available; language of the summary). With articles from books the place of publication shall be given before the date of publication.

   Example 2
   Byron, William:
   Dotting the dot map with steel drill stamps. In: the Professional Geographer. 8, 1956, 4. S. 5–7.

   Example 3
   Kost, Werner:
   Zur topographischen Kartographie im niedersächsischen Raum von 1764–1863. In: Carl Friedrich Gaub und die Landesvermessung in Niedersachsen. Hannover 1955. S. 115–140.

3. Titles written in non-Roman type shall be transcribed according to the code for research libraries.

   Example 4
   Sališčev, Konstantin Alekseevič:
   Kartografija na XVIII meždunarodnom geografičeskom kongresse. In: Izvestija Akademii Nauk SSSR. Serija geografičeskaja. 1957, 1. S. 3–18 (Die Kartographie auf dem 18. Internationalen Geographischen Kongreb Russisch).

4. For titles which are not in a Germanic or Roman language, a translation into German shall, on principle, be given at the end of the reference. In case a summary in a German or Roman congress language is available for such titles, the German translation can be replaced by the title of the summary; this does not apply to the translation of titles in the index (contents).

   Example 5
   Kovařik, Jaroslav:
   Kartometrické urvocáni délky vlonek na topografické plosé, in: Kartografický přehled. 11, 1957, 3. S. 97–105, 8 Abb. Mit engl. Résumé: Cartometric determination of curve lengths on a topographic surface.

A STUDY OF THE STANDARD METHOD OF PHOTO-INTERPRETATION USED IN RESEARCH FOR PLANNING AND CONSTRUCTION

Paper presented by Japan[1]

INTRODUCTION

More than 20 years have elapsed since aerial photographic interpretation was applied to fundamental research in various planning and construction areas in Japan. Progress in research techniques, which broadens the scope of applications and requirements in these fields, has reached a point where prospects are very favourable. However, deficiencies and waste still exist in recent methods. An effective and economical method must therefore be developed. On the other hand, much of the research in the Ministry of Construction is conducted by private companies rather than by the Ministry itself. In this respect, too, the most desirable standard method of research must be applied from the viewpoint of quality control and scheduling. In this study, we have attempted to investigate the problems and standard methods of the three most common types of research, namely, the geological survey, the debris control survey and the snow survey. In addition, new standard methods were proposed for these three types of research.

GEOLOGICAL SURVEY

Effects of photo-interpretation on geological surveys

Aerial photographic interpretation is very useful for geological surveys, from which 1:10,000 to 1:50,000 geological maps are produced. Its effectiveness decreases for larger-scale maps, but at all events photo-interpretation can be a great help for all types of geological surveys. It is difficult to use photo-interpretation for geological surveys in Japan since the geology cannot be seen directly on the photographs owing to the thick vegetation and soil cover, except in special cases such as high mountains and waste lands. Moreover the topography does not clearly reflect the geology in Japan. Nevertheless, photo-interpretation is important for geological surveys since it is easy to make macroscopic observations, as well as to infer results from the field observations and to obtain information for engineering geology. By observing photographs, it is easy to obtain not only macroscopic information, but also geological data which are difficult to derive from field work, however thorough it may be.

Standard method of photo-interpretation for geological surveys

Photo-interpretation in geological surveys is carried out as follows: study of references, cartographic and morphometric analyses, reconnaissance interpretation, field work, final interpretation and compilation of a geological map. In reconnaissance interpretation, lineaments, topography of movable deposits, landslips and landslides are interpreted; then the entire area is divided into subareas which are distinguished from each other by characteristics on the photographs, independently of existing geological maps or references. In field work, the results of the reconnaissance interpretation are examined. Whatever is not clear on the photographs and is to be studied in detail in relation to engineering geology is also investigated at this time. Then the final interpretation is made. The geological map is compiled from the results derived from the study of the references, cartographic and morphometric analyses, photo-interpretation and field work from the viewpoint of

[1] The original text of this paper, prepared by the Geographical Survey Institute, Ministry of Construction, Tokyo, appeared as document E/CONF.57/L.33.

the engineering geology characteristics. The results of the reconnaissance, final interpretation and field work are indicated on the photographs. These are added to the geological map, which constitutes the final result. The interpretation table is prepared during the reconnaissance interpretation phase, as well as at the final interpretation if necessary. Examples of the photograph on which the results of the reconnaissance interpretation are indicated and the reconnaissance interpretation table are shown in figure I and figure II.

measurement of mass movements; and the last involves forecasting or catastrophic landslides.

Standard method of photo-interpretation in debris control survey

The standard method of research proposed here includes cartographic and morphometric analyses, the geological survey, geomorphological land classification, vegetation research, distribution of landslips, debris avalanches and

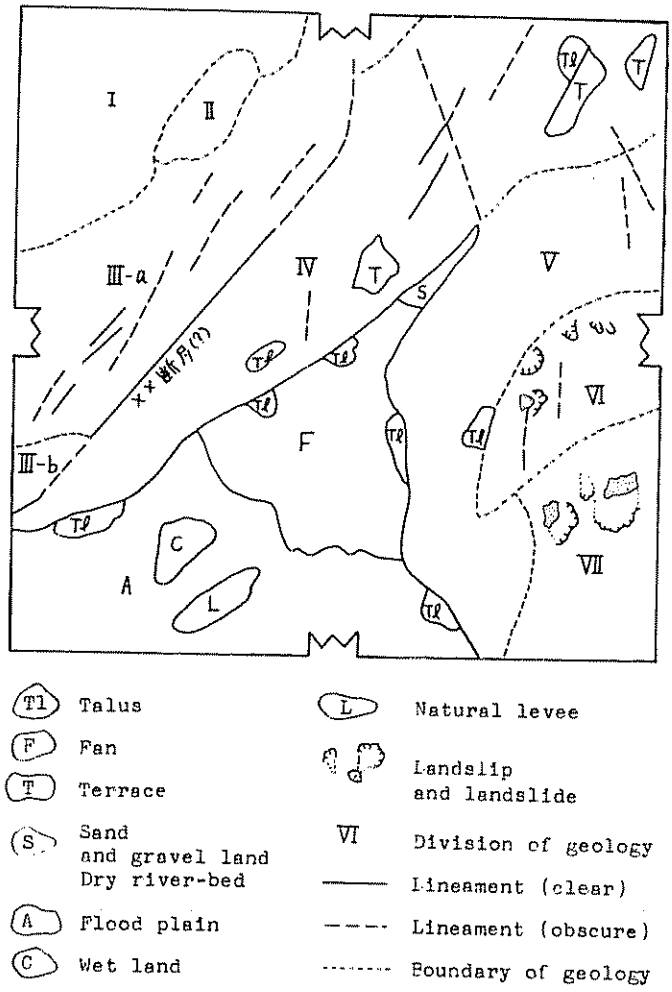


Figure I. Result of reconnaissance interpretation

DEBRIS CONTROL SURVEYS

Effects of photo-interpretation in debris control surveys

The areas which require debris control surveys are usually located in steep mountains where on-the-ground research is difficult. Aerial photographs are essential for research in such regions. In debris control surveys there are four types of research where photo-interpretation is used. The first involves the research of natural conditions, for example, geomorphology, geology, vegetation etc.; the second involves the study of distribution of landslips, debris avalances and landslides; the third has to do with the landslides, measurement of debris and landslide movements and forecasting of catastrophic landslides. In most cases, the work is performed as follows: study of references, reconnaissance interpretation, field work, final interpretation and map compilation. Another principle is often used when the result of the research is first indicated on the photographs and then the map compilation is carried out. Standards have been established for geomorphological land classification and vegetation classification for debris control surveys. Examples of maps compiled by this standard method are shown in figures III and IV.

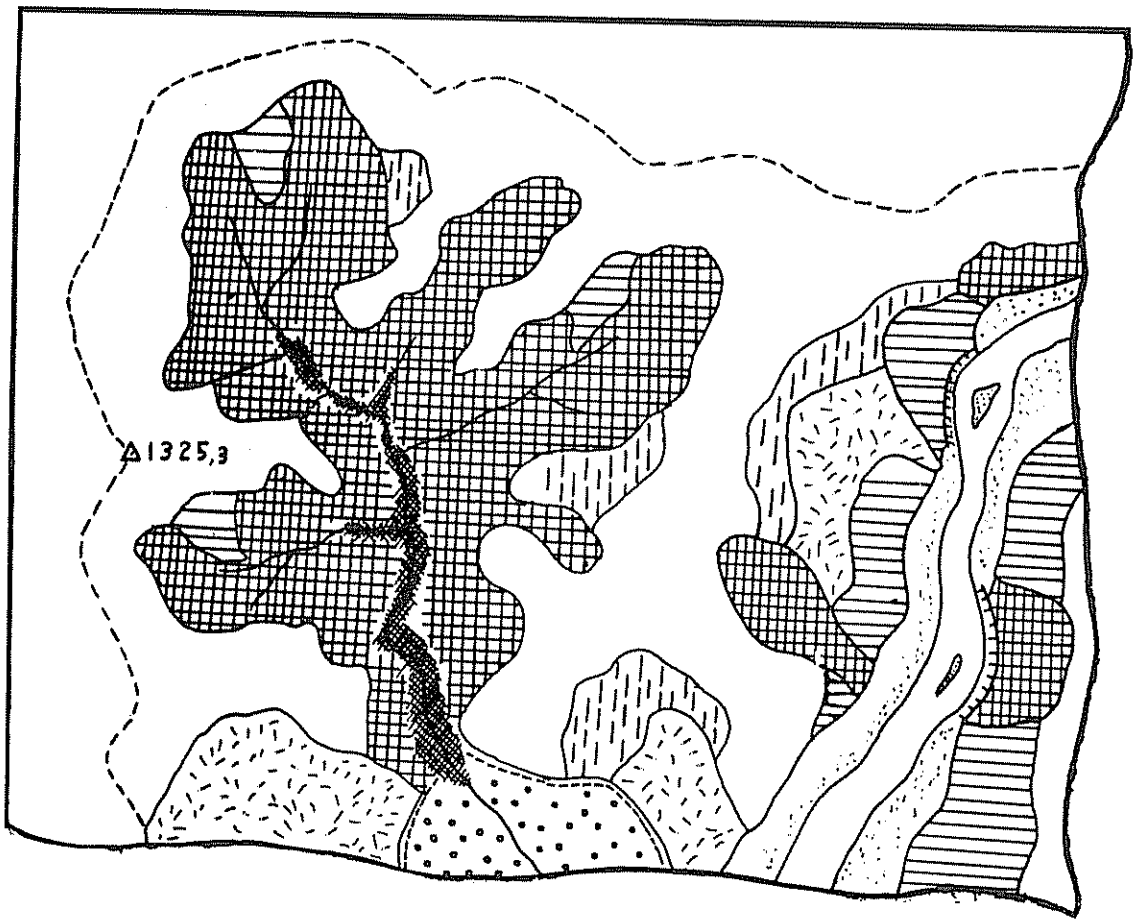
Division of geology					
Result of photointerpretation	Mountain	Shape of ridge			
		Shape of slope			
		Inclination			
		Relative relief			
		Other characteristics			
	Valley	Drainage pattern			
		Drainage density			
		Shape of cross-section			
		Debris of river-bed			
		Other characteristics			
	Texture Tone				
	Lineament				
	Landslide				
	Landslip				
	Vegetation Land use				
	Other characteristics				
Result of field work	Geology				
	Rock				
	Quality of rock	Material			
		Hardness			
		Weathering			
		Joint and crack			
		Other characteristics			
	Condition of landslide and landslip				
	Method of process for geology				
	Other characteristics				

Scale of photograph: Principal distance:
Date of photography:

Figure II. Reconnaissance interpretation table

SNOW SURVEYS

Aerial photographs are used in snow surveys to determine the distribution of snow depth and avalanches, cornices and wind directions marked on the snow surface, volume of deposits brought by avalanches, etc. The depth of snow is measured on the photographs by comparing the height of the snow surface at a point which has no snow in winter because the snow has been removed (e.g. road, roof of a house etc.) with the height of the ground at the same point on the photographs in summer From the snow depth thus measured, field work results during the snow season and weather station data, a map showing the distribution of snow depth with contour lines is compiled. The distribution of avalanches, cornices and wind directions on the snow surface are also shown on this map. On the other hand, a method for estimating the degree of danger from avalanches for each slope has been proposed. Dangerous slopes can be indicated thanks to this method, and the results of this work are shown on a map. Examples of a map showing the distribution of snow depth and avalanches, and a map showing the degree of danger from avalanches are represented in figures V and VI.



Dangerous slope of landslip (rank A)
Pente où des décollements risquent de se produire (catégorie A)

Dangerous slope of landslip (rank B)
Pente où des décollements risquent de se produire (catégorie B)

Slope subjected to soil erosion (rank A)
Pente susceptible d'érosion (catégorie A)

Slope subjected to soil erosion (rank B)
Pente susceptible d'érosion (catégorie B)

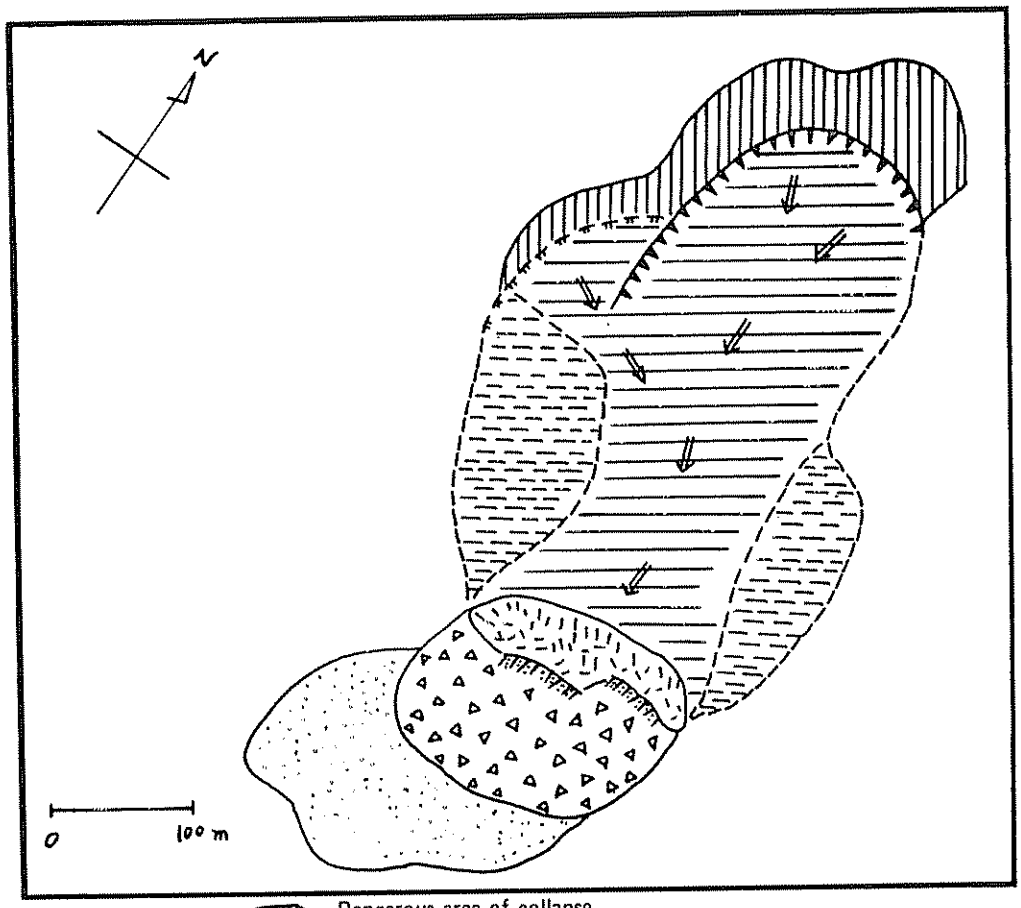
Expected course of debris avalanche
Trajectoire prévue pour l'avalanche sèche

Expected area of deposition
Zone de dépôt prévue

Dangerous side of bank erosion
Berge susceptible d'érosion

2354 X

Figure III. Forecast map of debris disaster



Dangerous area of collapse
Zone où un affaissement risque de se produire

Dangerous area of move (rank A)
Zone où un mouvement risque de se produire (catégorie A)

Dangerous area of move (rank B)
Zone où un mouvement risque de se produire (catégorie B)

Dangerous area of fall of disturbed material
Zone où il y a danger de chute des matériaux mis en mouvement

Dangerous area of deposition of disturbed material
Zone où les matériaux mis en mouvement risquent de se déposer

Expected principal direction of move
Direction principale du mouvement

New scarp
Nouvel escarpement

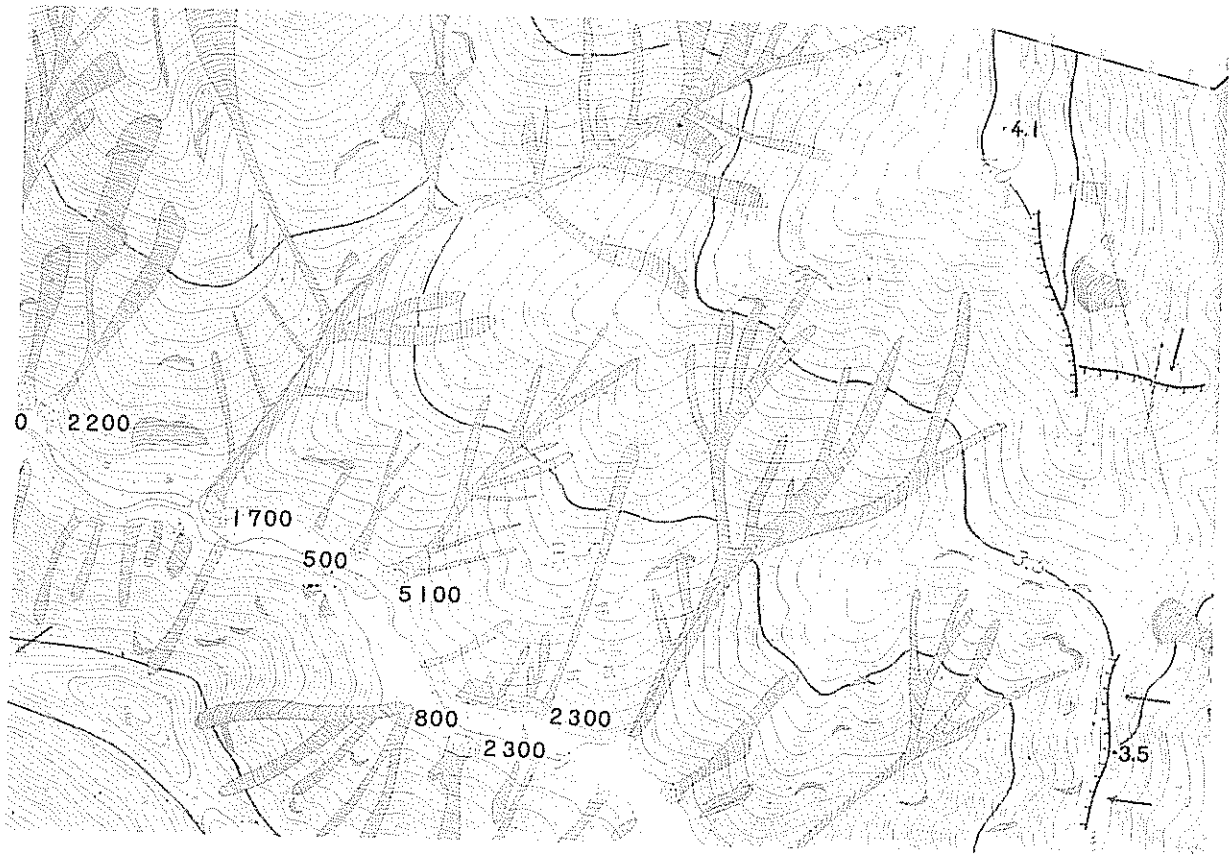
Old scarp
Ancien escarpement

Scarp of pushed mass
Escarpement de la masse déplacée

Area of deposition of disturbed material
Zone de dépôt des matériaux mis en mouvement

2355 X

Figure IV. Forecast map of landslide danger



2.5 / 2.0 Contour line of snow depth
Courbes de niveau des neiges

Bottom avalanche and crack
Avalanche de fond et crevasse

Surface avalanche and snow creep
Avalanche de surface et cheminement des neiges

2500 Deposit of avalanche, its amount
Dépôt d'avalanche (hauteur)

Cornice
Corniche

Wind direction on the snow surface
Direction des vents sur la surface des neiges

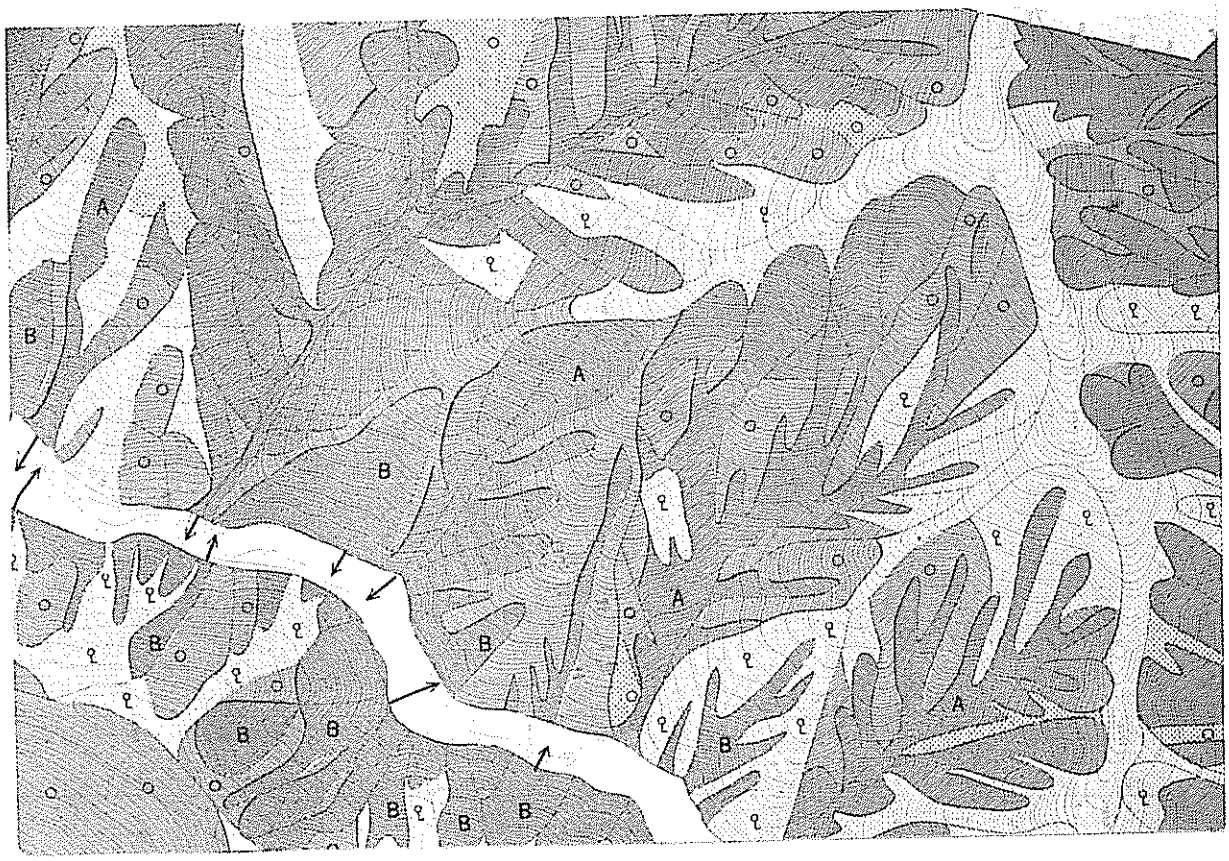
2 15(3.56) Snow depth at the weather station
白川(気象庁) Hauteur des neiges à la station météorologique

⊙ 1 35 Snow depth by field work
Hauteur des neiges d'après les travaux sur le terrain

· 1 3 Snow depth by photogrammetry
Hauteur des neiges d'après les levés photogrammétriques

2356 X

Figure V. Distribution of snow depth and avalanche



Dangerous slope of avalanche (rank 1)
Pente présentant des dangers d'avalanche (catégorie 1)

Dangerous slope of avalanche (rank 2)
Pente présentant des dangers d'avalanche (catégorie 2)

Dangerous slope of avalanche (rank 3)
Pente présentant des dangers d'avalanche (catégorie 3)

Slopes where avalanches do not occur
Pente où il n'y a pas d'avalanche

Reach of avalanche
Etendue de l'avalanche

A Conifer (higher than 4m)
Conifères (de plus de 4 mètres)

A Conifer (lower than 4m)
Conifères (de moins de 4 mètres)

Broad-leaf (higher than 4m)
Arbres à feuilles caduques (de plus de 4 mètres)

Thin forest
Forêt clairsemée

◎2.25(0.80) Maximum snow depth
白鳥(気象庁) Hauteur maximale de la neige

2357 X

Figure VI. Degree of danger from avalanches

REPORT ON THE PUBLICATION OF THE ECONOMIC ATLASES OF CHINA*

Paper presented by China[1]

The Government of China considers that the publication of economic atlases is very important in the utilization of resources and implementation of construction projects for economic development, and is proud to make a contribution to the co-operative mapping project initiated by the United Nations. The project of compiling these economic atlases was started under the direction of the Ministry of Interior immediately after the Fourth United Nations Regional Cartographic Conference for Asia and the Far East held in 1964. More positive action was taken after the Fifth Conference held in 1967 in order to meet the requirement.

In view of our current particular situation, we found it difficult to collect adequate information for the compilation of these atlases. However, we finally obtained sufficient mapping material through different means, even though the data were often unavailable. However, there was an abundance of mapping information since the investigation and development of economic resources have always been stressed by our Government. To facilitate compilation and reproduction, these economic atlases have been published in colour by areas and various classifications.

An economic atlas was compiled according to the Lambert Conformal Projection at 1:6,500,000. Legends and explanatory notes were added to the map to facilitate reading. This atlas is composed of four sheets. The first sheet shows the terrain features, communications and administrative areas, and is printed in gradient tints of eight colours, with blue colour to indicate drainage features. The second sheet shows agricultural crops, fisheries and animal husbandry. The various crops are shown in pink, light yellow and light blue, with brown to indicate their outlines. The third sheet shows the minerals that are available in the area. The fourth sheet provides information concerning water conservation and distribution of electric power, with black symbols for water reservoirs, red ones for thermal power plants, blue ones for hydroelectric plants and brown ones for irrigation and reservoir sites.

Another economic atlas was compiled in accordance with the Lambert Conformal Projection. This multicolour atlas also consists of four sheets. The first sheet shows the terrain features, communications and administrative areas. The second sheet shows the agricultural and soil classifications. The third sheet gives detailed geological and mineral information. The fourth sheet provides data on water conservation and electric power.

In addition, we have published a geological map of China. Printed in thirteen colours, this map consists of two sheets at 1:4,000,000. With forty-five symbols used to indicate geological conditions, this map is intended to revise the geological features in previously published geological maps and to supplement the information in the north-western and south-western areas of China which was usually missing from other geological maps. This map will be presented as a reference map to the United Nations.

Our Government has tried by all means to fulfil its obligations with regard to the completion of the economic atlases of this area as called for by the resolutions of the regional cartographic conferences. In accordance with article 12 of the resolutions adopted at the Fifth Cartographic Conference, we sent one set of atlases to the committee in Thailand and another set to the United Nations Information Centre for reference.

* See introductory note at beginning of volume.

[1] The original text of this paper appeared as document E/CONF. 57/L.40.

BASE-MAP TYPES FOR THEMATIC MAPS

Paper presented by Switzerland[1]

Increasing need for thematic maps

The number and variety of problems to be solved on a regional basis is growing fast, and these tasks are becoming more and more complex. On the one hand, the amount of information about a certain area is increasing enormously, but it is not yet as homogeneous as one would like it to be. Therefore the mere comprehension of the basic data already presents considerable difficulties. On the other hand, the mutual implications and correlations of the information components render every thorough analysis of a regional problem extremely delicate and time-consuming. The solutions offered often lack lucidity and clarity.

It has recently been confirmed[2] that the map is one of the few efficient means that lend themselves in various forms to improvement of this situation, with which every planning organization is faced in regional studies. The thematic map, a graphic representation in map form of a selected number of components, either directly or indirectly related to the topographic surface, is especially suited to an immediate and efficient presentation of facts, plans or hypotheses for a restricted field of study.

IMPORTANT FUNCTION OF THE BASE MAP IN THEMATIC MAPPING

The geographical relationship of a theme is an essential and most important part of this kind of information. It must always be ensured by some selected base-map components of a general topographic nature. Without such external identification any mapped thematical information is absolutely useless, as it cannot be located and evaluated against the geographical background or used as a basis for regional comparisons. Our considerations must therefore be directed also towards the content and the graphical form of the base maps for thematic maps.

[1] The original text of this paper, prepared by E. Spiess, Professor of Cartography, Swiss Federal Institute of Technology, Zurich, appeared as document E/CONF.57/L.43.

[2] Jacques Bertin, *Sémiologie graphique*, Gauthier-Villars and Mouton (Paris, 1967), 431 pp.

In practice, however, the main concern in thematic mapping is generally the presentation of the special topic that is treated. The number and variety of these topics increases steadily. Each of them absolutely needs a base map that meets perfectly the purpose of the map. But can we really afford, in terms of time and costs, to spend so much cartographic effort on each thematic map by producing each time a new base map? A careful study of the map-reading and comprehension processes and of the various forms in which thematic maps are used shows that use must be limited to a few main types of base maps.[3]

Demands for detailed base maps

For the initial compiling of any thematic data some kind of work-sheet base map is needed. Its form is at this stage independent of the final function of the map. All it has to guarantee is a precise location of all the thematic material. Although much depends on the compilation method used, e.g. photogrammetry, photo or map identification, in most cases a base as detailed and precise as possible is necessary. Compilations are based on a network of unambiguous reference points to which thematic data are related by measuring, identification or estimation. The degree of accuracy of these points should be somewhat higher than that of the thematic material.

These requirements are normally met by relatively large-scale topographic maps. There is a danger, however, in using obsolete and inaccurate topographic base maps. Much too much laborious data collection in the field has become completely valueless because it has been related to such weak bases. Serious problems are caused also by the use of copies on paper instead of waterproof and stable polyester materials in the field. If topographic coverage does not exist in an area and for specific purposes, orthophotos or ordinary aerial photographs may be useful. They offer a wealth of detail which can be easily used as reference elements by specialists in the initial compilation process. In later stages they must generally be transposed into map form in order to be comparable with other data of the region.

The reverse process to that of compiling is the relating of the thematic content of the map back to the terrain. Many inventory maps and plans with legal obligation are directly taken out to the field. The information stored in map form is extracted again and located in the terrain with the help of the nearest reference points. This procedure will be the easier the more reliable the latter are. Here again a dense network of reference elements, such as one finds in detailed, large-scale topographic maps or aerial photos, is an essential prerequisite. Special care must be taken that only prominent elements, which are stable over a long period, are shown on the base map. Any other detail merely causes confusion.

It is of the utmost importance that in the conception of a topographic map series these demands are also taken into account. Topographic maps which lack a sufficient amount of detail are of scarcely any use for field inventories. From this point of view, it also seems dangerous to include in the topographic maps too many features that are subject to considerable changes over a long period of time. A careful selection of the features of topographic maps should therefore include, at any rate, geodetic controls, all stable constructional features, lakes and selected rivers, and administrative boundaries, as well as topographic details with distinct delineations. In spite of their minor importance, all the other hydrographic features, boundaries of settlements, main cultivation features and local names could also be indicated because there will be numerous themes directly related to these components. Although no grid co-ordinates may be directly necessary in the compilation stage, they become indispensable in map comparisons. They serve as a link between various data stocks, and are already widely used as a geographical data reference system for numerical information storage. In conjunction with data banks, topographic maps will remain an ideal inventory storage medium, because of the easy access to the information, easy transportability and simplicity for the general user (figure 1).

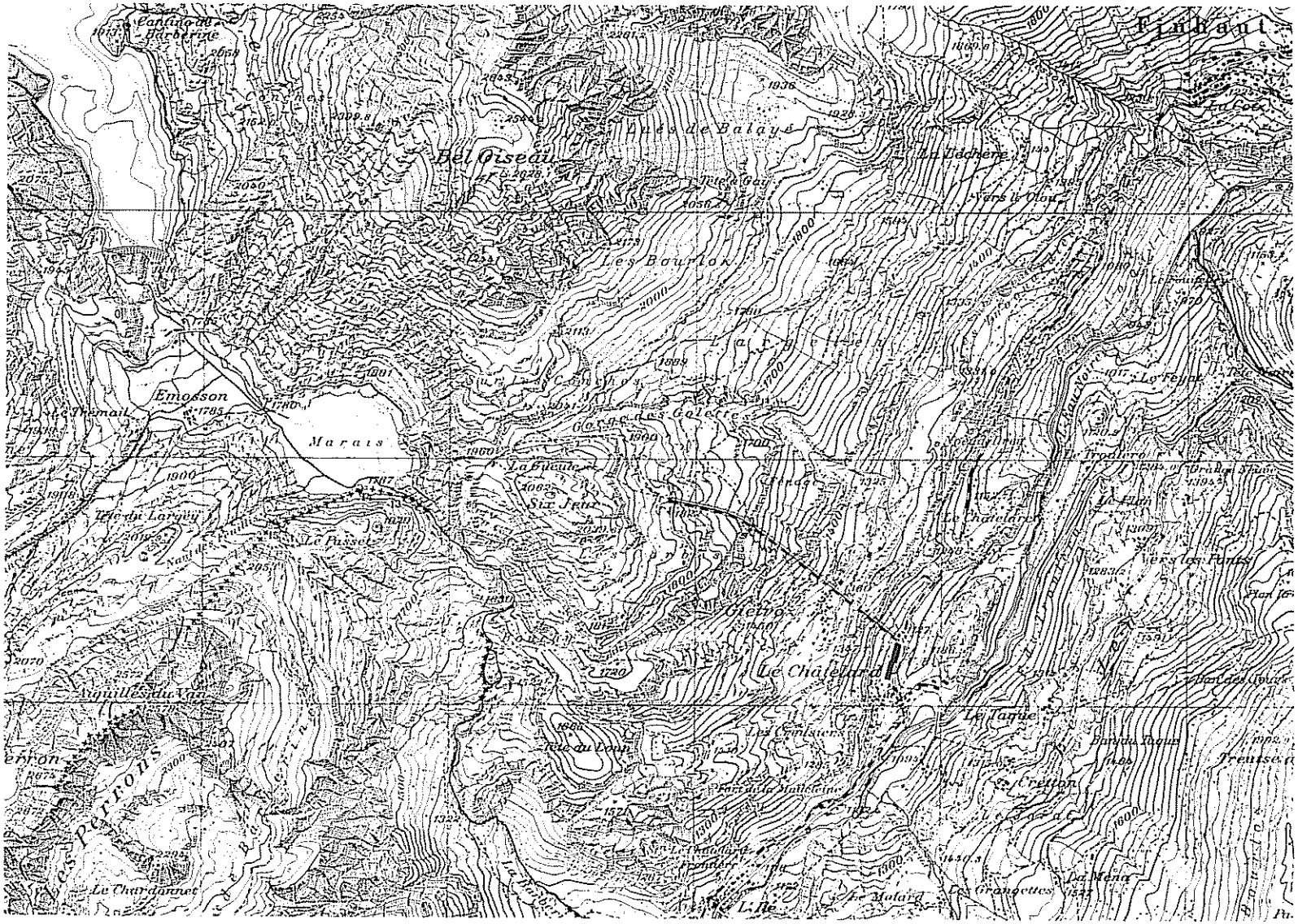
Thematic material can vary widely in its over-all dimensions and in its degree of accuracy. These two factors mainly determine the map scales needed. In order to match ideally those varying conditions, a whole range of scales of topographic maps is necessary. There is a noticeable tendency towards the larger scales which provide for miniature details. On the other hand the smaller scales are indispensable, because they are able to meet smaller format requirements or poorer and sparser information.

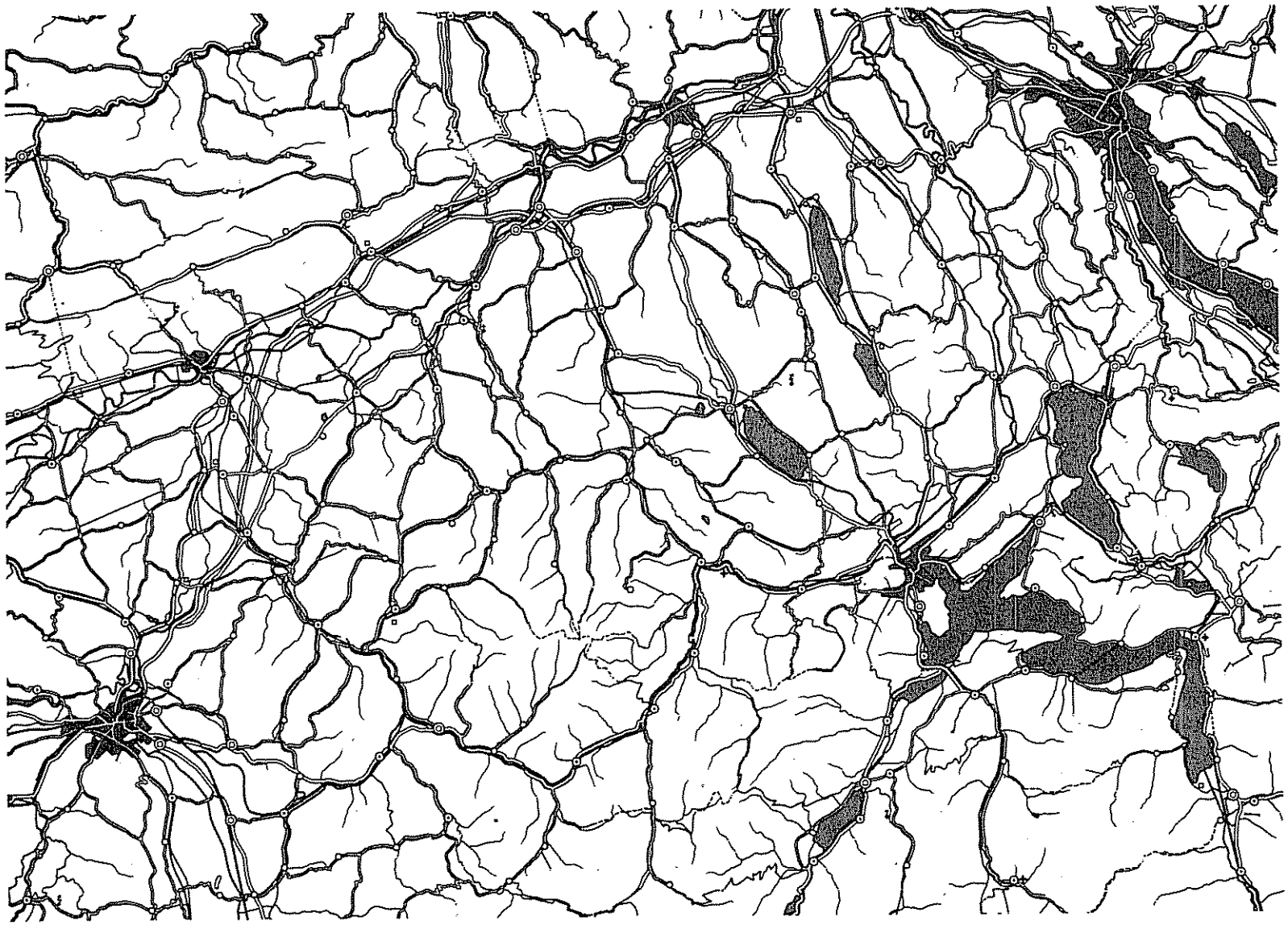
The production of topographic maps, which will be used as detailed base maps for thematic maps, is furthermore conditioned by several graphical rules. First of all, a monochrome edition must be made available. Special care must therefore be taken that the usually variously coloured lines and zones can be sufficiently differentiated if printed only in one colour. This implies a lower image density and very careful symbolization, which does not lead to confusion between the different components. This reduction to only one colour for the detailed base map is not only a step of economy; it is also necessary to increase image contrast between the base map and the thematic map, especially when the subject is complicated. The base-map image should always be in the background in relation to the thematic material, but available nevertheless. Such a separation on two visual planes can also be obtained by using lighter printing inks, e.g. grey or brown instead of black, or by screening base maps with very heavy lines. This technique can be successful when enlarged topographic maps are used. At their original scale, they contain mainly fine point and line symbols and are therefore especially suited for zonal thematic elements. Point or linear components for the topic to be represented must be rendered normally in a coarser grain. These considerations should help the editors of topographic map series to develop maps which can also be used for thematic mapping.

Demand for simplified base maps

For some other map-reading and comprehension processes the contents of a detailed base map, such as the normal topographic map, are too great. This is especially true in the case of regional comparisons of maps or map components, or when locating or delineating new facts or findings within the user's knowledge of the geography of the area. A too high image density has a disturbing effect on these processes. It creates a kind of fog for the map

[3] Ernst Spiess, *The Need for Efficient Base Maps in Thematic Mapping*, Kartographisches Institut Eidg. Tech. Hochschule (Zurich, 1970), 14 pp.


Cantalaube
Barbérine
Bel Oiseau
Les Bauloz
Emosson
Le Chemaï
Marais
Col des Golettes
Six Jeur
Le Passet
Tête du Largey
Giétro
Le Châtelard
Aiguille du Van
Les Perrons
Le Chardonnet
Le Tapie
Le Motard
Le Fenay
Les Granettes
Vers le Cloux
Vers les Ponts
Le Tauleron
Le Feuge
Le Châtelard
Le Fion
Tête du Lion
Tête du Barmet
Pierre à Stalle
Lac d'Emosson
Barrage d'Emosson
Eaux Froides
Tête du Grand Chavalard
Tête de Balay
Les Dzodzets
Les Tseppes
Les Ecandies
Les Ecandies
Les Ecandies



2359 X

Figure II. Simplified base map for regional comparisons and general location, showing a combination of the hydrographic and main traffic network and main towns at 1:500,000 (by courtesy of the Topographical Survey of Switzerland, September 1970)

reader. To meet these entirely different requirements, another series of simplified base maps is recommended for each region, in addition to the detailed base maps mentioned above.

In order to arrive at some specifications for this type of base map, one ought to look at these processes in more detail. It is a major point in favour of cartographic representations that comparisons between well-made thematic maps may lead to entirely new geographical approaches. There is no better means of communication for immediate answers to complex regional problems than maps. A first visual analysis or synthesis of an area may require additional mathematical verification, but the study of maps offers an incontestable advantage, because all decisions are made in the light of all the main relevant facts. For a given area data and information can be gathered and interpreted in a mutual context. The correlations between various components of one or several maps can be determined. On the other hand, the zonal limits or geographical positions of certain types of correlation or the lack of homogeneity can be established by comparing selected map components.

Several maps can be compared efficiently only if the corresponding image elements of the various base maps are identified immediately. This is equally true if these visual links function subconsciously. This process therefore has some special implications for simplified base maps.

First of all, image density must be reduced considerably, when compared with that of the detailed base map, in order to attract the eye more specifically. Redundant detail is no longer needed, but an optimal selection of prominent features is required. The eye is first drawn by particularly striking shapes, such as straight lines, symbols in rows, angles between crossing lines, obvious changes in curvature, symmetry, proportions and similarity to elementary shapes. In map comparisons an easy identification of such corresponding base elements is of the utmost importance. It implies the necessity to retain at least one or two base components in each map or area. Experience shows that the marked preference for the hydrographic network and the map grid makes these features compulsory for all maps, except perhaps in densely populated areas and in deserts. If these components are more or less standard for a whole series of maps, an individual choice for further base components is left open for each map. If base maps are to be suitable for comparison they must also have similar aspect, comparable image density, approximately the same colour, not too different map scales and a good generalization that retains the main characteristics (figure II).

After he has identified or compared thematic material, the map user will normally wish to locate his findings within his already existing knowledge of the geography of the area. By this process he incorporates this new information about a region into his memory. In this respect, of course, individual starting levels are far from uniform. Geographical knowledge of this kind is normally poor and inaccurate. It is therefore impossible to provide a sufficient number of good reference points for everybody. Local names, coastlines, mountains, lakes, valleys and motorways, together with some regional peculiarities, are probably the most easily remembered features. Preference should therefore be given to these components in the simplified base map.

For this second type of base map a whole range of map scales will be needed, according to the size of the region. As in the case of the detailed base map, some saving in the number of scales is possible by reducing or enlarging some main scales up to a factor of about 1.7. A series of smaller map scales will therefore have to be derived from the largest ones, with a reduction factor of 2.5 between adjacent scales. There may be some advantage in keeping each component on a separate film in order to meet most specific needs. However, some problems will arise from such a composition of separate elements, especially in the smaller scales, because the generalized elements may be subjected to considerable shifts. The same graphical rules should be observed as indicated for the detailed base maps.

Conclusion

The constantly increasing output of thematic maps has definite drawbacks for topographic mapping. On the one hand, a whole range of conventional topographic maps at different scales is required to serve as base maps in initial compilations, in all kinds of inventories and to set up legally acceptable plans. Their specifications should guarantee both a high density of accurate reference points that are stable through time and monochrome reproduction. On the other hand, almost all regional problems require extensive map comparisons with general geographical location. This process becomes efficient only if the thematic material is related to a simplified base map. Another series of comparable maps in a complete range of scales must therefore be derived from the topographic bases, featuring much less detail, but including the hydrographic network and the grid, the boundaries of larger administrative units and possibly the main traffic networks with some very general and prominent topographic features. These components can be combined according to specific needs and complemented with a selection of the most important place names according to the subject of the map.

These two map series are recommended as a minimum programme for every developing planning region. For most thematic mapping purposes they will provide an efficient base map. In a few cases the preparation of a special base map may be required.

Automatic drawing equipment will eventually offer more flexibility in future and allow for specially tailored base maps. But those already available will always be welcome. Moreover, for the time being, large-scale aerial photos and orthophotos can to some extent replace the detailed base map for certain inventories, but they will hardly be serviceable as simplified base maps. For use in intensive comparisons, such interpreted photographs must be transformed into maps so that their data can be made compatible with other data for the area. Whatever equipment is used for this transformation—that is, not only photogrammetric stereo-plotting instruments, digitizers and computer-generated plotters or cathode-ray-tube projectors, but also conventional cartographic transfer equipment—and independently of the form of representation of the thematic data, the two series of base maps will be the essential means for communicating regional information.

AGFACONTOUR FILM AS A TOOL FOR PHOTO-INTERPRETATION

Paper presented by the Federal Republic of Germany[1]

Efficiency of tonal reflection in photo-interpretation

The interpretation of aerial photographs is still largely based on a distinction between different tonal values. The problem of tonal quality and its dependence on lighting, reflection, the season and time of day, the weather and climate, the type of film, filter and photographic process is an ever-recurring topic for discussion. These questions are justified as long as most of the aerial photographs available for interpretation are black and white photos. Even if the narrow latitude of an aerial photograph's tonal range always results in overlapping of the grey tones of various objects, various examinations with panchromatic material have indicated ways of interpreting certain types of cultivations during the vegetation period. A series of systematic examinations of spectral reflection of various types of trees, grasses, cultures and soils in the visible spectral region began with Krinow's work[2] on the spectral reflection of natural formations in 1947. The reflection readings obtained showed differences in the types of plants and in the seasons of the year. By using tone scales (stepwedges) and densitometers, direct measurements were taken of tonal values on aerial photographs, in particular to distinguish between and identify field produce.

The work carried out by M. Smith Goodman,[3] D. H. Brunnschweiler[4] and particularly by D. Steiner,[5] K. Ruppert, D. Lehmann[6] and P. Meienberg[7] is all aimed at identifying agricultural cultivations by means of differences in grey tones. The sensitometric photograph can only be evaluated linearly and by interpolation, while use of a stepwedge involves sources of error associated with the human eye's power of discrimination. It is to all intents too much for the eye to detect a given grey tone from a collection of different grey tones alongside each other.

The result was that the question of clean area differentiation of tone in a black and white film could hitherto only be solved in an unsatisfactory manner. The reconnaissance ranges for grey tones have actually been extended with the inclusion of the near infra-red by means of the infra-red film and the middle and distant infra-red by means of thermal mapping. Another advance allowing a differentiated distinction of grey tones is the development of multiband cameras[8] with which filters and various film emulsions are used to render visible tonal ranges which could not be detected in conventional photographs. These improvements also include radar mapping with lateral radar.

It was only recently, at the International Symposium for Interpretation of Aerial Photographs held in Paris in 1966, that A. Reinhold, Eberswalde[9] read a paper on the identification of arable land which is wet or permanently subject to the influence of moisture, and introduced, in addition to the false colour film, the use of photographic equidensities by the Sabattier effect as a modern method of automatic analysis of aerial photographs. In photography, equidensities are the lines or, to express it more generally, the places of equal density in a photographic original. An equidensity can appear either as a line or area, depending on the slope of the original's characteristic curve. The advantage of producing equidensities is that we can extract from a collection of data one or more selected groups of information of equal kind or value.

The Sabattier method yields equidensities, which is equivalent to filtering out a density of the photographic original belonging to a selected object. To produce the Sabattier effect an exposure of a given object is made on a photographic emulsion and the image is partially developed. It is afterwards re-exposed to diffuse light and development continued to the desired degree. A critical aspect in this respect is re-exposure of the emulsions in a moist state.

What is known as the negative–positive process can also be used to produce equidensities. In this case a transparent positive (or negative) is produced from a photographic negative (or transparency). Both are then brought into exact register or slightly displaced, and a copy of this combination yields a kind of equidensity. One disadvantage is the difficulty in obtaining precise register of negative and positive and the interval between both emulsions, which can cause faults in the copy. Both the Sabattier effect and the negative–positive combination are a tedious and clumsy process which gives poor reproduction. Another method is large-area photometry with screen equidensities, but in this case reduced sensitivity must be accepted.

THE AGFACONTOUR® FILM

The disadvantages and difficulties of the equidensity processes mentioned here are not experienced in the Agfacontour® equidensity film developed by Agfa-Gevaert and scheduled for introduction into the market in the summer of 1970. In a very simple way, using a normal short process and without any critical re-exposure, the equidensities of an original can be reproduced as lines for areas of equal density of the same kind described by Reinhold.

Process:

1. Development	2 minutes
2. Stop bath	30 seconds
3. Fixer	3 minutes
4. Wash	15 minutes

[1] The original text of this paper, prepared by E. Ranz, Leverkusen and S. Schneider, Bonn–Bad Godesberg, appeared as document E/CONF.57/L.46.

[2] E. L. Krinow, *Spectral reflection properties of natural formations*, Russian Izdatel'stvo Akademii Nauk SSSR, Moscow, 1947.

[3] M. Smith Goodman, "A technique for the identification of farm crops on aerial photographs", *Photogrammetric Engineering*, vol. XXV, No. 1, 1959, pp. 131–137.

[4] D. H. Brunnschweiler, "Seasonal changes of the agricultural pattern—A study in comparative air-photo interpretation", *Photogrammetric Engineering*, vol. XXIII, No. 1, 1957, pp. 131–139.

[5] D. Steiner, "Die Jahreszeit als Faktor bei der Landnutzungsinterpretation.—Landeskundliche Luftbildauswertung im mitteleuropäischen Raum", vol. 5, Bad Godesberg, 1961.

[6] K. Ruppert and D. Lehmann, "Uber Möglichkeiten zur Verfeinerung und Objektivierung der agrargeographischen Interpretation panchromatischer Luftbilder", *Mitt. Geogr. Ges.*, Munich 46, Munich, 1969, pp. 87–97.

[7] P. Meienberg, "Die Landnutzungskartierung nach Pan-, Infrarot- und Farbluftbildern", *Munchener Studien zur Sozail- und Wirtschaftsgeographic*, Kallmunz/Regensburg, 1966.

[8] E.g., the nine-element multiband camera developed by Itek, Palo Alto/California.

[9] A. Reinhold, "Studie über die Möglichkeiten der Identifizierung von ständig feuchtebeeinflußten und vernäßten Ackerböden durch die Anwendung von falschfarbenen Luftbildern und photographischen Äquidensiten", *Archives Internationales de Photogrammétrie*, vol. XVI, "Actes du IIe Symposium International de Photointerprétation", Paris 1966, pp. II/13–25, Paris, 1967.

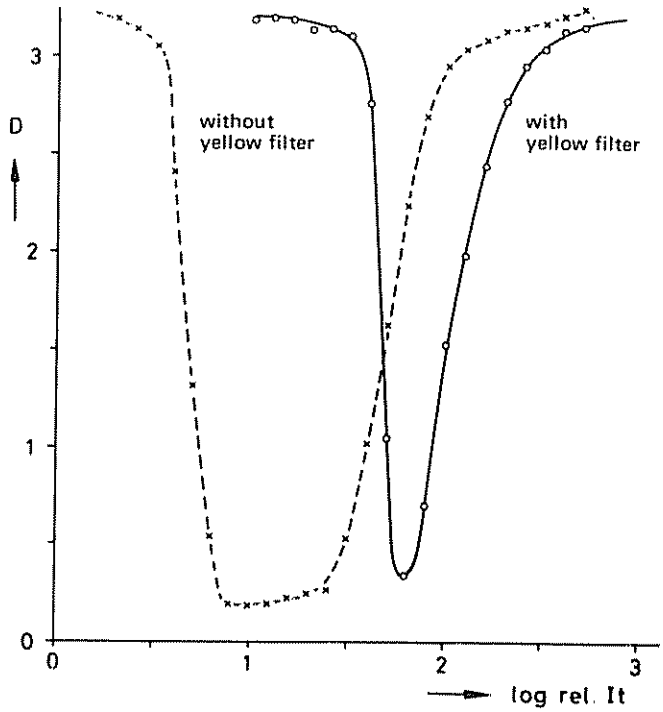


Figure I. Agfacontour film density curves after exposure to light at 2,800°K

The film's speed lies between that of normal contact and enlarging materials. Its resolving power is forty pairs of lines per mm. The film base consists of shrink-resisting polyester (film-base thickness 180/μ). This is a completely new type of photographic material which differs in important respects from traditional photographic emulsions. The new emulsion consists of a mixture of a chloride emulsion with a small quantity of a rather more sensitive bromide emulsion and colloidal silver sulphide. After exposure and development in a special developer a *positive* characteristic curve results alongside a *negative* characteristic curve with a trough in-between (see figure I). The positive branch of the characteristic curve has its maximum sensitivity in the blue spectral region, whereas the negative branch is chiefly sensitized for the green region of the spectrum (see figure II).

When exposed to white printing light (e.g., 2,800°K) the broken-line characteristic curve shown in figure I is obtained. The width of the trough corresponds to the density range reproduced as equidensity from an original—in this case, about 0.9 density units (measured from density 1 of the contour film). The log rel $I \times t$ axis represents the distribution of density in a copying original at a constant exposure time t. Here the intensity of light is inversely proportional to the density of the original.

If the proportion of blue in the printing light is reduced by a yellow filter, the blue-sensitive part of the emulsion (positive branch) then receives less light in its inherent sensitivity. As a result the positive branch of the characteristic curve is displaced to higher exposure intensities—that is to say, lower densities of the original. Since the negative branch is mainly sensitized for the green spectral region, the latter is only slightly displaced to higher exposure intensities. The result is a new characteristic curve (continuous curve in figure I) which reproduces as an equidensity a much narrower density range—in this example, about 0.2.

This means that the width of the equidensity can be varied by means of the density of the yellow filter used, i.e., the higher the density the narrower the equidensity. A suitable range of yellow filters is recommended by Agfa-Gevaert. A density range of 0.1 can still be well represented by a first-order equidensity (see figure IV).

If a photographic original such as a negative or transparency is now copied on to the contour film, the parts of the original representing a given density range are reproduced directly as transparent places on the contour film. In other words, all parts of a given density are extracted from an original. A direct proportionality exists between exposure time and the density of the original from which the equidensity is obtained. Given a constant intensity of light, this association can be represented very satisfactorily by the following equation:

$$t = t_0 \times 10^D$$

where t_0 = the exposure time at density 0
t = the exposure time at density D
D = density of the original

If, for example, an exposure of 1 second should result in the equidensity of density 0 of the original, an exposure of 10 seconds would have to be given in order to obtain the equidensity of density 1 of the original.

It is therefore possible to split up an original of a given density range into a family of equidensities of desired equidensity width by changing the exposures when copying on to contour film. All equidensities are reproduced in different colours and bound up together exactly in register. The equidensities can therefore be arranged in relation to each other so that one adjoins the other, or so that they overlap slightly. In the latter case, mixed colours are formed at the points where they overlap, i.e. when the individual coloured equidensities are arranged exactly in register, additional equidensities result.

The coloured equidensity images can be produced by the methods described in Figure III. Both methods are the same up to and including the stage at which the contour films are recopied individually on black and white films (Gevalith O 81 P is very suitable), in order to obtain individual "positive" equidensities—i.e. black equidensities with a transparent surrounding area.

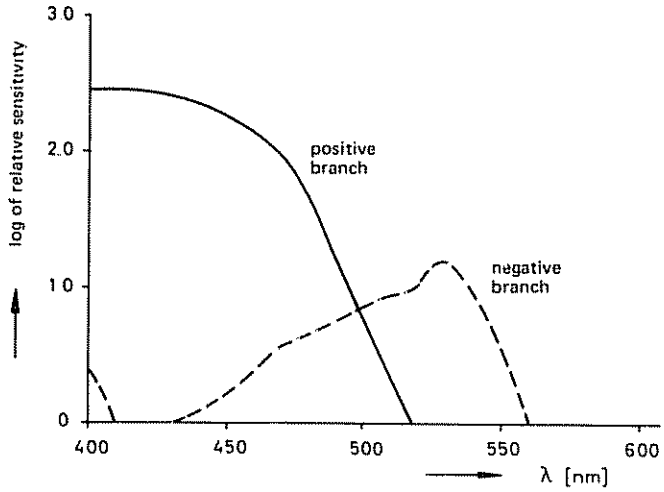


Figure II. Agfacontour film. Spectral sensitivity distribution

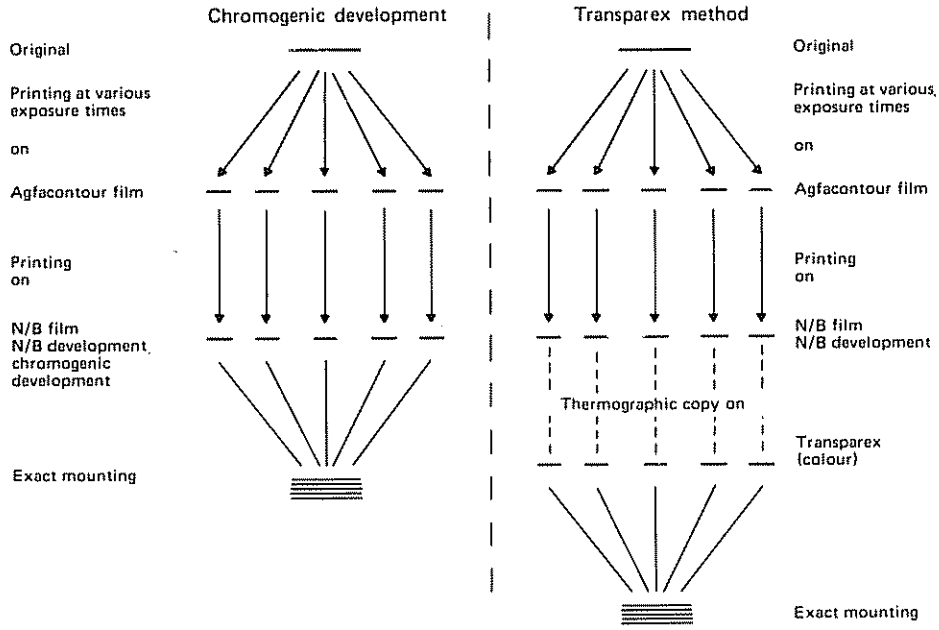


Figure III. Production of coloured equidensity images

The original equidensities on contour film can be described as "negative" since they are transparent places with a black surrounding area. The positive equidensities given black and white development can now be transformed into colour equidensities in different ways.

Chromogenic development

The silver is converted to silver halide by means of a rehalogenization bath. Colour development consists of development in normal Agfacolor developer S, to which Agfa-Gevaert yellow, magenta or cyan colour coupler is added. Any remaining silver and silver halide is removed by subsequent treatment in a bleach-fix bath.

About seven well-differentiated colours can be produced: yellow, magenta, cyan; suitable mixing of these three colour couplers yields orange, green and blue as well. The seventh possibility is to use an equidensity in unchanged form as black (silver image). Colour development permits high resolving power.

Colouring by the Transparex® method

The Agfa-Gevaert Transparex® process, a thermographic copying method, gives a coloured positive copy in a very few seconds without the use of processing baths.

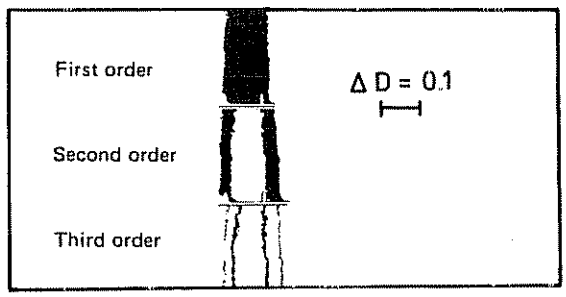


Figure IV. First-, second- and third-order equidensities of a continuous stepwedge

The equipment consists of a thermographic copier and the Transparex washing apparatus. Transparex emulsions are available in five strong colours, including black. Further mixture colours can be obtained by using various Transparex sheets for one equidensity. The speed of the Transparex method makes it preferable to colour development, although the resolving power is stated as only 10 lines per mm. If a continuous stepwedge is copied simultaneously alongside the original this provides a direct means of control with regard to the density or the original from which an equidensity is obtained.

The equidensities resulting when an original is copied for the first time on contour film are described as first-order equidensities. If a first-order equidensity is recopied onto another contour film, a very narrow equidensity is obtained from each of the two flanks of the first-order equidensity—in other words, two second-order equidensities; further recopying produces four even narrower third-order equidensities, and so on. Figure IV shows the first-, second- and third-order equidensities of a continuous stepwedge. In this respect, roughly the following density ranges of an original are reproduced as equidensities: first order 0.1; second order 0.03; and third order 0.008.

Applications

Agfacontour equidensity film has been developed as a film material for equidensitometry[10]; i.e. the conversion of a photographic original to equidensities in order to increase measuring accuracy is attracting great interest in cases where photographic originals have a more or less indistinct density distribution.

As far as geographical and other interpretations of aerial photographs are concerned, it is very useful that fine lines can be reproduced as the actual centres of density steps in the form of frontiers and structural lines and that

[10] E. Lau and K. Krug, *Equidensitometry*, London–New York, Focal Press, 1968.

areas of equal density can appear as areas of a different shade or colour.

When interpreting aerial photographs containing structures with linear demarcations such as plots of land, drainage systems, terraces, prehistoric parcels and divisions, the limits of currents, tectonic lineaments and depths in waterways, the equidensity image obtained can greatly clarify the subject for examination and speed up work. One example of linear and area equidensities is provided by the aerial photograph of the land in the community of Louisendorf on the Lower Rhine, near Kleve (figure VI*).

The black and white linear image clearly brings out the outlines of the plots of arable land and also shows the structure of the fields formed by the various plots and network of paths. It is easy to compare the outline structures from the methodical arrangement of the block of land which has, as its centre and the centre of the town, the church with which are connected the main thoroughfares of the community. The square layout of the community centre, the rectangular network of paths and the blocks divided up within the big squares reflect the picture of the land constructed on the drawing-board plan. The structural image reproduced was obtained from second-order equidensities (figure V*).

Compared with the linear structural image reproduced by equidensities, the objective method of area portrayal involving tonal differences appears to be of special importance to all sciences connected with our Earth. Whatever may be involved, arable fields, shoals or turbulent places in waterways, clouds of smoke, species of trees, different water temperatures and the salt content of the sea, or the contamination of waterways, the accentuation of selected steps of grey tones corresponding to certain very interesting phenomena remains one of the indispensable processes in interpretation of aerial photographs.

In the case of density classification undertaken with a stepwedge or densitometer, it is clear that mean values have to be plotted or interpolation has to be undertaken between the readings for classification of areas. On the other hand, a real picture of tonal values is provided by area accentuation of regions of density in the above-mentioned Agfacontour film, depending on their selection (figure VII*).

It can be expected that slight differences will also be registered and be recognizable from another colour on the density separations (e.g., patches on fields). For example, a density range of 0.26 (fog) to 1.15 (maximum density) was measured on the densitometer for the aerial photograph of Louisendorf. Here certain density ranges of the original were selected as an equidensity and coloured as required in the primary colours yellow, red and blue: the mixed colours resulting from overlapping also indicate a given density range just as the primary colours do:

Colour	*Density range*	*Mean value*
Red	0.26 to 0.48	0.37
Red-brown (from red and blue)	0.48 to 0.56	0.52
Blue	0.56 to 0.74	0.65
Green (from yellow and blue)	0.74 to 0.90	0.82
Yellow	0.90 to 1.15	1.02

It was possible to distinguish between nine density steps in a classification of density of the kind used in topographic work, this being undertaken "visually" with the aid of a twelve-step wedge on the original separation (figure V*). If an attempt is made to correlate these density steps to the above-mentioned density ranges (figure VII*) set off in colour, this results in groups which, as far as tonal value is concerned, yield the same appearance as the crops in the Louisendorf district.

The red group (1–3) covers the light-coloured fields in which the ripe or ripening grain is growing; the yellow and green group (6–9) covers the darkest fields in which hoed vegetables and fodder plants grow in mid-summer; the red-brown group (3–5) follows the light group, whereas the blue group (4–6) forms the transition to the dark fields.

A spot-check coverage of the ground cultivated by some three or four representative farms during the year of the photograph and coverage of the phenological conditions could be the key to an interpretation of the entire cultivation structure of this community; for the great value of the equidensity image lies in its faithful area recording of density and in a comparable survey of the entire image.

However, compared with the value of density estimated (generalized) in a uniform manner for every field when using the stepwedge, the accuracy of the photograph of equidensities is expressed in the many different coloured patches on the equidensity image. Their frequency and distribution on the fields should influence the relevant correlation to one of the groups mentioned. Even if a comparison of fields is always necessary for interpretation of land use, it is advisable before making the colour separations to consider how far differentiation of the density ranges must be carried. Too fine a differentiation within the same crop, which registers even the smallest shadow sections or slight differences in moisture and fertilization, would tend to make identification more difficult. In this case it is possible that the visually generalized colour photograph by the Transparex method (figure VII*) would produce a better solution. If the colours are also adjusted to the density ranges from light to dark this will facilitate a comparison with the original photograph.

A test flight over agricultural areas with a comparison of fields and preparation of coloured equidensity images by both methods (colour development and Transparex method) during the same vegetation period is recommended. A systematic examination of this kind can make use of the progress offered by coloured equidensities for land-use interpretation.

According to tests so far carried out, the points considered with regard to application of the equidensity film to land use can also be applied to other cases of tonal distinction using black and white aerial photographs, radar and thermal mapping; for example:

(*a*) The terrace cultivation method in Mesozoic sediments, which are difficult to distinguish because of their horizontal position, has been rendered visible in one colour in an aerial photograph taken in the mountains of Judea;

(*b*) The density of smoke over residential areas produced by a big Japanese steel works is illustrated in a differentiated manner by coloured equidensities;

(*c*) Turbulence in sea water and shoals can be emphasized in aerial photographs and thermal mapping of amphibious coastal areas;

* See pocket at end of volume.

* See pocket at end of volume.

(*d*) Roads subject to heavy traffic may be distinguished by the emphasis given to the dark tracks caused by tyre wear;

(*e*) Water pollution and differences in temperature (cold sources at the coast) can be made distinct by coloured equidensities.

There is no doubt that the list of useful applications for equidensities could be made even longer, for example for geological interpretation of satellite photographs with special attention given to linear structures.

Equidensity film, which was not originally intended for the interpretation of aerial photographs, appears to have a very wide range of applications in precisely this field of research.

The final example is taken from a test flight by the United States Geological Survey over Hawaii, in which the aim was to try out the thermal mapper, particularly over volcanic areas (figures VIII and IX*). During this assignment cold fresh water currents indicated in the original photograph by their dark shade were discovered off the coast (this picture shows a section to the west of the port of Hilo). There were more than 300 of these springs, which were very welcome to the island for its supply of fresh water. The coloured equidensity image of this thermal mapping photograph was produced by the colour development process, the following density ranges being selected:

Colour	*Density range*
Red	2.39 to 2.49
Yellow	2.49 to 2.59
Green	2.59 to 2.69
Blue	2.69 to 2.79
Dark blue	2.79 to 2.83

* See pocket at end of volume.

The coloured equidensity image goes far beyond the grey steps of the original thermal mapping photograph detectable and distinguishable with the human eye, and shows a differentiated graduation in sea water which the formation of mixed colours increases to a total of seven steps. The extension of the cold spring water and of the area where it mixes with the warmer sea water is thus clearly defined in this section.

REFERENCES

Krinow, E. L. *Spektral'naja otrazatel'naja sposobnost' prirodnych obrazovanij.* Izdatel'stvo Akademii Nauk SSSR. Moskva–Leningrad, 1947. English translation: G. Belkow. *Spectral reflectance properties of natural formations.* Ottawa, 1953. Natural Research Council of Canada. Technical translation No. 439.

Smith Goodman, M. "A technique for the identification of farm crops on aerial photographs." *Phot. Eng.* XXV, 131–137, 1959.

Brunnschweiler, D. H. "Seasonal changes of the agricultural pattern—a study in comparative airphoto interpretation." *Phot. Eng.* XXIII, 131–139, 1957.

Steiner, D. "Die Jahrezeit als Faktor bei der Landnutzungsinterpretation.—Landeskundliche Luftbildauswertung im mitteleuropäischen Raum". H.5. Bad Godesberg, 1961.

Ruppert, K. and D. Lehmann. "Uber Möglichkeiten zur Verfeinerung und Objektivierung der agrargeographischen Interpretation panchromatischer Luftbilder." *Mitt. Geogr. Ges.* München 43, 87–97, München, 1961.

Meienberg, P. "Die Landnutzungskartierung nach Pan-, Infrarot- und Farbluftbildern." *Münchener Studien zur Sozial- und Wirtschaftsgeographie.* Kallmünz/Regensburg, 1966.

Reinhold, A. "Studie über die Möglichkeiten der Identifizierung von ständig feuchtebeeinflussten und vernässten Ackerböden durch die Anwendung von falschfarbenen Luftbildern und photographischen Äquidensiten." *Arch. Int.* Vol. XVI, "Actes du II[e] Symposium Int. de Photo-Interprétation", Paris, 1966. S. II/13–25, Paris, 1967.

Lau, E. and K. Krug. *Equidensitometry.* Focal Press. London/New York, 1968.

UPDATING OF TIME ZONE CHARTS

Paper presented by Japan[1]

Standard time or legal time is one of the most basic elements for civil life and economic and social activities. At present, information about standard time or legal time is provided generally by time zone charts or similar publications prepared by national cartographic institutes, especially hydrographic institutes.

However, changes in standard or legal time are made so frequently in various parts of the world that it is difficult to keep up with them. Consequently, many inconsistencies are now found between published time zone charts and similar publications. This lack of exact up-to-date information constitutes not only an inconvenience but also an obstacle in the fields of navigation, air navigation and communications.

It should be noted that there is no international organization which is responsible for the collection and dissemination of information about standard or legal time. The period and interval of time are determined by the method of atomic physics in conjunction with astronomical observations. The organizations concerned with this method are the International Astronomic Union (IAU) and the Union Radio Scientifique Internationale (URSI). The length of a second as unit of time is determined by the *Conférence générale des poids et mesures* (CGPM) which comprises the *Bureau international de l'heure* (BIH) and the emission of time signals is controlled by the national institutes in accordance with the resolutions of the International Telecommunications Union (ITU).

The international organizations concerned with standard or legal time as users are intergovernmental (IHB, IMCO, ICAO and ITU) and scientific (International Geographical Union (IGU) and International Cartographic Association (ICA)).

In view of the importance of standard or legal time in social and economic affairs, it is strongly desirable that an international or national organization should act as a central information bureau on standard or legal time to keep the contents of the time zone charts and similar publications up to date.

This central bureau will be established with the approval of the above-mentioned intergovernmental and scientific organizations, and its functions will be as follows:

(*a*) Each Government is required to report immediately to the central bureau whenever any change of standard or legal time is made within its borders;

[1] The original text of this paper appeared as document E/CONF. 57/L.53.

(*b*) The central bureau updates the original edition of the time zone chart, which may consist of four sheets of the size of an ordinary nautical chart (ca. 100 × 70 cm), for example;

(*c*) The central bureau reports to all nations regularly what the standard or legal time is in the world by sending them a copy of the original time zone chart brought up to date;

(*d*) The central bureau, upon request of a national, scientific or user organization, provides it with the information on standard or legal time and, if necessary, sends it a copy of the portion of the updated chart in question.

As for the information concerning summer time or winter time, it is preferable to indicate the period to which it applies. But if it is difficult to provide this data, the applicable area should at least be indicated.

REPORT ON THE PROGRESS OF WORK UNDERTAKEN BY THAILAND TO PREPARE THE REGIONAL ECONOMIC ATLAS FOR ASIA AND THE FAR EAST

Paper presented by Thailand[1]

Background

The Fourth United Nations Regional Cartographic Conference for Asia and the Far East, held in 1964, considering the need of the region for economic maps as basic tools for economic and social development, recommended that member countries should prepare a regional economic atlas for Asia and the Far East. Thailand assumed responsibility for the compilation and publication of this atlas in co-operation with the United Nations, ECAFE and the countries of the region.

Difficulties and co-operation

The Royal Thai Survey Department encountered problems, many of which it was able to resolve by itself, while the remainder required advice and assistance from more experienced countries. Thailand therefore submitted to the Fifth Conference a report on the progress of its work. An advisory committee was established comprising, Australia, the Federal Republic of Germany, Israel, Japan, the Philippines, the Union of Soviet Socialist Republics and the United States of America, with Thailand as chairman.

Progress

The Royal Thai Survey Department established contact with members of the committee. Valuable advice was received from some of them, particularly from the Federal Republic of Germany.

The representative of the Federal Republic of Germany to the advisory committee came to Bangkok; on his recommendation the Government of Thailand asked the Federal Republic of Germany to send an advisor. This advisor is scheduled to arrive in Thailand in the spring of 1971.

In the meantime, the Royal Thai Survey Department, in close co-operation with the ECAFE advisor on demographic and social statistics has prepared a population density map for Asia and the Far East, which will be used as a pilot map. The Government of Thailand also requested the co-operation of ECAFE, through its Statistical Office Chief.

An explanatory note for the population density map displayed at the present conference follows.

In conclusion, the Royal Thai Survey Department has been facing the following difficulties:

(*a*) Inadequacy and incompatibility of the data obtained;

(*b*) Lack of qualified personnel in applied geography and thematic cartography;

(*c*) Limited budget, which enabled the Department to carry out only the initial phase of the work.

The Government of Thailand hopes that the United Nations will co-operate extensively in the most important phase of the work, namely map production.

[1] The original text of this paper appeared as document E/CONF. 57/L.67.

ANNEX

Population density map for Asia and the Far East

(*Explanatory note*)

Base map

The base map used to compile the population density map was the outline of the map of the ECAFE oil and natural gas for Asia and the Far East prepared by ECAFE at 1:5,000,000 by Lambert conical orthomorphic projection, with two standard parallels at 40° north and 10° south latitude.

This base map consists of four sheets, with the two southern ones covering south-east Asia, and India and south-west Asia, respectively, and the two northern ones covering the Soviet Union, and China and Japan, respectively. Thus the initial difficulties about the availability of the material could be realized.

Data acquisition

The population data were obtained from the United Nations demographic yearbook for 1962, which includes the data for 1960–1961, as well as unpublished data from various countries for earlier or later years.

The area units (geographical and administrative) selected for this map were obtained from Geographic Report No. 14 of 8 July 1968, entitled "Asia: Civil Divisions", and issued by the Geographer Bureau of Intelligence and Research Office of Strategic and Functional Research, of the Department of State of the United States of America. The atlas "Census of India 1961" (vol. 1) and the Batas Pembagian Administrasi Dari Indonesia (1957) atlas at 1:6,000,000 were the sources of the area units for India and Indonesia, respectively.

Data analysis

In order to obtain the population density for 1960–1961 the data for earlier years were adjusted upwards and the data for later years were adjusted downwards.

In order to arrive at a group classification of density distribution, the available atlases for various parts of the region were compared, namely, the India Census (1961); the Indonesia Landerbericht (for Java and all of Indonesia); the Iran Population Census (1966); the Mekong atlas; and the Thailand national resources atlas (1969).

Presentation

Area units for presentation on the map had to be of comparable size rather than conforming to the administrative units. The classification of the administrative units varies considerably from one country of the region to another, as may be noted in comparing the *changwat* (first-level unit in Thailand) with the Indonesian "province"—thus, the Ubon Ratchatham *changwat* (the largest after Phranakhon—that is, Bangkok) has a population of 1,130,712, whereas the "province" of East Java has a population of 21,823,020.

Hence the *changwat* of Thailand was considered as being of reasonable size to constitute the standard unit of population density on the map, but the *kabupaten* was adopted for Indonesia and the "district" for India.

For the presentation of density groups on the map, colours were selected to correspond as closely as possible to the 3122/I *Atlas der Bundesrepublik Deutschland* (population density by Kreise, 1961).

Only municipalities of 500,000 or more inhabitants are represented on the map. A single agglomeration is shown for cities which could not be shown separately, such as Bangkok and Thon Buri; Saigon and Cholong; Calcutta, Howrah and South Suburban.

The radius in millimetres of the circles representing the population of the cities was computed by using the following formula:

$$r = a\sqrt{\frac{\text{Population}}{10{,}000}}$$

where $a = 0.56$.

PROVINCIAL LAND CAPABILITY MAP OF THAILAND

Paper presented by Thailand[1]

Introduction

The preparation of a provincial land capability map of ten provinces in northern Thailand is a joint project of the Soil Survey Division and the Land Classification Division. The map will be used for broad planning of an agricultural development project for the area.

A land capability classification is made in accordance with the system written in SSR 60 (*Soil Survey Interpretation Handbook for North-east Thailand No. 60*, part II, "Land Capability Classification") issued by the Land Development Department. The land capability classification is a kind of interpretation that can be made from soil maps. The system groups soils according to their agricultural potential. Map units and soil series of the Soil Survey Division, Land Development Department, are used as a basis for this capability classification. This system groups soils on two levels or categories: (*a*) land capability classes and (*b*) land capability subclasses. Capability classes broadly group soils according to the degree of limitation in their use or hazard when they are used. Land capability subclasses group soils according to similarity in kinds of limitations. A number of assumptions must be made if soils are to be grouped consistently within the capability classification. Hence the land capability classification is an interpretative classification based on the combined effect of many soil characteristics on risks of soil damage, limitations in use, productive capability and soil management. Slope, soil texture, soil depth, effect of past erosion, permeability, water holding capacity, type of clay, etc., are considered permanent soil qualities and characteristics.

The system of land capability classification divides land into eight classes for upland crops and five classes for rice. In each class many kinds of soil are grouped together. Soils in classes I to IV for upland crops and paddy when used run little risk of damaging the soil. Soils placed in various classes of upland crops may be in completely different capability classes for paddy, since the requirements of upland crops and rice are different. Some soils have acquired steep slopes that are difficult for cultivating crops but may be suited for rubber, fruit or other trees and will be placed in classes VI and VII, since these crops do little damage to the soils. Soils that are suited for cultivable crops may be suited for pasture or other uses and soils placed in classes I to IV do not necessarily have to be cleared and farmed. Soil and water requirements for upland crops and rice are completely different; the best soils for rice are sometimes the poorest for upland crops.

A land capability system comprising both rice and upland crops would be difficult to interpret and would be too complicated for most people to use. The land capability classification is therefore divided into two parts: (*a*) a capability classification for rice; and (*b*) a capability classification for upland crops.

The land capability classification for upland crops is similar to the land capability classification system of the Soil Conservation Service, United States Department of Agriculture. Both systems divide soils into eight broad groups. The system of land capability classification for rice was developed in Thailand; it divides into five broad groups.

Description of the system

Land capability classes for paddy

Class P-I: Soils very well suited for paddy land. Soils in class P-I have few limitations that restrict their use for rice.

Class P-II: Soils well suited for paddy land. Soils in class P-II have slight hazards or limitations that restrict their use for rice.

Class P-III: Soils fairly well suited for paddy land. Soils in class P-III have moderate hazards or limitations that restrict their use.

Class P-IV: Soils poorly suited for paddy. Soils in class P-IV have severe hazards or limitations that restrict their use for paddy land.

Class P-V: Soils generally not suited for paddy land. Soils in class P-V have severe limitations, difficult or impossible to correct, that make them unsuited for rice.

Land capability classes for upland crops

Class U-I: Soils very well suited for upland crops. Soils in class U-I have few limitations that restrict their use. They are suited for growing many plants, and they may be used safely for cultivable crops, pasture or woodland.

Class U-II: Soils well suited for upland crops. Soils in class U-II have slight hazards or limitations that restrict

[1] The original text of this paper, prepared by S. Panichapong and T. Charasaiya, Department of Land Development, appeared as document E/CONF.57/L.69.

their use; they are suited for many cultivable crops, and for pasture and woodland, although the choice of crops is not as wide as it is for soils in class U-I.

Class U-III: Soils fairly well suited for upland crops. Soils in class U-III have moderate hazards or limitations that restrict their use. Choice of crops may be limited; however, these soils are suited for cultivable crops, pasture or woodland.

Class U-IV: Soils poorly suited for upland crops. Soils in class U-IV have severe hazards or limitations that restrict their use. Cultivable crops may be grown if soils are carefully managed; however, the choice of crops is limited. Some of these soils may be well suited for pasture or woodland. Many soils in this class are suitable for cultivation for a few years, but when fertility declines they are abandoned. Some soils in class U-IV are well suited for special crops, such as fruit, rubber and coffee.

Class U-V: Soils having little or no erosion hazard, but having other limitations that are impractical to remove, making them unsuited for upland crops. Some soils in class U-V are flooded for long periods, or subject to frequent overflow; some are shallow to laterite. Because of these limitations, common crops cannot be grown; however, these soils may be suited for pasture, woodland or other specialized uses.

Class U-VI: Soils having severe limitations that make them generally unsuited for cultivation and limit their use for pasture, woodland, wildlife food and cover and water supply. Soils in class U-VI have limitations that cannot be corrected, or correction is not feasible. Some of these soils can be used for trees or other crops if unusually intensive practices, such as terracing, are used.

Class U-VII: Soils having very severe limitations that make them unsuited for cultivated crops and that restrict their use largely to woodland, wildlife food and cover, water supply and recreation. Soils in class U-VII have limitations that cannot be corrected.

Class U-VIII: Soils and land types having limitations that preclude their use for commercial plant production, wildlife food and cover and water supply. Badlands, rock outcrops, limestone crags, sandy beaches, river wash, mine tailings and other nearly barren lands are included in class U-VIII.

Definitions of limitations for land capability subclasses

Capability classes divide soils according to the degree of limitation or hazard. Capability subclasses group soils within a class according to kinds of limitations.

Eight subclasses or kinds of limitations are recognized.

(1) Subclass *e*—erosion. This subclass is made up of soils for which susceptibility to erosion is the main problem or hazard. Erosion susceptibility and past erosion damage are major soil factors for placing soils in this subclass;

(2) Subclass *s*—soil limitation in the root zone. This subclass is made up of soils for which the major limitations are problems such as shallowness, unfavourable texture, stoniness or low fertility difficult to correct;

(3) Subclass *m*—lack of moisture for plant growth. This subclass consists of soils on which plant growth is severely reduced by lack of moisture after short periods of little or no rain. This limitation is due either to the inability of soils to hold sufficient water to maintain plant growth during dry periods, or to lack of water for plants in dry seasons, or both;

(4) Subclass *t*—unfavourable topography. This subclass is made up of soils whose high topographic position or distinct microrelief, such as abundance of stream channels, limits the use of crops.

(5) Subclass *f*—flooding. This subclass is made up of soils susceptible to flash floods, or in the case of upland crops, prolonged deep flooding, or both, which damage crops or limit the choice of crops. In areas where flood water rises slowly and floating rice is the main crop, prolonged, deep flooding is not a limitation for rice. However, deep and prolonged flooding is a severe limitation for upland crops;

(6) Subclass *d*—impeded drainage. Subclass *d* consists of soils whose use for crops is limited by excess water. Wetness is caused by high water table, slow permeability or slow surface drainage, or a combination of all three;

(7) Subclass *x*—salinity or alkalinity. Subclass *x* is made up of soils for which the major limitation is salinity or alkalinity;

(8) Subclass *a*—soil acidity. Subclass *a* consists of soils for which strong acidity difficult to correct is the major limitation in their use for crops.

The dominant kind of limitation or hazard that limits use determines the assignment of group of soils to capability subclasses. For example in a classification for upland crops, gently sloping soils with erosion as a major limitation would be assigned to subclass U-II*e*. If more than one subclass symbol is shown, the symbol will be listed in order of importance as it affects the class level. For example, in a classification for paddy lands, a group of gently sloping, moderately permeable soils on which it is difficult to impound water, would be assigned to subclass P-IV*ts*. Rarely will more than three subclass symbols be needed to give adequate soil groupings.

LARGE-SCALE MAPS IN POPULATED AREAS

Paper presented by the Republic of Viet-Nam[1]

The past few years have seen unprecedented dislocations in the population of the Republic of Viet-Nam, due mainly to the following:

(*a*) A strenuous effort by the Government to organize war-refugee camps and establish "new-life hamlets";

(*b*) A too rapid increase in the population, which rose from 13 million in 1958 to 16.3 million in 1968, representing a mean annual growth rate of over 2.5 per cent, which is a very steep rise when compared with 1.7 to 1.8 per cent for the world population as a whole.

(*c*) An unprecedented migration of peasants, who are ready to abandon the land to which they have clung for a thousand years and are now leaving the villages for the greater security of the towns, where they can find more remunerative work by replacing the manpower absorbed

[1] The original text of this paper appeared as document E/CONF. 57/L.84.

by the armed forces, and for the surroundings of allied troop camps, which provides opportunities for an easier life.

Shantytowns are springing up more rapidly than mushrooms. Satellite towns with a very dense working population (3,000 inhabitants per hectare) occupying incredibly small spaces are forming rapidly in the suburbs of the capital, Saigon, and of other major towns, such as Hue, Da-Nang, Plei-Ku, Qui-Nohn, Nha-Trand, Bien-Hoa, Vung-Tau and Can-Tho. The "green belts" which once served as "safety valves" and recreation areas for the big towns and were the pride of town planners, are gradually being invaded by buildings and becoming an increasingly rare luxury.

This has so changed the aspect of some areas that the 1:50,000 scale of our base-map series covering the whole country and the 1:25,000 scale of our maps of heavily populated areas are now proving too small, since they do not provide sufficient detail for certain studies.

Recognizing the need for up-to-date, large-scale, detailed maps for the study of development projects and urban facilities, the National Geographic Department has drawn up a 1:5,000 and 1:10,000 mapping programme which will to some extent supplement the existing town maps. The Department has decided, first, that the large-scale maps should cover rectangular sections of 4×6 km. This makes it easier to join sheets when several contiguous areas are mapped.

The 2,100 km², Bien-Hoa–Saigon area, which includes the capital and the two major centres of Bien-Hoa and Phu-Chong, was chosen as a pilot project and mapped at 1:5,000. Photographic coverage at 1:10,000, detailed triangulation and up to third-order levelling have been carried out for this area. A stereo-plotting control was prepared for 1:10,000 stereoscopic pairs with a view to subsequent aerial triangulation by a foreign firm under contract.

The towns of Tay-Ninh (north-west of Saigon, near the Vietnamese–Cambodian frontier) and Vung-Tau (an east-coast port) have been mapped at 1:10,000, as well as the Tan-An–My-Tho area, which extends along National Highway No. 4 linking the capital with the country's southernmost provinces. Apart from the detailed geodetic surveys—triangulation, traversing and levelling—to improve the terrain, a stereo-plotting control framework has been prepared for double-photography aerial triangulation with the use of 1:50,000 and 1:10,000 aerial photographs. Four stereo-plotting control points have been established for each 1:50,000 stereoscopic pair, one for each corner. A Wild A7 Universal Autograph is being used to obtain orientation points for the 1:10,000 stereoscopic pairs.

The 1:5,000 and 1:10,000 maps are plotted with Wild A8 and a Kelsh plotter. The operator accurately plots everything he sees: buildings with contour, roads with both edges and the centre line of narrow roads, railways, embankments, hedges etc.

The plotting is first done on transparent sheets (this facilitates reproduction on photoprint paper for prompt distribution of the plotting sheets to users). Subsequently, it is done on plastic-coated sheets, ordinarily used for scribing, with a fixed-point scriber. Colour separation proceeds simultaneously with plotting. A three-colour product, for example, requires three plates: one for planimetry, one for hydrography and the third for contour lines and spot heights.

Relief is shown by contour lines at 1-m intervals, with four or five spot heights per square kilometre. In the case of Vung-Tau alone, its highly varied relief is represented by 5 m contour lines with 2.5 m intermediate lines; spot heights are indicated at cross-roads and at the corners of crop lands.

Identification is carried out in the field by a specialized team, called a "field classification team", which makes use of aerial photographs. The team makes a quick tour of the area, notes important structures—churches, pagodas or other religious buildings, schools, public buildings etc.—classifies crops and vegetation, and roads—asphalted, macadamized or hardened earth roads, and at the same time collects toponymic and administrative-boundary data.

The National Geographic Department is not at present contemplating the definitive publication of these maps in colour. A simplified version is being edited so as to make cartographic material available to users as quickly as possible. The plates employed consist of:

(*a*) One plate with planimetric detail;

(*b*) One plate with hydrographic data;

(*c*) One plate with contour lines and spot heights;

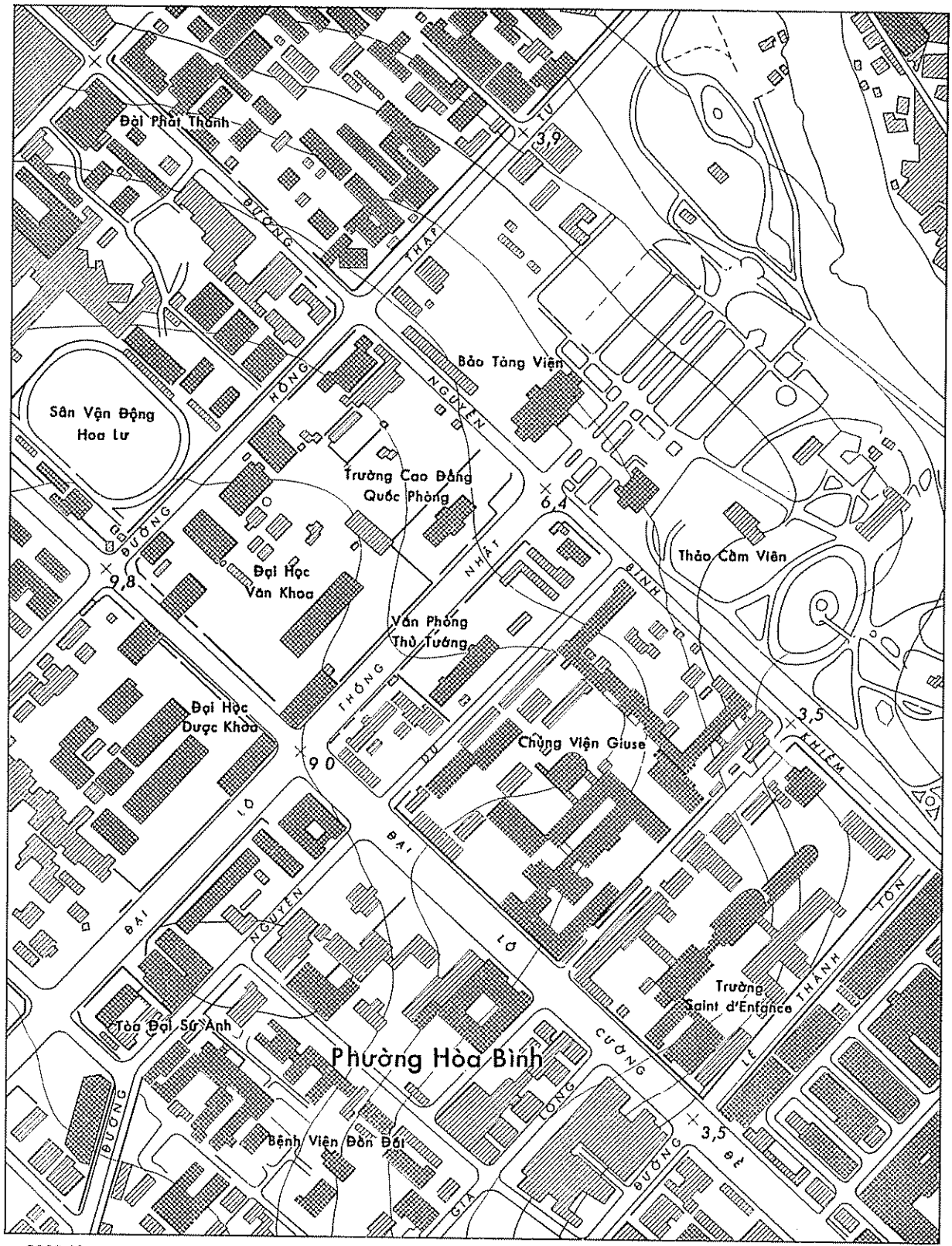
(*d*) One transparent plate with lettering and marginal data.

This set of plates can be utilized in making either reproductions on transparent sheets as required by the map user; or a provisional edition in three colours: planimetry and toponymy in black, hydrography in blue, contour lines and spot heights in brown.

The progress made with large-scale mapping during 1968–1970 may be summed up in the following table:

Region	*Area (km²)*	*Scale*	*Total number of sections*	*Work done so far (number of sections)*		
				Plotted	*Edited*	*Published*
Saigon–Bien-Hoa	2,100	1:5,000	100	38	12	0
Tay-Ninh	216	1:10,000	9	9	9	9
Vung-Tau	216	1:10,000	9	9	9	9
Tan-An–My-Tho	552	1:10,000	23	19	7	0

The 1:5,000 and 1:10,000 scale maps referred to contain all the information needed for town and country planning. For the purposes of a map that is clear, accurate and that can be produced quickly and cheaply, the National Geographic Department considers the results obtained satisfactory.



2360 X

Figure I. Fragment of the 1: 5,000 map of Saigon



Figure II. Fragment of the 1:10,000 map of Vung-Tau

THE STATE OF THEMATIC MAPPING IN HUNGARY

Paper presented by Hungary[1]

The cartographic requirements of the general public, of education and, through the preparation of national and regional atlases, those of national and regional planning are met in Hungary by the cartographic establishment, "Cartographia"; the other thematic maps are prepared and published by the institutions of the various scientific specialties.

Since the foundation of the cartographic establishment in 1954, the importance of the various maps published is illustrated by the following figures: in total, 825 different maps were produced in 38,000,000 copies, including eighteen atlases in 11,000,000 copies. Many of the maps issued are intended for the tourist. Thus far fifty-five town maps have been published of Hungarian and foreign towns, seventeen tourist maps of Hungarian regions, nine road maps of European countries and road atlases of various European regions.

World atlases and reference maps help to inform the public in the fields of political and economic geography and to meet cultural demands in general. The most important of these publications is the illustrated political and economic world atlas, comprising 185 map pages, which has seen four editions and a total of 130,000 copies. Special mention should be made of the international bi-monthly *Cartactual* comprising maps in English, French, German and Hungarian and indicating geographical and political changes, as well as recent technical projects throughout the world.

After the Second World War in Hungary, it became possible to centralize the management and organization of economic life. The establishment and realization of the aims of economic development envisaged by the Government required the initiation of thematic mapping.

GEOLOGICAL AND GEOPHYSICAL MAPS

In order to meet the demands for power and raw materials of the rapidly developing industry as fully as possible from Hungarian resources and so as to comply with basic plans for establishing new mines, in-depth geological and geophysical maps were prepared in the early 1950s. However, the explorations also required a new geological reference map. By 1956 the new geological map of Hungary at 1:300,000 was completed. The stratigraphic map which also identifies the most important types of rocks covers ninety-seven formations.

Owing to the growing number of thermal water and hydrocarbon prospecting holes, knowledge is increasing with regard to the structure and conditions of stratigraphic and geological evolution of the basins which play the most important role in the country's geological structure. On the basis of the growing quantity of data and international large-structure syntheses, the orographic map of Hungary was completed in several versions in 1967 at 1:1,000,000; the compilation of paleogeographical and paleogeological maps was also begun.

Knowledge of the deep structures is facilitated by large-scale geophysical research which has resulted, among other things, in publication of the map of seismic intensity and frequency in Hungary.

HYDROLOGICAL MAPS

The geological mapping of the plain regions of the country carried out from 1950 to 1955 also included the determination of depth and quality of subsoil waters. The results of regular observation of more than one million subsoil water wells were published in a set of six maps at 1:400,000. At the same time, an analysis of the data of artesian wells was undertaken in Hungary. The results of this scientific work, complemented by the data of subsoil water prospecting, are contained in the hydrogeological atlas of Hungary issued in 1961 and comprising seventy-three maps at an average scale of 1:1,000,000.

PEDOLOGICAL MAPS

Work on the soil map series at 1:25,000 started in 1933 was completed in 1948. On the basis of this series, the pedological map series of Hungary comprising 114 sheets at 1:75,000 was prepared. These soil maps represent the water-holding, aquiferous capacities, humus content and chemical composition of the soils and at the same time facilitate the establishment of optimum harvest lands for specific plants.

In order to promote preventive measures against erosion, a map series at 1:75,000 was prepared from 1953 to 1960 showing the effects of erosion in Hungary.

PHYSICO-GEOGRAPHICAL THEMATIC MAPS

The scientific evaluation and synthesis of the trends and importance of the evolution of the relief resulted in the early 1950s in the mapping of a variety of surface forms and their evolution and a compilation of geomorphological maps. This mapping started in Hungary in 1959 in the Geographical Research Institute of the Hungarian Academy of Sciences. The detailed, uniform legend of the survey was completed in 1963. The legend comprises 346 signs in eleven colours, and special emphasis is placed on the representation of the evolution's dynamics.

The direct practical utilization of the research undertaken in the field of physical geography gave rise around 1960 to the method of physico-geographical regional evaluation, whereby the physical conditions are studied with reference to their effects on the economics of natural resources and the theoretical economic potential of the region is established by comparison of specific factors. The application of this method required the development of new methods of cartographic analysis.

The dynamics of surface waters, their surface-forming effects and the changes of river-beds are represented by hydrogeographical maps. Hydrogeographical mapping is closely associated with the new soil-erosion maps which promote the development of agricultural production.

CLIMATOLOGICAL MAPS

The International Meteorological Organization was already considering as one of its main objectives, in the

[1] The original text of this paper, prepared by Prof. S. Rado, Director, Cartographic Department, National Office of Lands and Mapping, Budapest, appeared as document E/CONF.57/L.91.

early 1930s, publication of the climatological atlas of the world. The aim of this important work was the issuance of climatological atlases compiled by individual countries according to uniform principles. In 1937 the Hungarian Institute of Meteorology started the compilation of a climatological atlas of Hungary, but this work was interrupted by the Second World War.

In 1950, with a view to facilitating the organization and planning of agricultural production and management of water supplies and transportation, the publication of the climatological atlas of Hungary was again given prominence. The single maps of the atlas were compiled on the basis of the cumulative average data from 1901 to 1950. The climatological atlas comprising 130 maps at an average scale of 1:1,125,000 was published in 1960.

The scientific depth and attractive presentation of this atlas gained international recognition. Accordingly, the World Meteorological Organization and UNESCO entrusted the Hungarian Institute of Meteorology with the preparation of the first volume of the climatological atlas of the world, namely, the climatological atlas of Europe. The maps are prepared and printed by the Cartographic Establishment of Budapest. The atlas will be issued in 1971.

Land-use maps

In addition to maps showing soil quality, the organization of large-scale farming also requires land-use maps showing the location and qualitative evaluation of individual branches of agriculture. In Hungary an attempt was made to prepare such maps in the late 1950s. The first map was presented in Stockholm in 1960, at the congress of the International Geographical Union. Since then, the legends for several scales and the methodological instructions for the detailed survey have been completed in close co-operation with the geographers of the socialist countries.

With a view to encouraging land-use mapping in Hungary, the annual international exhibition and conference on thematic mapping organized by the Hungarian National Office of Lands and Mapping dealt with this subject in 1968. The scientific discussions and evaluation of the maps exhibited also had a stimulating effect on Hungarian cartography.

Thematic economic geography planning maps

The Hungarian Ministry of Construction and Town Planning regularly prepares map series and individual maps for the purpose of establishing development plans for settlement networks and specific economic regions. Moreover, considerable economic geography mapping is carried out by the Hungarian Ministry of Transport and Post. Postal service route and bus route maps, as well as shipping and air traffic maps are issued regularly.

National atlas of Hungary

A comprehensive collection of Hungarian thematic maps is contained in the national atlas of Hungary, published in 1967 in Hungarian and English and comprising 268 thematic maps on 112 pages. The compilation of this atlas had a notable effect on the development of Hungarian thematic mapping:

(*a*) It drew attention to the advantages of cartographic representation and to the abundance of themes suitable for such representation;

(*b*) By experimenting with the most expressive methods of representation, it promoted to a large extent the development of Hungarian thematic cartography;

(*c*) It facilitated the completion of thematic map work; thus for this atlas the following were prepared: the geomorphological and land-use maps of Hungary at 1:500,000, and the complex economic geography map of Hungary at 1:525,000, which attempts to represent a synthesis of agriculture, industry and transportation. These maps were published in the atlas at 1:1,000,000.

Regional atlases

The regional atlases represent in the same way as the national atlases the natural resources and the economic life of particular regions of the country in the form of thematic maps. Owing to their limited printings, not more than two or three colours are used. A clear, well-arranged expression of the thematic contents therefore raises serious methodological problems. In most of the maps included in the first regional atlas published in 1968, the regional atlas of south-eastern Hungary, this problem was solved with some success. The preparation of the atlases of the other five regions of the country (south-eastern Transdanubia, north-eastern Hungary, northern industrial area, north-western Transdanubia and central industrial area) is also under way.

SCHOOL CARTOGRAPHY

Paper presented by the Union of Soviet Socialist Republics[1]

In the USSR, the series of maps and atlases intended for education is one of the most complete. The schools of general education, which number more than 200, comprise over 49 million pupils. The geography and history courses require wall maps and atlases. Maps are also needed in many technical schools. Even in the high schools, some branches of science cannot be mastered without maps. Accordingly, the preparation and publication of maps in conformity with the aims and programmes of Soviet education have become an important State concern.

The compilation and publication of school maps and atlases form part of the Central Administration of Geodesy and Cartography (GUGK). The printing of such maps

[1] The original text of this paper appeared as document E/CONF. 57/L.110.

and atlases takes up about 70 per cent of capacity of the cartographic workshops of GUGK.

The centralized production of school maps and atlases made it possible to provide the schools with the cartographic training aids that they required.

A constructive co-operation has developed between cartographers and teachers of geography and history. The maps and atlases are examined by a special editorial board and approved by the methodological services of the Soviet Ministry of Education.

Wall maps and atlases are now available for nearly all types of geography and history courses. Maps and especially atlases are issued in a great many copies.

From the beginning, the school maps were published in various languages spoken in the USSR. In addition to the colour maps, there are many blank maps to help students learn geography and history. In 1969, 395 million copies of blank maps were issued.

Thus far 460 geographical and historical wall maps have been issued for schools. Some series of geographical maps of the world, continents, individual countries, the USSR as a whole, its republics and regions are also available. Depending on the school programme, political, economic, physical and population maps are included in these series.

Recently, a large series of maps of the USSR regions was issued to be used in the schools for the study of regional characteristics. These maps include not only specific physical features of the various regions, but also economic and agricultural data, and the location of historical and other monuments and places of interest for tourists.

The historical maps series are also numerous and varied, and relate to the various historical periods in the programme of studies. Several series of maps relate to the history of the USSR, ancient history, history of the Middle Ages and modern history, as well as to contemporary history.

Six geographical school atlases are available which contain the training materials needed for all physical and economic geography courses for grade 4 up to grade 9. The historical atlases, which number nine, have the same subdivisions as the wall map series which correspond to the history course subdivisions. In 1969, nearly 19 million copies of geographical and historical atlases were published. All these atlases are intended to be used for a period of from one year to eighteen months. They do not take up much room and they are inexpensive, with a flexible binding.

In addition to the mandatory small geographical atlases corresponding to the various kinds of courses, a "School Atlas of the World" is available, which contains all the materials of the geography programme. The third edition of the "Geographical Atlas for Teachers" has also been issued.

Some years ago, much work was done to compile and publish several series of special educational maps intended for high-school geography departments.

Soviet cartographers have by now acquired much experience in the compiling of school maps; they apply basic principles and methods which make it possible to issue all the training aids which the schools require.

On wall maps and school atlases, the cartographers endeavour to show the regularities and interrelations of the various elements in the natural environment (relief, climate, soils, vegetation and so on); on geographical and historical maps they try to reflect past, present and future facts in a dynamic way and to show the development of industry and agriculture.

With regard to contents and design, all school maps and atlases are conceived with such factors in mind as the type of course, the age of the pupils and the programme and textbooks used. The complexity of the maps increases as students proceed from the lower to the higher grades.

The school maps and atlases, especially those for the elementary grades, are presented in a most effective and visually striking manner; colour illustrations are widely used.

The educational maps are published in series, which is convenient from the methodological, editorial and technical points of view.

On maps of the same series, the mathematical elements (scales and projections), the principles of elements selection and the conventional signs are standardized. This makes it easier for the pupil to compare the maps and go from one to the next more easily.

School cartography requires research and experimentation; this work has a continuing character in the USSR.

New types of school maps are in preparation, and attempts are made to increase the clarity of the maps, especially the representation of relief. Experiments have been attempted in the direction of a more complete and more scientific standardization of conventional signs to ensure that the wall maps correspond to the atlases. More rational methods for editing, compiling, designing and printing of school maps and atlases are also being sought, and the possibility of reducing the number of colours is being investigated. This research work should improve the quality and reduce the cost of the maps.

AGENDA ITEM 12

Small-scale mapping

RADAR MAPPING FOR EARTH RESOURCES EXPLORATION IN INDONESIA

Paper presented by Indonesia[1]

Radar mapping, which is known as the SLR (side-looking radar) system, is a system of mapping based on the use of radar. This radar operates at very short wave lengths which produce high-resolution images owing to the reflectance characteristics of the Earth's surface. The radar image is a record of the interaction of electromagnetic radar waves transmitted to Earth and returned in a non-uniform manner to produce a composite image of the area being mapped. A special camera records each line of scan on film which moves at a speed proportional to the aircraft ground speed, producing an image similar in appearance to an aerial photograph.

The radar image is recorded on a continuous strip throughout the flight. The scale of the radar image varies from 1:98,000 to 1:225,000, depending on the flight altitude above the terrain.

The side-looking radar system can operate in all kinds of weather conditions during day or night. This system has been used for a number of years for mapping certain areas in Indonesia. It has been used in conjunction with the exploration of Earth resources, especially in mineral and oil explorations, and for geological and agricultural surveys as well as for natural resources inventory.

General situation

Geographically, Indonesia is located between 6° north latitude and 11° south latitude, and extends from 95° to 140° east longitude. The archipelago consists of many islands, and is spread out between two continents, Australia and Asia. The approximate total land area is 1,904,000 km^2. The large islands are Kalimantan (540,000 km^2), West Irian (397,000 km^2), Sumatra (435,000 km^2), Sulawesi (172,000 km^2) and Java (127,000 km^2). The remaining islands occupy less than 100,000 km^2 and include some very small, isolated rocks.

Indonesia is a tropical country characterized by high temperature, high humidity and much rainfall. Most of the country is covered by dense forests; a relatively small part of this forest has been exploited. Even in Java, a very densely populated island with a population of hundreds per km^2, 20 per cent of the area is still covered by forests. In the islands where population density is low, such as in Kalimantan, Sumatra, and Irian, forest coverage can be as high as 70 to 80 per cent of the total land area.

The mean annual temperature above sea level is 26°C or more, with a mean humidity of 80 per cent. The annual rainfall goes up to 2 m.

It usually rains in the tropical areas heavily and frequently, and this has a marked effect on the geological condition of the area. Rainfall combined with humidity and high temperature intensifies the weathering process of rocks. The effect of the weathering process is very important, since several minerals in Indonesia are found in weathered rocks or originate from weathered rocks.

Geological phenomena such as volcanic activity, gravity anomalies and seismic and geosynclinal movements which occurred during the geological period play an important role in mineral resources in Indonesia. The area covered by topographic maps at scales from 1:50,000 to 1:25,000 is very limited; most of these maps cover Java and a small portion of Sumatra and Kalimantan. The total area covered by maps at 1:50,000 or larger does not exceed 10 per cent of the entire country. The other islands are usually covered by small-scale topographic maps (1:500,000 up to 1:1,000,000), and there are many islands which have not been mapped at all. Owing to the lack of large- and medium-scale maps it is difficult to conduct Earth resources inventory or exploration surveys.

Aerial photography

Prior to the Second World War, the utilization of aerial photographs was very limited. In the years 1945–1960 aerial photographs were used mainly for military purposes.

In 1960 the Government established the Aerial Survey Institute to cope with the increasing use of aerial photographs of a non-military nature; a year later the Institute became the State Enterprise of Aerial Survey (P.N. Aerial Survey). The aerial photographs were taken by using Wild RC-8 or T-11 aerial cameras installed in DC3 aircraft.

Since 1961 the aerial photography operations have been intensified and the negatives have been systematically filed in a library. The aerial photographs are at scales of 1:5,000 up to 1:40,000.

The photographs are used for civil mapping and exploration purposes. Topographic map coverage and air photo coverage are far from adequate at present, since only 30 per cent of the whole archipelago is covered.

The Government of Indonesia views as nationalized activities all surveying activities carried out within

[1] The original text of this paper, prepared by M. Fargani, P.N. Aerial Survey, Djakarta, appeared as document E/CONF.57/L.73.

national boundaries. All foreign survey companies operating within Indonesian territory are therefore considered as sub-contractors of the P.N. Aerial Survey with the exception of KLM-Aerocarto Indonesia, 40 per cent of the shares of which are owned by the Government of Indonesia. Subcontractors operating in Indonesia at present are Techdata, Casco, Teledyne, Lockwood, Aero Service Corp., and the like.

In a tropical climate such as in Indonesia, the weather conditions and particularly the cloudiness is an important factor that influences the aerial survey missions. When the weather is cloudy, the crews are compelled either to wait for a long time in operation bases far from the home base or to return without having completed their mission.

The effective time for producing air photos is limited since the area to be mapped is open only for a relatively short period. Early in the morning, the mountainous area is covered by mist; it clears up for a few hours, then, before noon, clouds form from 2,000 ft to 13,000 ft above the ground and cover the area. The unproductive time caused by weather conditions significantly increases the cost of aerial photography.

SIDE-LOOKING RADAR FOR EXPLORATION

Airborne side-looking radar was developed as an all-weather, day-or-night technique for mapping of surface areas which could not be photographed by using conventional methods.

Side-looking radar developed for high resolution mapping of military targets has been applied to the aerial exploration of Earth resources for non-military purposes, especially to oil and mineral exploration and other mapping uses.

In Indonesia, where topographic maps at large to medium scales do not cover the whole area and where the aerial photographs cover only a small part of the country, the side-looking radar system for exploration purposes is very useful. In the stage of reconnaissance or preliminary survey, the radar images at from 1:20,000 to 1:225,000 give much more reliable data and can be obtained despite frequent cloudiness, which for conventional aerial photography is a decisive factor.

At the present time, about thirty-five foreign oil companies and more than six foreign mineral contractors are operating in Indonesia. Many of them need radar imagery over most of their concession areas, since there are no aerial photographs or topographic maps covering these areas.

Area covered by the SLR system

Area	*Contractor*	*Exploration*	*Area coverage (km^2)*
Central Sumatra	Total Oil & Co.	Oil	3,010
Northern Sumatra	Mobil Oil & Co.	Oil	11,700
South-eastern Kalimantan	Union Oil & Co.	Oil	14,750
West Irian (coast)	Phillips Oil & Co.	Oil	26,304
Misool/Onin Peninsula	Pertamina/Phillips	Oil	37,050
West Irian (inland)	Kennecott	Copper	20,886

Several foreign mining contractors are using the side-looking radar system to collect geological data in some parts of the country. The list above shows that only a small portion of the country is covered by radar photos.

Radar system parameters

The system may be operated at three different range sweep settings for dual-polarized side-looking radar imagery. The width on the ground of each strip mapped could be 9, 13 or 21 km depending on the altitude of the aircraft during the flight. One or two kilometres of the strips located directly under the aircraft are usually unsatisfactory.

Slant range sweep (km)	*Ground range sweep (km)*	*Optimum altitude above ground (ft)*	*Approximate radar film scale*
7	9	9,000	1:98,000
10	13	12,500	1:140,000
16	21	20,000	1:225,000

Percentage of area coverage

At least 95 per cent of the collected radar images will be usable good-quality images. If the percentage is lower over the area of interest, excluding shadow areas, a second flight to acquire usable data at no additional cost will be required.

After each flight the radar film is processed and the images are reviewed in order to determine the percentage of coverage, and the quality and usable value of the images prior to acceptance.

Radar image interpretation

The quality of radar photos is very similar to that of conventional photos. Strong signal returns, light tones are usually indicative of prominent cultural features or man-made structures. Intermediate energy returns, medium grey tones may indicate areas of open country where the terrain is flat and smooth. Weak returns, denoted by dark images, usually indicate the presence of water and hydrological features.

Cost of side-looking radar survey

For implementation and complete acquisition of side-looking radar images, the cost is $US 3 per km^2. For an area exceeding 16,000 km^2, the cost is $US 2.83 per km^2. For additional copies of SLR imagery at original scale (duplicate) negative or positive film format, or positive paper print format, the cost is $US 0.75 per running foot. For mosaics including images at 1:216,000 (image acquisition scale) and at 1:50,000 (image interpretation scale), the cost is $US 0.55 per km^2. For interpretation tracings including surface drainage overlays and geology/geomorphology overlays registered on 1:50,000 sheets, the cost is $US 1.93 per km^2.

Radar system capabilities

The need for obtaining ground information accurately under cover of darkness and during all-weather conditions

was established during wartime operations. There are several radar capabilities governing interpretation, as follows:

(*a*) The composition and conditions below visual rock and soil surfaces can be "read" by analysis of absorbed or modified signal returns;

(*b*) The vegetation can be penetrated to detect subsurface information, such as the presence of water under marsh grass;

(*c*) The texture of terrain-surface materials down to small gravel size can be read directly on radar displays;

(*d*) The moisture content of the terrain can be determined when temperature data are available;

(*e*) The surface temperature can be determined when the moisture content of terrain materials is known;

(*f*) Selected radar bands can be used to read the metallic content of surface and near-surface features. With refined equipment, it may one day be possible to selectively filter a radar indicator in exploring for iron, bauxite and the highly ferruginous magnetite sands that commonly also bear titanium, rare earths, and radioactive minerals.

(*g*) Terrain properties of a snow cover or of features beneath a snow cover can be determined. The ability of some radar systems to penetrate clouds and atmospheric haze makes them especially valuable for obtaining images on overcast or stormy days. As a rule, radar images can be obtained wherever aircraft can be sent aloft.

Advantages of the SLR system

Side-looking radar makes it possible to see through clouds; map independently of natural lighting; produce imagery in a continuous strip map requiring less time for photo-interpretation; recognize the exposed geological surface easily (the longer the radar wave length at which radar operates, the better the radar penetrates vegetation. In some areas covered by dense vegetation, it reveals the geological structure of the terrain); the contrast of surface features in radar images is strikingly more pronounced than in aerial photographs; the radar APO-97 system produces two images or photos of different polarization. Certain geological structures may stand out more clearly in one than in the other.

Disadvantage of the SLR system

Owing to its small scale, side-looking radar does not yield much information for detailed study; it does not provide information on the shadow zones of mountainous areas; and it is not suitable for topographic mapping.

SLR MAPPING APPLICATIONS

Geological engineering maps

Side-looking radar imagery has proved to be an invaluable supplement to both aerial photography and ground mapping in geological engineering. Side-looking imagery has discovered lava, sand, fragmentary volcanic materials, alluvial slopes, granite plutons and potential and existing faults. Sedimentary and igneous rocks are easy to find and follow by means of side-looking radar.

Geological structures such as anticlinal, synclinal, bedding planes, strike and dip, fault systems, joints, dikes and escarpments can easily be recognized with radar imagery.

Surface material maps

Geological interpretation of radar imagery provides ample information about the nature of the soils and the estimate of depth between 0 and 30 m. To prepare surface material maps, a unified soil classification system and geological knowledge of the relevant area are still needed.

Surface configuration maps

The mapped area is depicted, such as plains, low and high hills and mountains. The plains can be classified into upland, coastal, interior and alluvial. Local geomorphic features such as off-shore bars, natural levees, tidal flats, flood plains, oxbow lakes, deltas, lagoons and beaches can be recognized from the radar photos.

Ground state maps

The radar photo interpretations can provide several data, such as: ground always inundated—swamps and marsh; ground inundated daily at high-tide periods, otherwise ground wet throughout the year; mangrove swamps and coastal marsh; ground always wet and so on.

Vegetation maps

It is possible to evaluate vegetation forms on the basis of reflectance characteristics. Non-forest areas present an image texture that is generally quite fine, while various types of vegetation show up grey.

Grasslands give a very low radar return and are easily distinguishable, as are sage-brush and desert vegetation. These vegetation contrasts, although not individually significant, may indicate variations in bedrock soil or alluvium.

Surface drainage and ground-water maps

Bodies of water are very "photogenic" on side-looking radar; they are well defined, black "no return" areas due to their smooth, horizontal surfaces. From the imagery and other data the seas, lakes, major and minor streams can be depicted and the depth to the water table beneath the surface can be interpreted.

Surface hydrology maps

Water resources, swamps, lakes, lagoons, rivers and the turns of streams are very important to the agronomist and the land-use planner. All these natural features are easily recognized from the radar mosaics.

The most promising contribution which side-looking radar can make in the area of surface hydrology lies in the discovery and exact location of large bodies of water for drinking or irrigation purposes. Radar mosaics are an invaluable aid in determining the depth and width of such surface water.

Transportation engineering maps

Through interpretation of the radar imagery, it is possible to construct topographic profile maps that are very useful in design studies for roadways, canals, railways and long-line cable routes.

CONCLUSION

The geological situation of Indonesia is promising with regard to both metallic and non-metallic mineral deposits. About 35 foreign oil companies and more than six foreign minerals contractors are doing exploratory survey work in Indonesia at present. At this stage they need

topographic maps or aerial photographs. However, owing to the incomplete coverage of available maps and difficult weather conditions for conventional photography or other reasons, some of these companies are using the side-looking radar method to obtain the basic information they need. The main criterion in the use of side-looking radar is that it should be acceptable for reconnaissance or preliminary survey of an area which is not covered by conventional aerial photographs and for which no usable topographic maps are available.

Year by year the demand for aerial photographs increases. In an area where it is very difficult to conduct conventional aerial photography, side-looking radar can solve the problem. Five oil companies and one copper mining company are now using the side-looking radar system for exploration purposes.

The side-looking radar method is suitable for the difficult conditions prevailing in Indonesia as an early stage of natural resources survey, and if the area surveyed proves to be promising a conventional method of aerial mapping will follow.

REFERENCES

Colwell, Robert N., *Remote Sensing of Natural Resources*, 1969.

Delwig, L. T., J. V. Kirk and H. C. MacDonald, *The Potential of Radar in Geological Exploration*, 1966.

Westinghouse brochures: *Side-Looking Radar, Checkmate Your Mapping Problem*; and *Side-Looking Radar Used in Civil Mapping*.

Avery, Eugene K., *Interpretation of Aerial Photographs*, Burgess Publishing Company, Minneapolis, U.S.A., 1968, pp. 135–159.

HUNGARY'S PARTICIPATION IN THE ESTABLISHMENT OF THE WORLD MAP AT 1:2,500,000

Paper presented by Hungary[1]

The idea to publish a World Map at 1:2,500,000 was proposed by the Soviet Union in 1956 at the Economic and Social Council of the United Nations. The suggestion was declined; however, following Hungary's suggestion, the idea was taken up by the geodetic and cartographic services of seven socialist countries (Bulgaria, Czechoslovakia, Poland, Hungary, the German Democratic Republic, Romania and the Soviet Union) so that the joint publication of this cartographic work could be started. The organization of this work differs considerably from that of the International Map of the World on the Millionth Scale. It was the first time that co-operation took such a form, that the sheets of the map work covering the entire world were distributed to the participating countries, as well as the separate elements of compilation. Thus the mathematical bases of the World Map projection at 1:2,500,000 were developed by Soviet cartographers; the sheet system, conventional signs, lettering principles and classification of railways and highways by Hungarian cartographers; the principles and models of relief generalization, printing types and political shades of the countries by those of the German Democratic Republic; the scales for population breakdown by those of Czechoslovakia; and the technical layout problems by those of the German Democratic Republic and Czechoslovakia. The final instructions were drawn up by Hungarian and German specialists and were printed by the German Democratic Republic. The general instructions were discussed thoroughly and in detail by the representatives of the participating cartographic services before approval. In the interest of uniformity of the map work each of the participating countries drew up a pilot sheet; study of these sheets, the detailed analysis of the positive and negative aspects of relief generalization contributed to the establishment and standardization of methods to be observed in the course of compilation. The common work and the observation of the principles of compilation and processing is facilitated by the regular annual meetings of the editorial board during which the proof sheets of the previously revised map compilations are presented and their suitability for printing is decided. Decisions are also taken at these meetings to solve problems which have emerged during the compilation of the maps. These decisions must be observed by the cartographic services of the participating countries.

In the compilation of the map work special care is taken in the selection of suitable source materials. Generally, the sheets of the IMW at 1:1,000,000 and national map sheets at 1:1,000,000 and larger are recommended as initial source material. In the matter of acquisition, registration and lending of suitable source materials Hungary is acting as an information centre. By publishing the list of acquisitions, this Centre makes it possible for the participating countries to be regularly informed of recent publications and to use them in their work.

The World Map at 1:2,500,000 is a general geographical map covering the entire surface of the Earth, including the seas and oceans. The map contains general information for the study of scientific, economic, political, historical and organizational aspects of large geographical areas, and can also serve as a base map for all the geosciences and other general and thematic maps. Its contents correspond to the level of the most recent geographical knowledge and express the present physical, political and economic geographical conditions of the individual countries, in so far as these conditions can be represented on a general geographical map.

Special emphasis should be placed on the language of this work. The titles of the sheets and all the marginal text are printed in English and Russian. The maps themselves contain only Roman lettering. All geographical names appear in their official form in Roman characters; on the territories of countries which do not use Roman characters, the official transliteration or transcription in Roman characters is used; and in its absence, the internationally accepted transliteration is used. The Hungarian cartographic service has compiled a comprehensive instruction containing the official or unofficial ways of writing geographical names in 56 world languages.

The work comprises 244 sheets. The representation of the contiguous areas of the applied projections (between 64° north latitude and 64° south latitude conical projection

[1] The original text of this paper, prepared by S. Rado, Director, Cartographic Department, National Office of Lands and Mapping, Budapest, appeared as document E/CONF.57/L.92.

with two secant cones, between 64° and 90° azimuthal projection) is prepared in both projections; this requires the printing of twenty-two additional overlapping sheets. The sheet-numbering system is related to that of the IMW at 1:1,000,000. The preparation of the 244 sheets has been distributed among the participating countries as follows:

Bulgaria: 12 sheets (Central Africa, part of China);
Czechoslovakia: 18 sheets (Indonesia, Australia);
German Democratic Republic: 25 sheets (South America, part of Europe);
Hungary: 46 sheets (North and Central America);
Poland: 13 sheets (South Africa, part of China);
Romania: 7 sheets (North Africa);
Soviet Union: 123 sheets (Asia, Antarctica, the Oceans, part of Europe).

So far 140 sheets, about 60 per cent of the total, have been published; twelve more sheets will be issued by the end of 1970.

The third revised edition of some of the South American and European sheets is going to be published by the cartographic service of the German Democratic Republic. The timely character of the revised sheets is ensured by an adequate recording system and regular evaluation of new, usable documents, as well as by the use of working maps for each individual sheet, in which changes are indicated by means of conventional World Map signs and the sources of the corrections are indicated.

On the basis of the experience acquired in the preparation of this work, the compilation of scientific papers to improve the World Map was started. The examination of these papers and the approval of suggested modifications is also carried out in collective fashion.

The importance of this World Map is evidenced by the fact that it is possible, on the basis of close international co-operation, to produce a small-scale map work representing the Earth in a uniform manner and within a relatively short period of time.

NEW CONCEPT OF AERONAUTICAL CHART REPRODUCTION BY PROCESS PRINTING*

Paper presented by the United States of America[1]

Introduction

The effort to devise techniques and generate specifications for the reproduction of aeronautical charts by process-printing methods was induced by stringencies of rigorous time schedules under which ever-increasing quantities of many different types of charts were being reproduced. More efficient use of capabilities in facilities and equipment needed to be developed to effect economies of cost and time; this was to be accomplished with no degeneration of the quality of the product.

The objective sought was the benefit of an adaptation of the processes of colour process printing to the peculiar needs of reproduction of the sectional chart series, utilizing as far as possible those equipments and capabilities already at hand

There was no interest in incorporating colour process printing as applied in the commercial printing industry in producing all hues of the colour spectrum. The colours printed do not run the full gamut of the colour spectrum; indeed, this circumstance makes it possible to gain the advantages of the process without incurring the acquirement of some costly accessories of reproduction.

This was deemed an opportune time to attempt an improvement of the chart portrayal by incorporating the overprint of shaded relief.

Advance studies

Earlier efforts directed at chart portrayal had gained a degree of expertise in the approach to process printing. The objective then sought was the enhancement of the elevation presentation of the gradient tints. This was to be achieved by the selection of colour hues such as to provide optimum altitude definition by optimum chromatic contrasts even under adverse ambient light conditions. Since these area tints are the background of linear features and textual information, the degree of colour saturation afforded through the colour scale was necessarily low in order to keep these features lucid.

It was apparent at this point that control of the ink colours, as used in the then current printing, would need to be maintained rigidly; then later, when colour process printing was anticipated, the production of the screened images through reproduction would need to be controlled rigorously.

The selection of colours of the gradient scale, at this early point, corresponded with the subjective theory that cold colours are recessive and warm colours indicate proximity, thus respectively creating perception of distance or nearness. Beginning with blue as customarily used for hydrographic features and area water tints, the scale was grey for the first elevation step above sea level, then through two hues of green for the next two verdant elevation steps. Two neutral hues each of yellow, to orange, to red were chosen for the following ascendancy in elevation.

Some trial printings of a small area were made and proved the validity of the selection. One factor of colour selection seemed apparent: that a degree of brilliance can be achieved in the general appearance of the chart by the choice of hues that are slightly purer, while line features and text come up very well because of good contrasts.

Formulation of specifications

At the selection by the Inter-Agency Air Cartographic Committee of a scale of colours to be used for the gradient tints, there followed the process of quantitative resolution of each of the specified colours into values of each of the three printing ink colours. These values, customarily stated in screen percentages, had to be based on the ink colours selected.

It was at this point that difficulty was encountered. Examination of lithographs and illustrations showed that the specified colours could indeed be reproduced by colour

* Colour map will be found in pocket at end of volume.

[1] The original text of this paper, prepared by F. Junek and G. Lee, Coast and Geodetic Survey, ESSA, Rockville, Maryland, appeared as document E/CONF.57/L.128.

process printing. But this material had been reproduced by half-tone colour separations having infinite tone gradation, and the available colour guides with process colour combinations in 10 per cent increments did not begin to provide the fine gradation of hues needed for this chart colour resolution.

A vain search for colour guides in finer increments resulted in the printing of colour guides with 5 per cent increments. Colour comparisons showed much closer approximation with the needed colours, but left much to be desired in good colour match because the 5 per cent increments provided steps in colour change yet too large.

A different approach was then taken. Since there was no requirement for conventional reproduction of the colour circle in its entirety or of all hues in high saturation, there appeared a prospect of better match of colours through the mixing of ink colours. With limited availability of screens, the capability of very fine changes of ink colour would enable the printing of more exact colour match.

Since the chart colour specifications required several hues and tones of brown, the magenta process colour was neutralized with cyan and yellow in known proportions so as to closely approximate the browns needed. A new colour guide was printed with 5 per cent increments of this neutralized magenta together with the process cyan and yellow, producing matches very close to the Inter-Agency Air Cartographic Committee specifications. A preliminary test run indicated the need for slight adjustments.

A full-scale test run was made under production conditions, incorporating necessary adjustments in screen percentage and colour mix. The product now conformed with the desired colours, though with ink control on the press not in accordance with normal quality control operating procedures. A final adjustment in proportions of ink mixing was made so that press production runs could be made with normal ink charge.

During the effort in producing the desired colours, the screen alignments were adjusted in the sequence of printing trials so as to avoid creation of moire effects due to screen pattern interference.

A tabulation was now made up wherein screen percentages and screen angles of each of the final printing ink colours were indicated for each of the features appearing on the chart base. This tabulation served as record of the final conditions, as well as a specification guide for combinations of areas to appear on each printing plate, with value and angle for each feature.

A question then to be settled was: what utilization could be made of existing reproduction copies from the previous printing? An examination of the stages from compilation to printing plate revealed that no changes would be necessary.

Production of the portrayal of shaded relief on the aeronautical chart begins with the rendering on the manuscript copy. This is translation of the contour pattern to an image in highlights and shading. The dark-plate method of preparation, as developed by Mr. Joe F. Wilson, provides a facile medium for producing the rendering. The rendering of relief for the purpose of overprinting on the aeronautical chart is crisp and concise to an extent which, to a casual observer, would appear to be overdone. This rendering technique has been developed so that it may readily be half-toned and result in the desired effect when printed with the gradient tints.

A complexity in process printing was introduced when shaded relief printing was inaugurated. The specifications directed that this overprint be in a shade of grey of stated composition. Since the overprint was a half-tone ranging from a total dropout (zero per cent tone) to 90 per cent tones, the trapping properties of the ink would vary the gradient colours to a great extent. It was resolved to print the shaded relief in as black an ink as possible because black did not perceptibly change the hue of the gradient colour but only darkened the shade. To compensate for this effect, 5 per cent, 10 per cent, and 15 per cent densities of black were printed with the other inks when the 5 per cent colour guides were made. It became apparent that, because black ink does not trap with the other colours, the relief would retain a sharpness that would enhance relief perception by the chart user. This quality could not be retained if grey ink was used.

To compensate for the over-shadowing effect on type of the higher degrees of shading intensity, a wide-line negative was made of the type which is critical to navigation. This negative was used as a mask when the relief printing plate was made so as to produce an open window for the type in these darker areas. Thus the relief does not obscure but rather accentuates critical type in a dramatic manner.

Trial by production run

The Los Angeles sectional chart was selected for a production run, having elevation gradients ranging from below sea level to over 12,000 ft. This was a run of 30,000, printing the front and back sides of each sheet. It was found that the colour balance sought for was well maintained throughout the press run.

Summary

The adaptation of colour process printing techniques has enabled the printing of the chart base with a single run on the five-colour press, whereas two runs had been required heretofore. An incidental economy materialized due to the minimized tendency of the paper to go out of size because of increasing moisture content with each ink impression. This economy resulted from press time reduction by elimination of effort expended in maintaining size registration.

A collateral refinement gained was in the appearance of the chart product. The use of colour process inks creates an image brightness that is an aid in reading a chart that must carry such a wealth of information for the chart user.

(a) *Aeronautical charts*

REDESIGN OF WORLD AERONAUTICAL CHARTS FOR REMOTE AREAS OF AUSTRALIA

Paper presented by Australia[1]

Aeronautical charts in Australia at 1:1,000,000 initially produced in strict conformity with the specifications were outlined in Annex 4 to the Convention of Civil Aviation.

It was found that these specifications suited closely settled parts but were not entirely satisfactory for the remote areas of central and western Australia—a large portion of the continent. In 1969 an Aeronautical Chart Design Committee was set up in the Division of National Mapping to make recommendations to the Department of Civil Aviation on the presentation and symbolization for aeronautical charts in remote areas. The Committee is assisted in its investigations by the Department of Civil Aviation, which has arranged for the Division to use the facilities of the DCA Flying Unit, when their programme permits, to fly over the areas under discussion and study the problem first-hand. So far, 25,000 miles have been flown by officers of the Division on these visual inspection flights.

Some changes in Australian world aeronautical charts had already been made in 1966 as a result of experiments aimed at improving map legibility. These changes were:

(*a*) Using small condensed lettering (mostly Univers);

(*b*) Reducing the weight of line work and printing lines in brighter colours over paler backgrounds;

(*c*) Changing the symbol for non-perennial streams from the conventional dash and three dots to a fine pecked line;

(*d*) Changing the symbols for roads to full continuous lines of varying widths for the three classifications, and printing them in red instead of grey;

(*e*) Showing relief by a combination of contours, layer tints and relief shading, with changes in the colours of the layer tints and weight of contour line;

(*f*) Subordinating the external marginal information to give emphasis to the body of the map.

The resulting charts are referred to as "new format" charts, and were well received by all map users—except for light-aircraft pilots in the remote areas.

These areas were therefore given special attention by the Committee and the following recommendations have been made:

1. Relief features. The present relief shading technique fails to give the isolated mountain features of the inland the importance they deserve as aids to navigation. Scale is the main problem. Many relief features which show clearly at 1:250,000 are too small to show clearly on a map at 1:1,000,000. This is a point that many critics of WAC mapping overlook. Deficiencies will be overcome by accentuating the shading and, where scale permits, showing escarpments and other characteristics on the brown contour plate.

2. Drainage features. In the inland, all water features are non-perennial. Rivers develop a heavily braided pattern in wide flood plains in which it is difficult to define the main channel. Shapes of streams and the shorelines of dry lakes, so important in this country, cannot be shown clearly enough by pecked lines. Much laborious drafting time was required to produce the pecked line for streams. A continuous full line has therefore been adopted for all streams and a marginal note will be inserted: "Rivers, streams and shorelines are delineated in a full line to preserve continuity and accuracy. The presence of water in streams in wet or dry seasons is not indicated or implied."

3. Nomenclature and settlements. The reduction in types sizes gave little distinction between nomenclature in the sparsely settled regions. Sometimes large private cattle stations, homesteads and native mission centres have more buildings and people than the populated settlements. Names of comparatively minor features assume greater importance in the outback. Point sizes for names in remote areas have therefore been increased to give more emphasis to features with greater visual importance when viewed from the air.

4. Cultural features. The mapmaker has a problem in keeping pace with new developmental projects—roads, railways, mines, townships, port facilities and other cultural developments associated with the mineral boom. For example, all these facilities, including 265 miles of new railways, associated with the one mining development were completed in less than 18 months. The Government is also constructing beef roads for transportation of stock by road trains over hundreds of miles of the inland. Particular attention is being paid to updating cultural features on topographic bases at every reprint.

All changes are made in close collaboration with the Department of Civil Aviation. The International Civil Aviation Organisation concept of a standard world aeronautical chart is retained to a very large extent, but the pilot is presented with a chart which is a better graphical representation of the country below him when flying over the remote areas of Australia.

[1] The original text of this paper appeared as document E/CONF.57/L.48.

AGENDA ITEM 13

Hydrographic surveying and bathymetric charting; oceanography

REPORT ON THE MEETING OF THE *AD HOC* GROUP OF EXPERTS ON HYDROGRAPHIC SURVEYING AND BATHYMETRIC CHARTING

Paper presented by the United Nations Secretariat[1]

TERMS OF REFERENCE

The meeting of the *Ad Hoc* Group of Experts on Hydrographic Surveying and Bathymetric Charting was convened at Headquarters from 31 March to 10 April 1970 in pursuance of Economic and Social Council resolution 1313 (XLIV), which requested the Secretary-General to undertake practical measures in implementing, as appropriate, the recommendations of the Fifth United Nations Regional Cartographic Conference for Asia and the Far East. The Group considered the resolutions of that Conference and those of earlier Conferences especially concerned with the problems of hydrographic surveying and bathymetric charting.[2]

The Group considered the present status and progress of hydrographic surveys and bathymetric charting, taking into account present and future needs; ways and means for accelerating hydrographic surveys; the establishment of hydrographic services in developing countries, including the training of personnel; a review of modern techniques and instrumentation; and a review of the role of the International Hydrographic Bureau (IHB), as well as regional co-operation projects.

The meeting was attended by the following experts: A. E. Craig (United States of America); M. De Bakker (Brazil); H. R. Ermel (Federal Republic of Germany); Y. Oyamada (Japan); L. N. Pascoe (United Kingdom); B. Schrumpf (France); and I. V. Tegner (Adviser to the Group from the International Hydrographic Bureau).

Mr. E. C. Dahle, Chief of the Cartography Section, was the Executive Secretary and Mr. C. N. Christopher was the Secretary for the Group.

Mr. A. E. Craig served as the Chairman of the Group and Mr. L. N. Pascoe was the Group's Rapporteur.

STATUS OF CHARTING[3]

There is no doubt that the hydrographic charts available to the mariner today are, in general, adequate for safe navigation of conventional draught shipping. This statement however, must be qualified to take into account areas that are notorious for the uncharted dangers within their unsurveyed bounds. Areas in the South China Sea, the Gulf of Mexico, the Red Sea and the like which have not been surveyed and charted are avoided by prudent mariners.

The fact that one can sail from port to port in safety does not indicate that existing charting is complete; it merely indicates that safe routes have been established. The ability to sail with complete freedom in coastal waters only exists where modern surveys of the past 20 to 30 years have been completed. These modern surveys constitute only a very small percentage of existing data. Many of the established sea lanes, especially in coastal and continental shelf waters, are in fact not the most direct routes but those which have been established by usage as being safe.

With only a limited number of deep-water ports capable of accommodating deep draught vessels, a resurgence of coastal shipping can be expected to be required to tranship goods from deep-water ports in much the same manner as feeder airlines service international airports. Uneconomical sea routes requiring long detours to avoid unsurveyed areas close in to shore will no longer be acceptable. Direct routes not now available in many parts of the world will require survey.

Since much of the existing charting is compiled from surveys which were conducted during the past two centuries, there are many areas in which local knowledge is required for safe passage. Many of the problems are created by neglecting to report changes in aids to navigation, dredging works, new construction and so on. The nautical chart tends to become outdated not only because of the lack of hydrographic data but because man-caused changes have impaired the chart as a navigational tool. It is not possible to estimate the percentage of charts which are out of date owing to the lack of proper reporting procedures by some of the developing countries, but needless to say, it is a matter of great concern. The notice to mariners' systems by which most of the charts of the world are updated is only as good as the data provided by the maritime nations.

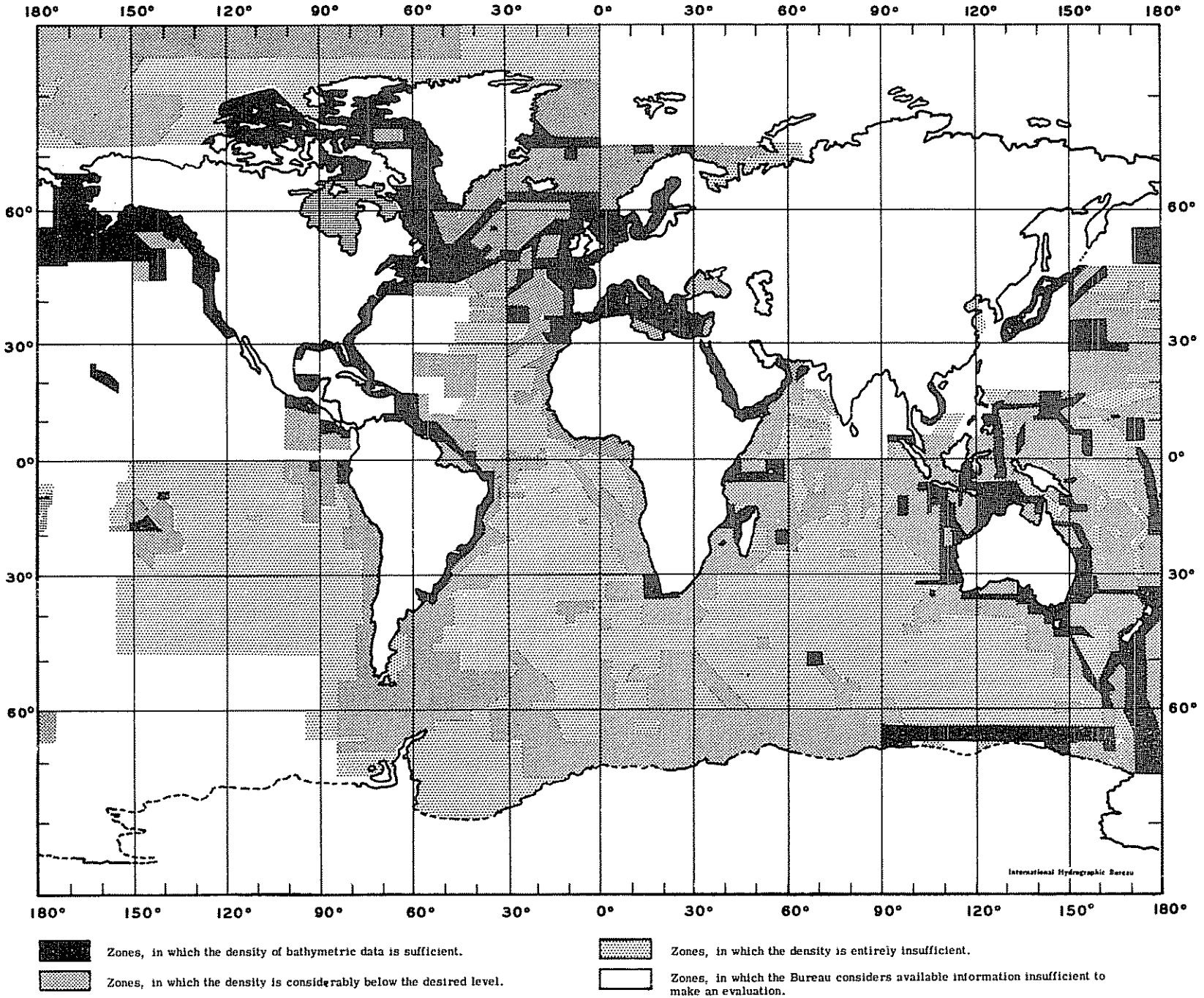
The navigation of ships has always required the exercise of prudent judgement. The best surveyed area is subject to change, rapidly by man-made events and more slowly through natural changes. Caution therefore must always be exercised, especially in areas not serviced by a hydrographic department.

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[1] The original text of this paper appeared as document E/CONF. 57/L.1.

[2] See *Fifth United Nations Regional Cartographic Conference for Asia and the Far East*, vol. I, *Report of the Conference* (United Nations publication, Sales No.: E.68.I.2), pp. 9–14.

[3] See map entitled "Evaluation of bathymetric knowledge in oceans".



IHB: Evaluation of bathymetric knowledge in oceans, July 1969

The deep-ocean chart for the most part is the product of the ingenuity of the hydrographer. The data from which these charts are made are of extremely low quality in comparison to information on the continental shelves and coastal waters. By and large, the great majority of data in the deep oceans are based on celestial navigation. It has only been in the past 20 years or so that recording echo sounders have been capable of producing a permanent record of the deeper parts of the oceans. Concentrations of reliable soundings follow established shipping lanes. Much data in the more remote areas are from old exploratory surveys conducted before sonic sounders were invented.

The lack of a world-wide system of precise navigation hampers the conduct of surveys. Only limited areas have coverage of electronic systems that are reliable enough to produce satisfactory surveys. Virtually no significant areas of the oceans have been surveyed with sufficient thoroughness to produce more than a generalized picture of the bottom. Vast areas are depicted through interpretation of data which are limited both in quality and quantity. Some of these areas are little more than a generalization of the extent of different physiographic provinces.

The bathymetric chart has become more a tool for the scientist in recent years. The oceanographer and the geophysicist have begun to make substantial contributions in understanding the formative processes of the ocean bottom. Surveys conducted for geophysical and oceanographic purposes have added a great deal of data in the remote regions; however, the lack of precise positioning imposes a limit on the value for charting purposes in the mid-ocean reaches.

The magnitude of systematically surveying the deep oceans is such that major technological advances will have to be made to bring such a programme within the realm of possibility. Even a programme which called for survey lines spaced at 10 to 20 mile intervals, would only provide data sufficient to generalize the bottom and would be a major multi-year undertaking.

Generally speaking, the bathymetric charts of the deep ocean are little more than approximate pictures of what lies beneath the surface of the sea. Features are positioned primarily by celestial fixes and can be subject to errors of many miles. Those who utilize these charts should be aware of the limitations.

The production of high-quality bathymetric charts of the deep oceans is considered to be of relatively low priority. Improved charts on the continental shelves for safe navigation and exploitation of resources command much higher priorities.

Review of hydrographic surveying capability

The existing hydrographic surveys over almost all of the coastal areas of the world have been carried out by those countries which for a century or so have enjoyed the benefits of a large efficient hydrographic service with adequate sea-going ships and trained personnel. These countries are, almost without exception, members of the International Hydrographic Bureau and have made their techniques of survey and the charts they publish mutually available.

These nations, principally France, the United Kingdom and the United States of America, have carried out immense surveys along the coasts of almost all of the newly independent countries and the charts published by them from their original surveys constitute the "accepted" charts, indeed the only "national" charts of the coasts and harbours of each country concerned.

In the century or so since the original exploratory surveys of these coastal areas were made, some additional resurveys have been carried out, but in many areas such important resurveys have not yet been made. It is considered by the *Ad Hoc* Group and the International Hydrographic Bureau that repeat surveys are necessary in many areas, especially along the coastal areas of the developing countries. Some are immediately necessary while others may be done later.

A hydrographic survey is a laborious, very time-consuming, expensive task. It must be carried out for the safety of navigation. It is also a basis for other national economic and development requirements.

It is known that most countries have a capacity, sometimes rather limited, to survey their harbours, for berthing, dredging and so on. It is also known that many commercial organizations are available to carry out specific surveys such as harbour surveys, including the approach areas out of sight of land.

However, table 1 gives the opinion of the Group on the existing capability for hydrographic surveying of all of the maritime countries of the world.

Hydrographic surveys for coastal areas and continental shelves

Until the introduction of echo sounding in about 1935, all bathymetric information was laboriously obtained by lead-line soundings, a massive accumulation of discrete, single-position depths. The density of this depth information depended on many factors, the time available, the nature of the sea-bed, e.g., whether it was flat or complex and irregular, sandy or rocky, mud or coral. Isolated pinnacles of rocks, wrecks and obstructions, dangerous to surface navigation were surveyed only laboriously. Within visual distance from the coast, the position of each of these isolated depth values could be accurately obtained. Out of sight of land, positions were in general inaccurate to some degree. Accurate positioning necessitated much time and effort. Hydrographic surveys of the lead-line period before 1935 are thus incomplete.

The degree of close examination of important navigational areas was controlled somewhat by the general maximum draught of shipping of the period, and the general increase in draught, especially after 1900, made it necessary to re-examine certain important areas.

In the important navigation areas of shallow water where the sea-bed is continuously under change, as in the approaches to many ports in north-western Europe, it has been necessary to carry out continuous resurveys.

The introduction of efficient echo sounding in the 1940s produced continuous profiles of the sea-bed instead of depths only at isolated positions and, with the development of sonar sweeping for wrecks and obstructions, surveys were produced which were much more accurate and complete. However, what is fundamentally necessary is a three-dimensional capability in hydrographic survey, and the development of instrumentation with regard to the situation at the present time is optimistic.

Table 1. Capability for hydrographic surveying

Country	Competent	Inadequate	Without[a]	Country	Competent	Inadequate	Without[a]
Albania			×	Lebanon			×
Algeria			×	Liberia			×
Argentina	×			Libya[d]			×
Australia	×			Madagascar		×	
Barbados			×	Malaysia		×	
Belgium	×			Maldives			×
Brazil	×			Malta			×
Bulgaria	?			Mauritania			×
Burma		×		Mauritius			×
Cambodia			×	Mexico		×	
Cameroon			×	Monaco			×
Canada	×			Morocco			×
Ceylon			×	Netherlands	×		
Chile	×			New Zealand	×		
China[b]	×			Nicaragua			×
Colombia		×		Nigeria		×	
Congo (Democratic Republic of)[c]			×	Norway	×		
Congo (People's Republic of)			×	Pakistan	×		
Costa Rica			×	Panama			×
Cuba		×		Paraguay			×
Cyprus			×	Peru		×	
Dahomey			×	Philippines	×		
Denmark	×			Poland	×		
Dominican Republic		×		Portugal	×		
Ecuador		×		Republic of Korea	×		
El Salvador			×	Republic of Viet-Nam		×	
Equatorial Guinea			×	Romania	?		
Ethiopia			×	Saudi Arabia			×
Federal Republic of Germany	×			Senegal			×
Finland	×			Sierra Leone			×
France	×			Singapore	×		
Gabon			×	Somalia			×
Gambia			×	South Africa	×		
Ghana			×	Southern Yemen			×
Greece	×			Spain	×		
Guatemala			×	Sudan			×
Guinea			×	Sweden	×		
Guyana			×	Syria[e]			×
Haiti			×	Thailand	×		
Honduras			×	Togo			×
Iceland	×			Trinidad and Tobago			×
India	×			Tunisia			×
Indonesia	×			Turkey	×		
Iran		×		Union of Soviet Socialist Republics	×		
Iraq			×	United Arab Republic[f]		×	
Ireland			×	United Kingdom	×		
Israel		×		United Republic of Tanzania			×
Italy	×			United States of America	×		
Ivory Coast			×	Uruguay		×	
Jamaica			×	Venezuela		×	
Japan	×			Yemen			×
Jordan			×	Yugoslavia	×		
Kenya			×				
Kuwait			×				

[a] The classification of Competent, Inadequate or Without is based on information already available to each member of the Group. The information contained may be changed as further data by countries become known. It is known that each State has some authority responsible for the placement and maintenance of navigational aids, for necessary dredging etc. These operations require some capability for local hydrographic surveying. The assessment of survey potential stated in the table is that of capacity for survey work along the coasts outside the harbours. The table indicates that almost all of the developing countries do not have adequate hydrographic services or capability.

[b] See introductory note at beginning of volume.

[c] Now Zaire.

[d] Now Libyan Arab Republic.

[e] Now Syrian Arab Republic.

[f] Now Egypt.

In the field of precise position-fixing, only in recent years, i.e., since about 1950, have electronic systems become widely available. These systems require transmitting/receiving equipment to be erected on land to cover the area to be surveyed, together with supporting technical personnel. Certain electronic systems installed for general navigational assistance are in general not precise enough for hydrographic surveying.

The existing hydrographic surveys of the coastal areas and continental shelves of the world have been accomplished almost entirely by laborious lead-line visual-fixing methods. Along the coastal areas their accuracy depends on the scale of the survey, the closeness of the sounding pattern, the nature of the sea-bed, its general depth and the probability of isolated rocks and obstructions.

Similar considerations affect the existing surveys of the continental shelf areas. In these extensive areas out of sight of land, very few accurate and complete surveys have been carried out. Only in very recent years has it been possible, by using special electronic transmitting stations on land, to carry out comprehensive surveys. However, existing lead-line "examination" surveys have been carried out to delineate approximately the 200 m (100 fathom) depth contour.

All these hydrographic surveys were concerned with bathymetry, surface-water movement and sea-bed characteristics. Geophysical, biological, oceanographical (water constitution) surveys have not been carried out except by scientific institutions and commercial firms in local areas.

Hydrographic surveys required

The requirements for hydrographic surveys along the coastal waters and over the continental shelves depend on many factors. As given in the general statement, very few detailed surveys by echo-sounder methods have been carried out of coastal waters and very few indeed of the continental shelf areas. However, existing surveys and charts are generally adequate as the pattern of (*a*) shipping in coastal waters and (*b*) international shipping over the continental shelf has developed using the existing charts.

Coastal waters

Shipping in coastal waters is assisted by navigational aids, lights, beacons and buoys in the case of the developed and certain developing nations. In many developing nations, "local" information is required. In the latter case, navigation by vessels of other nations is dependent on the information shown on the existing charts, which generally covers established routes offshore.

Developing nations, in general, own little or no deep draft vessels or do not require to use them for navigation along their national coasts.

The requirements for hydrographic surveys for surface navigation thus depend on:

(*a*) The adequacy of existing surveys;

(*b*) The general pattern of coastal shipping, the size and draft of the vessels and probable developments;

(*c*) The development of or changes in the character of ports.

In all of these coastal areas, some priority for resurvey can be stated for particular areas. This priority can only be stated properly following (*a*) an examination in detail of the existing surveys, and (*b*) an examination by the country concerned of its present and anticipated needs.

Continental shelf

Here similar factors affect the requirements for resurvey, but the extent, particularly the off-shore extent, of the continental shelf varies. In general, it is relatively narrow with easy access into the national coastal areas and ports, and international shipping along the coast passes offshore outside the continental shelf. The requirements for survey, and the extent of survey, necessary for many countries, of the continental shelf contiguous to their coasts have been of limited extent.

However, in certain areas, e.g. the Yucatan Shelf, Honduras–Jamaica, the offshore banks along the Maritime Provinces of Canada and the north-eastern part of the United States, off the west coast of North Africa, in the Malaysia–Borneo–Java area, off China,* Australia–West Irian, in the enclosed areas of north-western Europe and of the Persian Gulf etc., the extent of the national areas of the continental shelf is very large. As stated previously, except generally over the shelf areas of the developed nations and in certain areas of the Persian Gulf, very few adequate hydrographic surveys have been carried out. However, in recent years, increasing requirements are being made for marine geophysical exploration and survey of national areas of the continental shelf and these requirements also include the fundamental bathymetric survey.

As with coastal areas, the priority of resurvey can be stated for particular areas following an examination by the nation concerned of the extent of the existing surveys and of its detailed requirements of a combined geophysical/bathymetric survey.

There is an international requirement for surface navigational purposes for proper hydrographic surveys to be made of detached ocean bank areas, more especially along the existing routes of international shipping.

Minimum charting requirements for the oceans

It was not possible for the Group to consider in detail international programmes of oceanic exploration and research; however, charting for these purposes must be considered in a much wider context than that of just pure hydrography. It has become general practice to obtain bathymetric, geomagnetic, gravimetric and, in some instances, seismic information simultaneously when conducting offshore surveys. Collecting and interpreting composite data are much less expensive than working over the same area several times.

It is obvious that the first priority for this type of survey will be on the continental shelves. Each country has a vested interest in examining the area contiguous to its own coastline before any work is undertaken in the deep oceans. In general, the scales of charts thought to be satisfactory for exploratory work on the continental shelves are about 1:200,000 to 1:500,000. These scales provide sufficient detail upon which to base plans for large-scale developmental surveys. Surveys on the continental shelves should be controlled as accurately as possible since these areas are of the highest economic importance. Generally speaking, with the exception of Central America and the Caribbean, Africa from the Congo and Tanzania

* See introductory note at beginning of volume.

northwards, and south-eastern and south-western Asia, precise control of the continental shelves presents no problem since the continental shelves are relatively narrow.

Compared with the effort made on the continental shelves, even a very superficial treatment of the deep oceans is a tremendous undertaking. The first step in creating a world bathymetric chart is the General Bathymetric Chart of the Oceans 1:10,000,000 (GEBCO) published by the International Hydrographic Bureau in Monaco. The GEBCO presents a generalized picture of the configuration of the ocean bottom and is in most cases too small in scale.

Table 2. Type and date of the latest survey of the ports and coastal areas of countries with inadequate or no capability for hydrographic survey

N: *Not examined.* E: *Echo-sounder survey, since 1935.* L: *Lead-line survey.*

Country	*Ports*	*Coastal areas*		*Remarks*
		Good survey	*Low-density survey*	
Albania	N	N	N	
Algeria	E L	L 1921–1923		
Barbados	E	L 1869		
Bulgaria	N	N	N	
Burma	E L	L 1906–1935	L 1880–1890	
Cambodia	N	N	N	
Cameroon	E	L 1905–1909	L 1846	
Ceylon	E L	L 1905–1909	L 1860–1890	Inadequately surveyed areas 1838–1845
Colombia	N	N	N	
Congo (Democratic Republic of)[a]	N	N	N	
Congo (People's Republic of)	E		L	
Costa Rica	E L	L 1880–1936	L 1830–1843	Inadequately surveyed areas 1830–1843
Cuba	N	N	N	
Cyprus	E L	E L 1932–1962		
Dahomey	E		L 1826–1846	
Dominican Republic	E L	L	L	
Ecuador	N	N	N	
El Salvador	N	L 1880	L 1880	
Equatorial Guinea	N	N	N	
Ethiopia	L	L 1924–1935	L	Some inadequately surveyed areas
Gabon	E	E	L	
Gambia	E		L 1826	Some inadequately surveyed areas 1826
Ghana	E L	L 1928–1930	L 1826–1846	Some inadequately surveyed areas
Guatemala	N	L 1880	L	
Guinea	E L		L 1826–1838	
Guyana	E	E	North coast	Inadequately surveyed areas off shore
Haiti	N	N	N	
Honduras			L 1830–1840	Inadequately surveyed areas 1830–1840
Iran	E L	E	L 1857–1860	
Iraq	E L	L	L	
Ireland	E L	L 1860–1910	L 1840–1860	Inadequately surveyed areas off shore
Israel	L	L 1930–1933		
Ivory Coast	E		L 1826–1846	
Jamaica	E L	L 1870–1880		Inadequately surveyed areas off shore bank
Jordan	E			
Kenya	E L	E	L 1870–1880	
Kuwait	E	E		
Lebanon	E		L 1862	
Liberia	E L	L 1910	L 1826–1846	
Libya[b]	E L	L 1919–1930		
Madagascar	E L	E L 1893–1914 1947–1965	Some areas incompletely surveyed	
Malaysia	E L	E L 1910–1969	L 1868–1890	L 1844–1852. Inadequately surveyed areas off shore
Maldives		L 1840	L 1840	
Malta	E	E		
Mauritania	E	E		E Survey not completed
Mauritius	E L	L 1877–1897	L 1877	
Mexico	L	L 1870–1880		L 1830–1852. Inadequately surveyed areas
Morocco	E		L	
Nicaragua	L	L 1870–1880		L 1830–1840. Inadequately surveyed areas
Nigeria	E L	L 1911–1913		Inadequately surveyed areas
Panama	N	L 1880		Inadequately surveyed areas L 1817
Peru	N	N	N	
Romania	N	N	N	

Table 2 *(continued)*

Country	Ports	Coastal areas: Good survey	Coastal areas: Low-density survey	Remarks
Saudi Arabia	E L	E 1950–1960	L 1853–1849	1835–1849 Red Sea–Arabian Sea. Arabian Sea–Some incomplete Persian Gulf, Red Sea, Arabian Sea coasts inadequately surveyed
Senegal	E L	E 1936–1965		
Sierra Leone	E	L 1932	L 1870–1900	L 1826–1846—inadequately surveyed areas
Somalia	L		L	
Southern Yemen	E L	L 1900–1929	L 1835–1849	L 1839–1849 inadequately surveyed areas
Sudan	E L		L 1835	1835—inadequately surveyed areas
Syria[c]	E L		L 1860	
Togo	E L		L 1826–1846	
Tunisia	E L	L to 1935	incomplete off shore	
Trinidad and Tobago	E L	E 1950–1960	L 1867	Inadequately surveyed areas 1867
United Arab Republic[d]	E L	L 1910–1920	L 1861	L 1859–1861 L 1835 inadequately surveyed areas
United Republic of Tanzania	E L	L 1870–1890	L 1870–1890	
Uruguay	N	N	N	
Venezuela	N	N	N	
Yemen	L	L 1890–1925	L 1890	Inadequately surveyed areas 1835

[a] Now Zaire.
[b] Now Libyan Arab Republic.
[c] Now Syrian Arab Republic.
[d] Now Egypt.

NOTE: This table has been made from only a limited examination of the charts of the coasts of the countries listed. A more detailed examination of the existing situation concerning the adequacy and completeness of the hydrographic surveys of their coastal areas is required before countries can make a proper assessment of the needs for and extent of resurveys and determine priorities for specific areas.

The basic material for the compilation and maintenance of the GEBCO are the 1:1,000,000 ocean-sounding plotting sheets produced by seventeen national volunteering hydrographic services. The International Hydrographic Bureau (IHB) has stated that only 15 to 20 per cent of the bathymetric data of the plotting sheets are sufficient in accuracy. In about 80 per cent of all ocean areas the bathymetric data are either insufficient or entirely lacking. The volunteering hydrographic services are responsible for the compilation and maintenance of the plotting sheets and do their best. Nevertheless, the existing 1:1,000,000 plotting sheet series is the only source of this world-wide bathymetric information generally available. It does not appear practicable to publish world-wide bathymetric charts on a reasonably reduced scale. Efforts should be made, internationally, to bring this series of plotting sheets up to date, and for government, university and oceanographic research institutions to supply, in a convenient form, to the International Hydrographic Bureau or to the national hydrographic office concerned, the bathymetric information they possess and obtain in the future.

A chart series on the scales 1:2,000,000 or 1:2,500,000 which is desired by the scientific community cannot be produced in the near future. Yet, with the increasing international effort in oceanography, it appears necessary that some effort be made to make available in published form, on a reasonable scale, the results of this costly work.

In parallel with producing these charts it is also considered necessary to make such topical maps as magnetic charts, gravimetric charts, geological structural charts and so on, which are considered useful for ocean exploration and exploitation.

Summing up, one can say that much of the data in the deep oceans being gathered today are the result of scientific exploration rather than the results of specific projects undertaken to map the ocean bottom. The random nature of this work, the lack of precise navigational control and the general secondary priority assigned to bathymetry on some of these exploratory projects, result in data which do not justify display at large scales. Until a satisfactory world-wide navigational system is available, deep-ocean surveys will continue to be compiled on small scales.

ESTABLISHMENT OF HYDROGRAPHIC SERVICES

The Group is well aware that the creation of fully operational hydrographic services in developing countries cannot be easily and speedily achieved. However, developing countries should be encouraged to start their own hydrographic services at the earliest possible moment, even though it will have to be in a small way in the beginning. The International Hydrographic Bureau has published guidelines to be followed for the creation of hydrographic services, which might be of some assistance.[4]

Most developing countries have no charts for their coasts other than those published by the countries that formerly surveyed those areas. In many instances these charts are based on old surveys which today cannot be considered sufficiently accurate. The new countries may not be in a position to evaluate the validity of the charts and may not even think it necessary to make an evaluation.

Until the developing countries can produce their own charts, it is stressed that it is the responsibility of the new country to keep the charts of their coastline up to date by supplying information to the publishing country.

[4] Copies of these guidelines may be made available upon request either to the International Hydrographic Bureau or the Cartography Section of the United Nations.

The Group is of the opinion that the new countries should be aware of their responsibilities as regards hydrographic surveying and charting, and especially with regard to the value of existing charts.

Technical personnel for hydrographic surveying

The Group considers that the organization of a hydrographic service, implying the necessity to train specialized technicians, is a real problem for most countries that are beginning to conduct their own surveys. However, many of these countries already have advanced topographical services, and, as a result, a small nucleus of personnel drawn from them could form the initial unit for the development of a hydrographic service capable of carrying on its own basic hydrographic surveys. This would constitute the most economical point of departure for the venture.

Initially, more basic training for technical personnel should be given in their country of origin where local practical experience can be obtained. This type of training might be supervised by a professional hydrographer from one of the more developed hydrographic services or, if possible, carried out under the United Nations technical assistance programme. The professional hydrographer should not only possess a solid foundation of scientific knowledge relevant to the subject, but also administrative ability, and might be drawn from one of the countries with an organized hydrographic service.

More advanced technical training might well be obtained from countries with already established hydrographic services and where appropriate facilities already exist. However, mere training is inadequate if not supplemented with practical experience which can only be obtained from survey assignments over a period of years until the trainees acquire the technical and administrative maturity they need.

One of the problems confronting newly established hydrographic services is the difficulty in retaining trained personnel since they may be members of the armed forces (navy) and are often called upon to serve in other assignments in which this specific training is not needed. As a result, they tend to lose their acquired technical capabilities.

Diverse facilities exist for the training of technicians in hydrographic surveying, and the more advanced hydrographic services have collaborated and co-operated in the training of technicians for newly established hydrographic services. This co-operation has had limited results, perhaps because the organization and training of a technical staff have not been predicated on a realistic survey programme or on an accurate appraisal of the costs of carrying out such a programme.

The formation of a technical staff on several levels and the means necessary for the execution of hydrographic surveys depend upon several factors. The structure of a hydrographic service requires not only that the personnel be able to conduct the hydrographic surveys, but also to plan them, check them, design the plotting sheets and the like. A staff with all these talents available is important in order to avoid, for instance, that a well-executed survey in the field or at sea be presented as a badly drawn chart of doubtful precision.

Modern techniques and instrumentation

Modern techniques and instrumentation provide the capability for accelerating hydrographic surveys and charting. While the cost of some of this equipment will be prohibitive for many countries, the technology required to maintain and support these systems cannot be overlooked by those who do procure new equipment. For instance, the production of accurate hyperbolic lattices for certain types of navigation equipment requires the use of automated data processing (ADP) equipment to compute points along the lines of position for drafting purposes. This type of technology is often overlooked and is a hidden cost associated with many types of electronic equipment.

Many electronic systems are highly reliable and can be maintained quite easily; however, some of the equipment is also quite complicated and requires a substantial inventory of spare parts for adequate maintenance. The breakdown of a critical system, such as electronic positioning equipment, can stop the entire survey until repair can be made. The costs rapidly escalate depending upon the length of time the equipment is inoperative. The payment of salaries of boat crew, hydrographic surveyors and such things as operating costs of the survey vessel, all add up to several hundreds if not thousands of dollars a day. The use of modern equipment has limitations as well as advantages which must be recognized. Unfortunately, the advantages are emphasized while the disadvantages are often ignored or overlooked.

The level of technical skill and knowledge required to maintain some of the more complex systems is so high that it has become necessary for even the largest survey organization to employ a manufacturer's representative to perform maintenance during survey operations. Some of the more advanced instrumentation, however, is being constructed in such a manner that field maintenance has been reduced to replacement of defective components. This of course reduces the skill level required but necessitates the establishment of a large inventory of very expensive spare components. This approach also requires that defective components be repaired at the factory, sometimes at a high cost.

On the surface, it would appear that the cost per line mile of hydrographic surveys is getting more expensive as technology advances. This of course is not true, since with modern equipment it is sometimes possible to operate 24 hours a day, which in itself allows the use of capital equipment to the fullest extent possible. The use of classical visual techniques automatically limits the use of capital equipment to about 50 per cent of its potential.

It is most important to recognize the disadvantages not of modernization, but of too rapid modernization. It is very important to phase-in advanced equipment only after the technical and monetary resources are available.

On the assumption that most developing hydrographic services will be troubled by inadequate financing, it will often prove more cost-effective to charter a launch rather than to purchase one. This might require the use of portable echo-sounding systems, which could be permanently installed if a launch were acquired at a future time. The acquisition of electronic positioning systems should be deferred until competence is developed to conduct a survey using classical, visual techniques. Even the most advanced services still utilize visual control in certain circumstances, and an understanding of visual control is a basic requirement of hydrographic surveying.

The acquisition of one of the semi-automatic distance-measuring systems designed for hydrographic positioning

would be a logical step towards increasing productivity. These systems are relatively reliable, not too expensive, and comparatively easy to maintain. They do have limitations, such as operator fatigue, but the increase in productivity from their use is dramatic. The production of sounding sheets for these systems uses a simple graphic technique.

The advance from these semi-automatic, manually operated systems to the larger long-range circular and hyperbolic systems must be carefully weighed on the basis of the financial and technical resources available.

The survey launch should be outfitted with the most modern equipment possible. Echo sounders, both analogue and digital, are highly reliable and easy to maintain. Probably the first place for use of advanced technology will be with data-logging systems in the survey launch. As the civil mapping agencies modernize with electronic computers and electronically driven plotters, it will be easy to join hydrographic data-logging systems to those devices for rapid compilation.

It is important for the newly established hydrographic service to recognize that advances in technology will probably be made by the national mapping and geodetic institutes rather than by the hydrographers. The importance of co-operating with and utilizing already established facilities of another agency cannot be emphasized enough. Simple cartographic and printing support obtained from the local mapping agency is extremely valuable and eliminates the need for duplication in training and facilities.

Even the very largest services have had unfortunate experiences in rushing into a new development. It must be recognized that while it is important to accelerate the rate of production it must be done in an orderly manner.

International standardization

All new hydrographic surveys should, in the Group's opinion, be conducted according to certain standards in order to achieve equal accuracy. The International Hydrographic Bureau has published such standards in its publication SP.44. This publication has been issued to all members of the Bureau, but others may acquire copies at a reasonable cost. Charts produced from new surveys should be in metric units and should otherwise conform to the International Hydrographic Bureau Technical Resolutions; they should, moreover, as far as possible, conform to the chart size adopted for the international charts.

Regional co-operation

In the partially enclosed seas of the world, fronted by the coastlines of several nations, co-operation in hydrographic surveying on a multilateral regional basis would be of benefit to all the nations concerned.

Such regional undertakings would be carried out in the form of working groups of the hydrographic services concerned co-operating in bathymetric surveys, joint tidal and tidal stream surveys, in agreement in establishing electronic position-fixing stations in more than one country for combined multi-ship use, and in determining priorities for agreed areas and routes for survey, sharing aircraft for air photographic coverage and so on.

Areas where such co-operation could be extremely beneficial are as follows: Caribbean–Cuba, Honduras, Jamaica, Yucatan; Caribbean–Grenada, Guyana, Trinidad, Venezuela; Persian Gulf–Northern area; Persian Gulf–Southern area; South China Sea–Cambodia, Indonesia, Malaysia, Philippines, Republic of Viet-Nam, Singapore, Thailand; and Red Sea–Southern area.

Examples of several regional co-operative undertakings are summarized below.

Joint Malacca Straits hydrographic survey (JMSS)[5]

The Joint Hydrographic Survey of the Malacca and Singapore Straits was made of certain areas of the straits as a preliminary for a later detailed survey by a joint survey team consisting of personnel from Indonesia, Japan, Malaysia and Singapore.

Surveys in the Straits of Malacca and Singapore by both the United Kingdom in co-operation with Malaysia and Singapore and the joint survey team are required to establish a traffic separation scheme to include the problems of safety for the navigation of deep-draught vessels.

In this project, some of the participating countries are not members of the International Hydrographic Bureau, and in the case of the Joint Malacca Straits Hydrographic Survey, negotiations through diplomatic channels were required.

Northern Hydrographic Commission (NHC)

The Northern Hydrographic Commission was formed by the hydrographers of the Scandinavian countries, Denmark, Finland, Iceland, Norway and Sweden, not long after the creation of the International Hydrographic Bureau. The Commission has no governmental standing but is unofficially recognized by all the Scandinavian Governments. No contributions are required. The object of the Commission is to enable the hydrographers to exchange views and experiences on all hydrographic questions and to arrange for co-operation in surveying in Scandinavian waters where appropriate. The Commission meets once a year for a week in the country of one of the members according to a rotation plan.

North Sea Hydrographic Commission (NSHC)

The North Sea Hydrographic Commission (NSHC) was founded in 1962 by the hydrographers of Denmark, Federal Republic of Germany, Netherlands, Norway, Sweden and United Kingdom.

The aim of NSHC is to co-operate closely in all things concerned with the North Sea. The Commission's conferences are held at intervals of from one to one and a half years. Up to now, conferences have been held in Copenhagen, The Hague, Hamburg, London and Stockholm. The next meeting of the Commission will be from 25 to 30 May 1970 in Norway. This very successful co-operation has had the following results: joint surveying of deep-draught routes in the North Sea; joint tidal observation in the North Sea and creation of a co-tidal chart of the North Sea; joint production of the North Sea Fishery

[5] See "Joint preliminary hydrographic survey of the Malacca Straits", *International Hydrographic Review*, vol. XLVI, No. 2, July 1969, pp. 27–32; and "Report on a preliminary survey of the Malacca Strait and Singapore Strait", *ibid.*, vol. XLVII, No. 1, January 1970, pp. 7–22.

Chart 1:300,000 in fifty-four sheets with a Decca grid; and exchange of experiences in modern surveying methods.

The Commission does not have any governmental standing, but is a close association of the hydrographic services concerned.

South China Sea Co-operative Survey

As a result of the Fifth United Nations Regional Cartographic Conference for Asia and the Far East, held at Canberra, Australia, in March 1967, a corresponding working group was established as a consultative body to promote plans for undertaking surveys in the South China Sea. The Chairman, from the Hydrographic Department of Japan, will report fully to the Sixth United Nations Regional Cartographic Conference for Asia and the Far East on the work that has been done by his group.

The work of the Pan American Institute of Geography and History (PAIGH)

The Group reviewed a regional co-ordination organization of the western hemisphere under which the Committee on Hydrography of the Commission on Cartography of the Pan American Institute of Geography and History (PAIGH) operates.

That Committee, however, does not constitute an independent regional organization such as, for example, the North Sea Hydrographic Commission, but is only one of the various committees that constitute the Commission on Cartography of the Pan American Institute of Geography and History. The Committee has not achieved any practical results in regional co-ordination of hydrographic projects since it does not have the funds necessary to develop a programme that would satisfy the regional interests in the hydrographic field, this in spite of the various resolutions and recommendations that exist on the problem of hydrographic surveys within the Pan American area.

It should be noted that the success of JMSS, NHC and NSHC can be attributed to the fact that the countries involved had specific objectives in mind, while those of the South China Sea Co-operative Survey and PAIGH have been so broad that up to now it has not been possible to focus on a particular project on which all agree.

TECHNICAL ASSISTANCE

The creation of technical assistance programmes by some of the most advanced hydrographic services stemmed from an early recognition that the newer nations would be required to assume responsibility for their coastal charting after achieving independence. The need for establishing regional training centres has been recognized by the United Nations and is further proof that there is a technological gap and that developing nations will require assistance in establishing hydrographic services.

Bilateral co-operation is a simple and effective solution, and it should be considered first. This does not preclude multilateral aid at a future stage.

The co-operation of a young hydrographic service with the service that had previously assumed the hydrographic tasks of the country is to be strongly recommended whenever the situation permits it. The former service has knowledge of the coastal area of that particular country; it has, moreover, the archives of the surveys and has still, as far as international navigation is concerned, the responsibility for providing nautical information on the area, as long as the new service is not yet in a position to do so.

The International Hydrographic Bureau document on establishing a hydrographic service mentioned above gives a general idea of the problems encountered by a newly established hydrographic service and suggestions for their solutions. The assistance of a foreign expert is definitely needed at this stage. This expert should be a hydrographer who is still occupying an active position. A foreign hydrographic service will have to release him for this period of time and therefore the duration of the expert's mission will be limited; a period of three to four months would be reasonable. This expert would:

(*a*) Determine the framework in which the future hydrographic service will be formed and its composition;

(*b*) Advise on the recruitment and training of the initial personnel;

(*c*) Propose a first programme of activity (cartography, surveying);

(*d*) Establish a list of all necessary equipment.

The newly established hydrographic service will also find that foreign hydrographic services are often willing to give bilateral assistance in the following fields: tides computations; geodetic computations; exchange of documentation; processing of nautical information. The cost for such assistance will usually be minimal, if anything at all.

A document on available training facilities and courses of instruction in hydrography offered in various countries has been issued for this Conference.[6] Much of the training and assistance now being provided is on a bilateral basis. Since many of the newer hydrographic services have been established within military departments, much of the training is available under military aid programmes. There are, however, provisions under which trainees from civil organizations are admitted alongside their military counterparts.

Most of the training programmes are comprehensive in that they cover theory as well as the practical aspects of hydrographic surveying. These courses normally last at least one year and require that the student be well grounded in mathematics and the sciences and be proficient in the language of the country giving the training. Probably the most frequent mistake made in selecting an individual for training is in the area of language proficiency. A student who does not have a good understanding of the language is easily frustrated and misses a great deal of the work. This one aspect of technical training must be stressed. It is therefore important that the individuals selected for training be those who will be in responsible and decision-making positions at some point in their career. Training given away from the home country must be restricted to the professional since the course work is normally at that level and the costs involved are high.

The technical assistance programmes of the United Nations provide the means for the smaller hydrographic services to acquire both expert technical assistance and, to a limited extent, equipment to support operations. These new organizations should take advantage of technical assistance available under the United Nations Development Programme, and it is important that the administrative heads of new hydrographic services familiarize

[6] See "List of hydrographic training facilities" (E/CONF.57/L.2).

Table 3. List of countries that do not publish nautical charts of their coastal waters and countries that are the primary publishers of the existing nautical charts

Country	*Present primary publishing nation(s)*	*Country*	*Present primary publishing nation(s)*
Albania	Italy	Lebanon	France
Algeria	France	Liberia	United Kingdom
Barbados	United Kingdom		United States of America
Bulgaria	United Kingdom	Libya[b]	United Kingdom
Cambodia	France	Madagascar	France
Cameroon	France	Malaysia	United Kingdom
Ceylon	United Kingdom	Maldives	United Kingdom—India
Colombia	United States of America	Malta	United Kingdom
Congo (Democratic Republic of)[a]	France—United Kingdom	Mauritania	France
Congo (People's Republic)	France	Mauritius	United Kingdom
Costa Rica	United States of America	Mexico	United States of America
Cuba	United States of America	Morocco	France
Cyprus	United Kingdom	Nicaragua	United States of America
Dahomey	France		United Kingdom
Dominican Republic	United States of America	Nigeria	United Kingdom
Ecuador	United States of America	Panama	United States of America
Equatorial Guinea	United Kingdom	Peru	United States of America
Ethiopia	United Kingdom—Italy	Republic of Viet-Nam	United States of America
Gabon	France	Romania	United Kingdom
Gambia	United Kingdom	Saudi Arabia	United States of America
Ghana	United Kingdom		United Kingdom
Guatemala	United States of America	Senegal	France
Guinea	France	Sierra Leone	United Kingdom
Guyana	United Kingdom	Singapore	United Kingdom
Haiti	United States of America	Somalia	United Kingdom
Honduras	United Kingdom	Southern Yemen	United Kingdom
	United States of America	Sudan	United Kingdom
Iran	United Kingdom	Syria[c]	France
	United States of America	Togo	France
Iraq	United Kingdom	Trinidad and Tobago	United Kingdom
Ireland	United Kingdom	Tunisia	France
Israel	United Kingdom	United Arab Republic[d]	United Kingdom
Ivory Coast	France	United Republic of Tanzania	United Kingdom
Jamaica	United Kingdom	Uruguay	Brazil
Jordan	United Kingdom		United States of America
Kenya	United Kingdom	Venezuela	United States of America
Kuwait	United Kingdom	Yemen	United Kingdom
	United States of America		

[a] Now Zaire. [b] Now Libyan Arab Republic. [c] Now Syrian Arab Republic. [d] Now Egypt.

themselves with the procedures for obtaining United Nations help since this is one of the most important sources of technical assistance available.[7]

Recommendations of the Group

I

There are many countries which still do not possess established hydrographic services, but do have established mapping agencies. These countries should create a nucleus of personnel in the mapping agencies capable of carrying out elementary hydrographic surveys. These small units should be charged with the basic functions to support maintenance of the national charting until such time as a full hydrographic capability is achieved.

It is recommended that these countries take inventory of their *real* needs so that an objective programme may be devised. This inventory should take into full consideration the individual peculiarities of each nation and their real ability to carry out the programme.

II

Considering that hydrographic surveys of certain coastal areas are necessary for the safety of all shipping; that developing nations lack the capability for conducting detailed and adequate surveys of their coasts and of the contiguous areas of the continental shelf, and that it is not economically practicable for most developing countries to obtain this capability because of the big-ship requirement for survey of offshore waters, Member nations which have the capability of carrying out such surveys are requested to assist in these surveys.

It is recommended that countries requiring this assistance enter into bilateral agreements for the necessary help and it is further recommended that the United Nations pay increased attention to the need for assistance in this field.

[7] See *Assistance for Economic and Social Development Available from the United Nations System, a Handbook of Criteria and Procedures* (United Nations publication, Sales No.: E 69.I.23).

III

The present situation regarding the navigational charts of their coasts and harbours is called to the attention of all those countries listed above which do not themselves publish nautical charts. These charts give the only information for navigational use available both to national and international shipping. Nationally they may also be required for other purposes, such as customs, fishing, economic development and so on. These charts are published, printed and maintained, i.e. kept up to date for navigational changes and so forth by the hydrographic services of certain of the larger countries, more especially France, the United Kingdom and the United States of America. With the accession to independence, it is necessary that developing countries assume the primary responsibility for the maintenance of these, the only charts of their coasts, until such time as they themselves publish their own national charts.

All nautical documentation, charts and publications that are not kept up to date are dangerous to navigation, and accidents, some of which have even led to the loss of ships and human lives, have been attributed to the inadequacy of nautical information or to the slowness of its transmission to the authorities that publish these charts and publications for the general benefit of all navigators.

The quality of nautical documentation and consequently the keeping of this documentation up to date, are matters involving the safety not only of the ships of the maritime States concerned, but of all ships.

Maintenance of the existing charts of their coasts, even though those charts and ancillary publications are published by other nations, is an obligation on every State.

It is recommended that each country implement the establishment of a reporting system in accordance with the recommendations of the International Hydrographic Bureau in its document "Creation of hydrographic services in newly independent countries".

IV

Deep-draught shipping, such as tankers and container ships, can be accommodated only in a limited number of ports. These ports are expected to become distribution centres upon which coastal shipping will converge. Transshipment of goods over established coastal routes will often be more costly than need be because of the lack of direct, safely surveyed lanes between ports.

It is the consensus of the Group that national priorities will establish the need to chart the continental shelves and coastal waters as a matter of great urgency for the purposes of safety of navigation and for exploring and exploiting the natural resources of these areas.

It is recommended that Governments consider the economic benefits that result from having adequately surveyed the continental shelves and that a coastal surveying capability be developed as a matter of high national priority.

V

The training of technical personnel for hydrographic surveying is most often thought of in terms of the professional. In most of the newer countries there is a pool of skills in organizations closely allied with hydrographic operations that can be utilized to form a basic survey organization. Training in the basic hydrographic survey procedures can be had from several sources and can be utilized to accomplish useful work at the same time.

It is recommended that a basic capability in hydrographic surveying be built up within the framework of an existing organization such as the national mapping agency or a port authority. Training and assistance for in-country projects should be obtained through a formal request to the United Nations or through bilateral agreements with the developed nations. Towards this end, countries should establish hydrographic assistance as high-priority projects, in relation to other national projects, for consideration under United Nations technical assistance programmes. A most important impetus for the full understanding of the importance of hydrographic surveying and bathymetric charting for developing countries can be provided by the arrangements of United Nations seminars on this subject.

VI

It is recognized that the 1:1,000,000 plotting sheets are the basic documents upon which deep-sea bathymetric data are recorded. It is also recognized that much data in the archives of scientific and educational institutions are of value for this series of charts.

It is recommended that those institutions holding data in their files provide them to the hydrographic service concerned or to the International Hydrographic Bureau in order that they may be used to bring up to date the existing plotting sheets.

It is also recommended that those countries that have accepted responsibility for the compilation of these 1:1,000,000 plotting sheets should make every effort to include this new information at an early date so that it can be made available internationally.

VII

The nautical charts which are the documents most widely used internationally should preferably be of a uniform quality as regards the accuracy of the information contained; they should be easily understandable to every navigator regardless of nationality, and for practical reasons they should be of uniform size. To obtain this, charts should be compiled according to approved standards, and the hydrographic surveys constituting the base for the charts should be conducted according to approved standards.

It is therefore recommended that new nautical charts conform to the International Hydrographic Bureau Technical Resolutions,[8] that the unit of measurement be the metre and that chart size conform to the chart size adopted for the international chart series.

It is further recommended that new hydrographic surveys be conducted according to the standards laid down in International Hydrographic Bureau Special Publication 44.[8]

VIII

It is noted that, owing to the increase in maritime traffic, both in volume and draught of vessels, as well as the expanding interests in oceanographic developments, certain areas in international waters are becoming more critical for safe navigation owing to the lack of modern detailed hydrographic information.

[8] May be obtained by non-member countries from the International Hydrographic Bureau at a reasonable cost.

Regional co-operation can be accomplished within the structure of existing organizations such as PAIGH or it can be specially formed, as in the case of the North Sea Hydrographic Commission. The pooling of available resources and co-ordination of plans may to a great extent reduce the cost of an undertaking of joint interest to several countries.

It is recommended that those countries interested in such areas should either form joint hydrographic survey projects or organize a regional hydrographic commission in consultation with the International Hydrographic Bureau. Those countries should focus on a limited undertaking that can be accomplished in a reasonable time so as not to overtax the resources of the participating countries.

The Group discussed the problems concerning the present world-wide state of hydrographic surveys and nautical and bathymetric charting. It showed that some of the existing charts are incomplete or even inadequate and that hydrographic surveys are necessary in many areas both for navigation and for the development of national resources.

Without adequate understanding of its national charting and of the quality of the hydrographic survey of its coasts, a country is unable to assess realistically the requirements for the development of a hydrographic service.

The common misconception that, because charts exist, although they are published only by other nations, they constitute sufficient knowledge, and that no further survey or examination of the sufficiency and adequacy of the existing charting is needed must be appreciated by each developing nation. A review of the quality of nautical charting and of the requirements for coastal and offshore surveys should be of high priority in the national development programmes of all countries.

It will be necessary for all developing maritime countries to set up national hydrographic services and for these countries to realize and accept the responsibility of maintaining the present nautical charts of their coasts and to supply information to the present publishing authorities.

It should be emphasized that the importance of hydrographic information to the nations of the world, and of the necessary uniformity of its documentation and for its efficient distribution has led to the setting up of international organizations for the discussion of mutual problems and for the exchange of information. Of these, the International Hydrographic Bureau is an active organization of which most countries with established hydrographic services are members. Others are regional organizations, e.g. PAIGH, which has a hydrographic committee of its cartography commission.

Attendance by hydrographers is encouraged at the meetings of these organizations, as well as at the regional cartographic conferences of the United Nations, where items of mutual interest may be considered and discussed, including developments in new techniques, priorities for international and multinational surveys, training of personnel and the like.

It is emphasized that it is in the interests of developing countries to join the International Hydrographic Bureau since hydrographic surveys and adequate nautical charts are essential tools for assistance to the developing world.

ANNEX

Details of survey ships of the United Kingdom

Details concerning Royal Navy vessels employed for surveying duties are listed below for general information. These vessels were especially designed and built for hydrographic/oceanographic survey work; they have no military capability.

Name	*Displacement (tons)*	*Date launched*	*Officers*	*Crew*	*Approximate cost (dollars)*
OCEAN SURVEY VESSELS					
Hecla	2,800	1965	10	96	6,000,000
Hecate	2,800	1965	10	96	6,000,000
Hydra	2,800	1966	10	96	6,000,000
Vidal	2,173	1951	12	149	—

Special equipment etc: Fitted for oceanographic/hydrographic survey. All electronic aids. Oceanographical, geophysical and automated data-logging equipment. Helicopter carries two 35 ft survey launches and four smaller boats. Land Rover. Extensive cruising range.

Name	*Displacement (tons)*	*Date launched*	*Officers*	*Crew*	*Approximate cost (dollars)*
COASTAL SURVEY VESSELS					
Bulldog	1,000	1967	4	34	3,000,000
Beagle	1,000	1967	4	34	3,000,000
Fox	1,000	1968	4	34	3,000,000
Fawn	1,000	1968	4	34	3,000,000

Special equipment etc: Fitted for limited oceanographical and geophysical work on the continental shelf. All electronic aids. Carries one 28½ ft survey boat. 4,000-mile cruising range.

Name	Displacement (tons)	Date launched	Officers	Crew	Approximate cost (dollars)
INSHORE SURVEY CRAFT					
Echo	160	1957	2	16	650,000
Egeria	160	1958	2	16	650,000
Enterprise	160	1958	2	16	650,000
Woodlark	160	1958	2	16	650,000
Waterwitch	160	1959	2	14	650,000

Special equipment etc.: Electronic aids. Used for inshore coastal work in Thames estuary and around United Kingdom. Limited offshore capability.

Normal practice is for RN survey vessels to operate nine months of the year and to refit for the other three, during which lying-up period the previous season's work is compiled for departmental use.

A survey launch and party are also borne on HMS *Endurance*, ice patrol ship.

TRAINING IN HYDROGRAPHY

Paper presented by the United Nations Secretariat[1]

In pursuance of resolution 20 of the Fifth United Nations Regional Cartographic Conference for Asia and the Far East on training facilities,[2] the Secretariat provides a list of hydrographic training facilities, in co-operation with the International Hydrographic Bureau (IHB), as follows:

TRAINING OF HYDROGRAPHERS IN ARGENTINA

Physical oceanography and hydrography are taught at the Buenos Aires Institute of Technology. The courses are for Argentine naval officers and students, and are available to foreigners.

Three courses are given, one preparatory and two for specialization. The preparatory course, lasting two years, allows the trainees to acquire the standard of knowledge they should have before specializing in physical oceanography or hydrography. The two specialized courses, both of two years' duration, are in hydrography and physical oceanography. These courses, which are both theoretical and practical in nature, are given in Spanish.

The conditions of entry to the preparatory course are a secondary education diploma and the passing of an entry examination. For the specialization course, the conditions are either to have successfully completed the preparatory course or else to be able to show university or other qualifications to the satisfaction of the Institute of Technology authorities.

The courses are available to foreigners and are without charge provided that the number of trainees does not exceed eight. Programmes are given below.

Preparatory course	Hours of theory per week	Hours of practice per week
SUBJECT		
First year		
First term		
Mathematics	9	7
Geometry and drawing	3	6
Chemistry	3	3
Technical English	2 (theory and practice)	
Second year		
Second term		
Mathematics	4	4
Geometry and drawing	3	5
Chemistry	3	3
Physics	6	4
Technical English	2 (theory and practice)	
Second year		
First term		
Mathematics	5	5
Physics	6	4
Statics and strength of materials	7	5
Technical English	2 (theory and practice)	
Second year		
Second term		
Mathematics	5	5
Physics	6	4
Theoretical mechanics	6	6
Technical English	2 (theory and practice)	
SPECIAL COURSE IN HYDROGRAPHY		
First year		
First term		
Hydrography	4	4
Tides	2	—
Instruments	1	1
Geodesy	2	—
General electronics	6	3
Physics (complementary)	2	1
First year		
Second term		
Tides	3	1
Instruments	2	1
Geodesy	2	1
Radiotechnicals and acoustics	—	—
Submarine relief	3	1
Hydrography	2	—
Hydrographic surveying project	—	4

Summer work: Preparation and carrying out of hydrographic work in the field

TRAINING OF HYDROGRAPHERS IN BRAZIL

Through the Department of Education, the Directorate of Hydrography and Navigation directs the instruction,

[1] The original text of this paper appeared as document E/CONF. 57/L.2.

[2] See *Fifth United Nations Regional Cartographic Conference for Asia and the Far East*, vol. I (United Nations publication, Sales No. E.68.I.2), p. 12.

specialization and training of the personnel of the Ministry of the Navy, of which the Hydrographic Service is a part, in accordance with the general instruction policy of this Ministry.

The Department of Education's courses are the following:

(a) *Courses in hydrography and navigation for officers*

Inaugurated on 23 April 1933, this course aims at preparing naval officers for appointment in hydrographic, navigational, maritime, meteorological and oceanographic duties.

Language: Portuguese.

Nature of the teaching: This is in three parts: the first, theoretical, lasting 36 weeks; the second, practical, lasting 6 weeks; and the third, which includes instruction on the administration of the Directorate of Hydrography and Navigation's departments, lasting 4 weeks. Total duration: 46 weeks.

Level of knowledge: Superior.

Positions available to trainees on completion of the courses: In the first instance they are qualified to carry out technical duties on board hydrographic and oceanographic vessels; after that they can be appointed to technical positions in the Directorate.

Subjects taught: Aerophotogrammetry, compasses, astronomy, navigational aids, cartography, geodesy, hydrography, electronics as applied to hydrography, magnetism, tides, meteorology, navigation, oceanography and topography.

Time and duration of the courses: Take place each year, from February to December; duration 11 months.

Terms of admission for foreign trainees: The Directorate of Hydrography and Navigation each year makes available around six vacancies for naval officers from Latin American countries, upon invitation sent to the various ministries by the Brazilian Ministry of the Navy.

(b) *Courses in hydrography and navigation for ratings*

Inaugurated on 8 June 1960, this course aims at preparing ratings to carry out minor duties in navigation, hydrography, maritime meteorology and oceanography.

Language: Portuguese.

Nature of the teaching: The courses include three parts: the first and the second parts are theoretical, the third part is practical.

Level of knowledge: Secondary.

Positions available to trainees on completion of the courses: The trainees are qualified to become technical assistants on hydrographic and oceanographic vessels.

Subjects taught: In the first part of the courses, Portuguese, mathematics, physics, ethics and civic instruction, naval military training; in the second part, navigation, hydrography, meteorology and oceanography; the third part concerns the practice of the theoretical instruction.

Time and duration of the courses: The courses have a total duration of 44 weeks (20 weeks for the first part, 15 weeks for the second and 9 weeks for the third). They take place from February to December as a rule, but not each year (according to the availability of the necessary personnel).

Terms of admission for foreign trainees: Similar to the terms of admission for officers.

(c) *Training courses in hydrography and navigation for petty officers*

Inaugurated on 3 February 1964, this course has the same programme as the above course for ratings, the only difference being that in the courses for petty officers the subjects are more advanced because the trainees are prepared for duties carrying out higher responsibility.

(d) *Courses of sub-specialization in meteorology*

Inaugurated on 4 April 1963, these courses aim at developing the knowledge of meteorology of petty officers and ratings.

Language: Portuguese.

Nature of the courses: Theoretical and practical.

Level of knowledge: Elementary knowledge of meteorology is required.

Positions available to trainees on completion of the courses: Employment at the South Atlantic Meteorological Prediction Office.

Subjects taught: Meteorology: atmospheric observations on the surface and in altitude; atmospheric observations by radio sounding; meteorological charts; meteorological information.

Time and duration of the courses: The courses have a total duration of 21 weeks (12 weeks for theory and 9 for practice). The time of the year during which they take place varies according to availability of personnel.

Terms of admission for foreign trainees: The same as for admission to the other courses.

Training of hydrographers in Canada

The Canadian Hydrographic Service does not at present give any courses in oceanography but conducts two courses in hydrography. The basic hydrography course is given every year from 15 October to 15 December (approximately) and is both theoretical and practical, field training being normally conducted aboard a survey ship in the Caribbean Sea. The intermediate hydrography course takes place every year in May and June and is only theoretical.

This training is primarily for Canadian hydrographic staff, but candidates from other countries may participate if their application directed to the Dominion Hydrographer in the first instance is finally accepted by the Department of External Affairs.

Candidates for this training should be graduates of a technological institute, with a good grounding in mathematics, and a good working knowledge of the English language. Trainees will be admitted to the intermediate training course only if they have completed at least three years of field work.

An outline of the subjects taught is given below:

Basic hydrography course

Theoretical instruction

Introduction (7 sessions).

Orientation (26 sessions).

Map projections (12 sessions).

Horizontal control (general) (3 sessions).

Control stations (general) (2 sessions).

Vertical control (general) (3 sessions).

Instruments (theoretical) (7 sessions).

Instruments (practical) (20 sessions).

Computations (65 sessions).

Errors and adjustments (11 sessions).

Accuracies (2 sessions).

Electronic aids (5 sessions).

Sounding (6 sessions).

Shorelining (3 sessions).

Field sheets (12 sessions).

Special subjects (2 sessions).

Practical instruction

Recovery of survey monuments and bench-marks.

Station building.

Station description and monumenting.

Vertical control.

Horizontal control.

Wharf plans.

Field sheet work.

Stretchlining and sounding.

Shorelining.

Bottom samples.

Field notes and computations.

Miscellaneous (current metres, water level gauging etc.).

Intermediate hydrography course

Survey general (19 sessions): computations, distance measurement, theodolites, tellurometers, sextants, vertical control.

Hydrography (16 sessions): sounding, methods of sounding, shoals, range lines, shorelining, bottom samples, aids to navigation, field sheets, sounding equipment, echo sounding, echo sounders.

Air photographs (2 sessions).

Navigation and seamanship (16 sessions).

Navigation: chartwork, the compass, electronic aids, buoys and navigation marks, publications.

Chart production (8 sessions).

Currents (4 sessions).

Tides and water levels (8 sessions).

Radio aids (20 sessions).

Projections (14 sessions): shape of Earth, projections and grids.

Training of hydrographers in France

Foreign nationals with a good working knowledge of French may follow courses given at the training school of the French Naval Hydrographic Office. These courses are designed for training personnel in the following three categories:

Division I: Hydrographic engineers (officer rank);

Division II: Naval technicians (petty officer rank), for field or for office employment;

Division III: Civilian technicians, for office employment.

Division I courses

These are spread over two years, starting with a term of practical training (October–March), then six months participation in hydrographic work in the field, and lastly a second term of more theoretical training (November to June). The programme for the two terms is as follows:

Course	*Half days*
First term	
Practical hydrography	10
Practical oceanography	10
Practical geodesy	10
Practical knowledge of tides	15
Astronomy	17
Cartography	12
Hand computing	6
Administration	8
Supervised practical work	96
Electronic computer techniques	50
TOTAL	234
Second term	
Hydrography:	
Theoretical geodesy	6
Gravity, levelling	8
Marine acoustics	6
Radiolocation	5
Fixing by satellite (under consideration)	6
Oceanography:	
Tidal theory	15
Physical oceanography	15
Coastal processes	10
Regional oceanography	8
Other subjects:	
Photogrammetry	12
Magnetism	5
Meteorology	7
Oceanographic engineering	4
Supervised practical work	95
General electronics (course and practical work, both under consideration)	110
TOTAL	312

Division II courses

Instruction lasts 13 months. Six months of theoretical work and of supervised practical work at the headquarters of the Hydrographic Office in Paris (October to March) is followed by 7 months' participation in hydrographic work in the field (April to October).

The programme is as follows:

Course	*Sessions*
Mathematics	28
Navigation	16
Electricity–electronics	16
Geodesy	15
Hydrography	25
Cartography	15
Practice	
Computational practice:	
Mathematical computations	19
Navigational computations	12
Geodetic computations	20
Hydrographic computations	6
Cartographic computations	2
Drawing and plotting practice:	
Graphic work	50
Practical work:	
Electricity–electronics	9
Geodesy	43

Division III courses

These courses are designed for training civilian technicians of one of the three following specialities: Specialists in the graphic arts: cartographers, engravers, photoengravers, printers; specialists in scientific instrumentation: general instrumentation specialists, electronic instrument specialists; and technical secretaries: computers, cartographic and nautical librarians.

Instruction lasts two years, the first being devoted to general training of a nature common to all three categories, and the second to training which varies with the different specialities, usually acquired in training schools outside the Hydrographic Office.

The programme for the first year includes 5 months of courses with the Central Hydrographic Office (November to March) followed by a period of 3 months in the various departments of the Hydrographic Office (April to June) and finally 3 months in the field. The programme of courses is as follows:

Mathematics	12 lessons
Supervised practical mathematics	6 sessions
Navigation	16 lessons
Navigational computation	12 exercises
Electricity and electronics	16 lessons
Practical work in electricity and electronics	9 exercises
Geodesy	15 lessons
Geodetic computations	10 exercises
Practical geodetic work	11 sessions
Hydrography	25 lessons
Hydrographic computations	4 exercises
Cartography	15 lessons
Cartographic computations	2 exercises
Plotting and drawing	8 sessions
Cartographic drawing	—

Training of hydrographers in India

The Indian Naval Hydrographic Department conducts a number of courses for training various grades of hydrographic surveying personnel. Candidates from various maritime agencies within the country are also permitted to avail themselves of this facility. Facilities are also provided for training personnel from foreign countries. However, candidates should possess a good working knowledge of English as all instruction is conducted in that language.

Candidates from foreign countries wishing to avail themselves of these training facilities should apply to the Government of India through their respective national agencies.

The following courses are at present being conducted at the Naval Hydrographic School:

Officers: Hydrographic specialist officers' course. Duration 5 months. One course conducted annually.

Sailors: Surveying recorders 1st class course: 3 months. Conducted every alternate year.

Surveying recorders second class course: 3 months. Conducted annually.

Surveying recorders third class course: 3 months. Conducted annually.

The details in respect of these courses are outlined below.

Hydrographic specialist officers' course

The minimum academic qualifications required to undergo this course is a bachelor's degree in mathematics or science. During this course, the candidates are trained in actually carrying out all phases of a complete hydrographic survey of the approaches to a port. The syllabus includes the following:

(*a*) Basic hydrography	15 weeks
(*b*) Physical oceanography	
(*c*) Draughtsmanship	
(*d*) Meteorology	2 weeks
(*e*) Photography	1 week

Surveying recorders 3rd class course in hydrography

The minimum academic qualification required is School Leaving Certificate. The duration of the course is 14 weeks including 4 weeks' practical training on board a survey ship. This is a basic course meant to initiate junior sailors into the hydrographic branch. The subjects taught are:

(*a*) Elementary geometry and trigonometry
(*b*) Instruments—general principles
(*c*) Boat handling and sounding
(*d*) Rigging and sweeping
(*e*) Recording of observations
(*f*) Basic computation

Surveying recorders 2nd class course in hydrography

A survey recorder 3rd class with a minimum of three years' experience can be admitted to this course. The duration of this course is 12 weeks. The subjects taught are:

(*a*) Geometry and trigonometry
(*b*) Surveying instruments
(*c*) Sounding
(*d*) Computation
(*e*) Draughtsmanship and plotting

Surveying recorders 1st class course in hydrography

A survey recorder 2nd class with a minimum of three years' experience can be admitted to this course. The duration of the course is 12 weeks and is meant for surveying recorders. The subjects taught are:

(*a*) Geometry and trigonometry
(*b*) Electronic instruments
(*c*) Principles of radio aids in survey
(*d*) Computation, draughtsmanship and plotting
(*e*) Ability to use all survey instruments

All the above courses are being conducted at the Naval Hydrographic School, Cochin, Kerala, India. Plans to conduct additional courses for officers in higher surveying grades are at present under consideration.

Training of hydrographers in Italy

The Hydrographic Institute of the Italian Navy offers a course of ordinary specialization in hydrography in compliance with specific instructions received from the Ministry of Defence (Navy) of which the Hydrographic Service is a part. The purpose of this course is to give certain naval officers specialized training so that they may be particularly qualified to carry out hydrographic, oceanographic and navigational duties.

Language: Italian.

Nature of the teaching: The course is both theoretical and practical. It is divided into two parts: the first,

theoretical, lasting 7 months, is given at the Hydrographic Institute in Genoa; the second, practical, includes training aboard vessels carrying out hydrographic and oceanographic investigations, participation in geodetic or topographic expeditions on shore, and also a training period at the Hydrographic Institute for the purpose of completing the theoretical course with practical experience. Upon completion of the entire course those trainees who qualify are awarded a certificate of ordinary specialization in hydrography.

Level of knowledge: the course is at university level. Trainees should have completed the first two years of studies at university level in either engineering, physics, mathematics or the equivalent.

Positions available to trainees on completion of the course: Technical duties on board hydrographic or oceanographic units, after which they may be appointed to the staff of the Hydrographic Institute.

Subjects taught: Astronomy, geodesy, submarine electro-acoustics, photogrammetry, hydrography, magnetism, meteorology, oceanography, radionavigation, principles of electronic computer work.

Time and duration of the course: The course normally takes place every two years: the theoretical part from January to July (7 months), and practical training from August to March (8 months).

Terms of admission for foreign trainees: Individual authorization must be granted by the Ministry of Defence for officers of any foreign navy.

Training of hydrographers in Japan

Courses in hydrography for the training of hydrographers in Japan are given at the Training School which is a part of the Maritime Safety Agency. At present, however, this course is not open to foreign students; thus there are in Japan no regular facilities for training foreign students in hydrography.

On the other hand, the Hydrographic Office, one of the Divisions of the Maritime Safety Agency, has already accepted and can accept in the future several foreign students for training in hydrography from time to time, as requested. Students sponsored by UNESCO, UNTAB or the Colombo Plan can be received.

The training conditions are as follows:

Languages in which courses are conducted: Japanese and English.

Category of courses: Practical training.

Level of education necessary for acceptance: The student must have at least finished basic education in the subject he is going to take part in. Preferably, he should have some practical knowledge and experience in it.

Subjects taught: Physical and chemical oceanography, and cartography (compilation and drawing).

Frequency, dates and length of courses: Various, according to conditions, varying from a few weeks to almost a year.

Conditions of entry for foreign students: The student's travel and stay should be funded by UNESCO, UNTAB, the Colombo Plan or some other suitable foundation, governmental or private. The student must also have good linguistic knowledge and ability in Japanese or English, or both.

Other information: The number of trainees accepted at one time is strictly limited, because the Division has neither the staff not the facilities to be engaged exclusively in such training. Thus far only a few students have been accepted per year.

Training of hydrographers in Turkey

There are two courses, one for commissioned naval officers from a naval academy or naval college, the other for non-commissioned officers from a petty officers' school who have followed a navigation course. The course for commissioned naval officers is given in even years, and the course for non-commissioned officers is given in odd years. All courses last 6 months, from 1 September to 1 March. They may be completed by practical training in chart construction and reproduction.

The subjects taught are: basic hydrography, geodesy, cartography, map construction, lithography, maritime safety, basic mathematics, electronic navigation, instrumentation, physical oceanography, chemical oceanography geological oceanography, biological oceanography, meteorology and underwater sound. The training and instruction are one-third practical and two-thirds theoretical. The knowledge acquired is put to practical application on board survey vessels.

Courses are conducted in Turkish, but all instructors are fluent in English.

Foreigners may be admitted to the courses, their requests being subject to approval by the Turkish General Staff, and provided that no expenses are incurred by the Department of Navigation and Hydrography. These courses could be profitably followed by Turkish-speaking trainees from Middle Eastern countries that have not yet developed a hydrographic organization.

Training of hydrographers in the United Kingdom

Two types of courses available at the Royal Naval Hydrographic School at Devonport to trainees from other countries.

Basic course for hydrographic surveying officers

Three months' duration; three courses per year; two places per course. Courses begin in January, May and September. Candidates require the following qualifications:

A thorough knowledge of English enabling them to converse and read without difficulty. Ability to draw and write neatly. Ordinary knowledge of processes of arithmetic, British and metric systems of linear measures. Rectangle, triangle and figures derived from them; circle and sphere. Indices. Progressions.

Use of trigonometrical tables. Use of sine and cosine formulae. Trigonometrical ratios of angles of any magnitude. Solution of triangles. Very simple solutions of spherical triangles.

Changes of subject of a formula. Calculations using seven-figure logarithms to base 10. Solution of simple simultaneous and quadratic equations. Graphs and their simple application.

Navigation: determination of position by cross bearing; nautical and sea miles; the knot; triangle of velocities; drift, course and track; latitude and longitude; small and

great circles on a sphere; heights and distances. Simple map problems; scales, contour lines and slopes. Construction of plans and elevations. Elementary two-dimensional Cartesian co-ordinate geometry. Equation of a circle.

General appreciation of the terms used in nautical almanacs and nautical tables. Use of traverse tables.

Subject to the circumstances prevailing, in certain cases additional sea experience could be given in surveying vessels after the course is completed.

Basic course for surveying recorders (surveying technicians)

Ten weeks' duration; three courses per year; two places per course. Candidates must have a thorough knowledge of English enabling them to converse and read without difficulty. They require reasonable ability and speed in simple mathematics, and they should have neat and legible handwriting. (This course comprises able seamen of above-average intelligence.)

Both courses are normal naval courses to which outside candidates are attached. No special courses are available at present.

Accommodation during the courses cannot be provided, and candidates have to make their own arrangements. The courses are provided on a repayment basis.

Waltham Forest Technical College

A course for experienced land surveyors is available in hydrographic surveying at the Waltham Forest Technical College and School of Art, Department of Surveying and Construction at Walthamstow, London.

Hydrographic surveying for land surveyors

Five weeks' duration; three courses per year; enrolments limited to twelve students.

Brief syllabus:

Nautical knowledge: Ship and boat characteristics, operation, navigation and pilotage.

Hydrographic surveying: specifications, office and field planning and preparation; tides, observation, analysis, prediction, datums and computer application; sounding, echo sounders, traditional and electromagnetic position fixing, precise work; automated data processing; sweeping, by wire, conventional sonar and side-scanning sonar; bottom sampling, topography; rendering data and reporting to client.

Miscellaneous: basic oceanography, marine geophysics and deep-sea surveying.

Practical work: students will perform practical tasks under simulated conditions in the laboratory and the research vessel *Sir John Cass*. The course includes a field scheme and visits to see the full range of relevant instrumentation as detailed in the course schedule.

Training of hydrographers in the United States of America

Foreign nationals possessing a good knowledge of English can profit from training in hydrography in the United States, attending courses organized by the United States Naval Oceanographic Office (NAVOCEANO) and by the Coast and Geodetic Survey.

NAVOCEANO has two distinct courses suitable for junior naval officers, warrant officers and civilians of allied nations:

A series of courses in hydrographic engineering and basic oceanography. The series lasts one year, and deals with the following subjects:

	Weeks
Orientation	1
Technical English and mathematics review	1
Horizontal and vertical control	6
Electronic surveying	3
Geodesy	5
Map projections and plans co-ordinates	4
Geodetic computations	9
Geophysics	2
Nautical chart construction	3
Map reproduction	3
Geodetic astronomy	8
Photogrammetry	8
Hydrography	8
Basic oceanography	6

A series of courses concerning basic oceanography and applied oceanography. This series lasts 24 weeks and deals with the following subjects:

	Weeks
Basic oceanography	6
Orientation in applied oceanography	1
Statistical oceanography	1½
Marine biology	2½
Physical properties of sea water	2
Tides and currents	2
Ocean waves	2
Underwater sound	2
Marine geology	3

The two series can be followed consecutively. In that case the oceanography course would be of 16 weeks only, since basic oceanography is one of the subjects included in the other series.

The Coast and Geodetic Survey offers courses of further instruction for those already familiar with certain methods and practices:

(*a*) Hydrographic surveying. This course lasts 48 weeks (including 12 in the field). The principal subjects studied are cartography, currents, tides, electronic equipment, triangulation, geomagnetism and photogrammetry;

(*b*) Tides (22 weeks) and currents (22 weeks);

(*c*) Geodetic surveying (48 weeks including 12 in the field: triangulation, levelling, gravity, astronomy);

(*d*) Gravity and astronomy (30 weeks including 6 in the field);

(*e*) Geomagnetism (48 weeks including 18 in the field);

(*f*) Map and chart construction (48 weeks);

(*g*) Map and chart reproduction (48 weeks);

(*h*) Photogrammetry (38 weeks including 5 in the field);

(*i*) Seismology (professional) (48 weeks including 10 in the field).

TECHNICAL PERSONNEL FOR HYDROGRAPHIC SURVEYING

Paper presented by Brazil[1]

The Directorate of Hydrography and Navigation in Latin America has, for about 15 years, been training and instructing naval officers and civilians from Latin American countries in hydrographic surveys. In addition to theoretical courses, practical work in surveys along the Brazilian coast have also been offered on board hydrographic ships and in technical departments. Thus far the Directorate has trained and instructed in Latin America a total of thirty-one technicians, as follows: Argentina: 1 naval officer; Bolivia: 1 naval officer; Chile: 4 naval officers; Colombia: 3 naval officers; Ecuador: 7 naval officers; Guatemala: 1 civilian; Mexico: 2 naval officers; Paraguay: 1 naval officer; Peru: 5 naval officers; Uruguay: 2 naval officers; and Venezuela: 4 naval officers.

This is the contribution that Brazil has been making in the training of specialized technicians in hydrographic surveys. However, the maintenance of the individuals training in Brazil is paid for by the countries concerned.

[1] The original text of this paper, prepared by Commander Mucio Piragibe Ribeiro de Bakker, Diretoria de Hidrografia e Navegaçao, Ministerio da Marinha, Rio de Janeiro, appeared as document E/CONF.57/L.3.

RESULTS

The results achieved with the training of specialized technical personnel in Latin America have not been satisfactory. Perhaps one of the reasons is that the personnel trained in hydrographic surveys, after returning to their countries, are not employed in the execution of surveys, but are transferred to other activities; therefore the instruction acquired and the training achieved may be considered wasted.

CONCLUSIONS

The experience in Latin America has demonstrated that the training of personnel for hydrographic surveys only is not enough. It becomes necessary, first of all, to establish a programme involving not only training, but also a guarantee that the personnel trained will continue in hydrographic work. The hydrography courses in Brazil are, and have for many years been, for personnel from all the Latin American countries.

COASTAL BOUNDARY SURVEYS

Paper presented by the United States of America[1]

INTRODUCTION

New emphasis is now being given to the coastal zone as the nations enter into a new phase of world interest in the sea. Accelerated development and growth of the use of the sea are indicative of expanded exploitation for the benefit of commerce, industry, recreation and settlement. Some day aquaculture may well rival and surpass agriculture in importance as the population growth forces increased dependence upon the marine environment for survival.

Increased international effort must be made if our technology is to be used effectively in making intelligent use of our oceanic resources. One of the basic problems now being encountered is the determination of the extent of offshore waters over which a maritime nation has sovereignty. Ownership of rights to the ocean floor, State–Federal jurisdiction, the extent of fishing rights and other factors are pressing problems.

The Geneva Conventions clarify some of the legal questions involved, but many remain unresolved. The Federal–State contention in the United States of America over lands and minerals in the complex coastal areas is far from settled. The era of submarine law is here, and with it is a dire need for determining precise jurisdictional boundaries.

Determination of location and form of the baseline and other tidal boundaries involves two fundamental surveying procedures: (*a*) establishment of tidal datum planes which provides the vertical component; and (*b*) the horizontal delineation of the shoreline at the accepted tidal datum plane elevation.

The first is performed with tide gauges, and the second through aerial photomapping, where the state of the art in photogrammetry provides the best alternative for the accomplishment of the boundary mapping task.

International law defines the boundaries, but they must be determined and then located and mapped for practical purposes. Furthermore, precision in offshore boundary delimitation is necessary in order to resolve legal problems of jurisdiction. This means that the boundaries must be positioned in terms of geographic co-ordinates.

Hydrographic offices and mapping organizations have a historic responsibility for mapping the coastal frontiers and have accumulated a vast store of pertinent data. Nautical charts and topographic and hydrographic surveys, from which the charts have been constructed, will supply a large part of the information needed in meeting modern problems in seaward boundary demarcation. These archives include a wealth of accumulated tidal information, tidal datum planes, geodetic data and aerial photography.

The mapping becomes increasingly important as the value of onshore and offshore coastal properties increase. It is indeed a formidable task to acquire the great number of qualitative and quantitative measurements and observations necessary to produce the required coastal zone graphics. Existing charts and survey data are of inestimable value in portraying the coastal zone for boundary demarcation as well as engineering structures and alongshore economic development.

[1] The original text of this paper, prepared by Rear-Admiral D. A. Jones, Director, Coast and Geodetic Survey, Environmental Science Services Administration, Rockville, Maryland, appeared as document E/CONF.57/L.13.

Operational aspects

Boundary "demarcation," or the laying out of a boundary on the ground and with an appropriately detailed pictorial representation, is strictly an engineering and cartographic problem. The field work involved encompasses ground control; projection of the boundary line; mapping and boundary strip; and placement of survey monuments. Problems usually encountered in demarcating a dry land boundary are considerably more complicated in the demarcation of a submerged land boundary.

In mapping the shoreline for nautical charts, the general practice of the surveyor or the field inspector of aerial photographs is to identify the mean high-water line by examining the water marks and other features of the shoreline rather than levelling from tidal bench-marks.

In many of the States of the United States, the riparian boundary of private property facing tidal waters is the mean high-water line; in others, it is the mean low-water line. The demarcation and mapping of those tidal boundaries are important to property owners. In a more modern context, we must deal with the delineation of the seaward extensions of national boundaries. The problem is to either physically define the boundary by bottom markers or to devise a method by which a buoy, ship or structure can be placed on a boundary station as it is legally defined.

Rapid developments now occurring in the coastal zone and on the Continental Shelf of the United States make it increasingly imperative that the United States accelerate its traditional shore and sea boundary programme specifically for boundary purposes. Since the outer seaward boundaries for most of its coastal states extend only three nautical miles from the ordinary low-water line, accurate positioning can be obtained by onshore geodetic operations; that is, by triangulation, electronic distance measurements or a combination of both. Accuracy obtainable should be to within less than 0.3 m, which is probably far better than bottom markers can be placed or a ship can be manoeuvred directly over a bottom marker or into a predefined position.

As economic factors involving the Continental Shelf require seaward extensions well beyond the three-mile limit and the line of sight from shore, other methods for positioning must be considered. Some existing electronic positioning systems now in use provide control for distances as far out as 1,000 nautical miles. It is realized, of course, that the accuracy at these longer ranges decreases considerably.

For the recovery of a previously located offshore boundary point, there are certain applications of underwater acoustic positioning which depend on a series of arrays of active bottom markers. This method of positioning will permit high relative accuracies of a few metres in limited areas anywhere in the ocean, but the absolute positioning of this system will have to be provided by other means, such as the Navigation Satellite System or some long-range electronic fixing system.

Mean sea level takes on a new significance when we deal in the offshore area. Mean sea level is defined by geodesists as the equipotential surface which the oceans would assume if the only forces acting upon them were the Earth's gravitational forces and the centrifugal forces set up by the Earth's rotation. There are other forces, however, with which we must deal, such as the tidal forces of the sun and the moon, and the meteorological forces such as wind, atmospheric pressure, and others which vary from time to time and place to place.

These forces produce an ever-changing surface of the sea which is difficult to relate to the ideal equipotential surface of the geodesists' mean sea level. It is true that the differences between the outer surface of the sea and the equipotential surface are of a rather small order; perhaps only a few metres at most. Still some oceanographers are interested in what they call the slope of the sea and its position above or below the equipotential surface at any given time at a given place.

Definitions of datums

In general, aerial photography for mapping the coastline is other than tide-controlled photography, but tide-controlled photography for the location of both the mean high-water and the low-water lines is now coming into greater use. The topographer or field inspector of aerial photographs ordinarily judges whether the elevations of the tops of detached rocks lying close to shore are between mean low water or mean high water by their appearance and with his knowledge of the stage of the tide from the predicted tide tables. The low-water line and the elevation of off-lying rocks, ledges and shoals that are awash are of paramount importance in the establishment of sea and shore boundaries.

Much of the low-water line for nautical charts is mapped by the hydrographer. Soundings are made over this line at higher stages of the tide and then reduced in accordance with the tide records. The mean low-water contour is then drawn through the zero soundings. The hydrographer also positions and determines the elevation of many of these off-lying features. He usually records the approximate elevation of rocks lying far enough offshore to be a factor in navigation.

United States practice in charting rocks awash at low-tide stages along the Atlantic and Gulf coasts is to show a rock awash or by symbol on the nautical chart for land features that are bare anywhere between 0.3 m below mean low water or 0.3 m above mean high water. This practice is followed for the safety of navigation and does not bear any direct relation to boundary matters, although it becomes a factor in laying out the coastal baseline for boundary extension.

On the other hand, a low-tide elevation in terms of the Geneva Convention is a land feature that is bare at any stage of the tide between the low-water datum and the plane of mean high water. Occasionally, the question arises as to whether a rock awash shown on a chart may possibly be covered at low water or may be just bare at high water, making it an island. Such uncertainties can usually be resolved by existing survey records. On occasion, however, it is necessary to make a more definitive field survey in an area where a significant economic factor is involved.

Although United States nautical charts and the surveys from which those charts were made supply some of the information for establishing sea boundaries, they do not supply all of it. It is necessary to map the normal baseline in many places specifically for boundary purposes, either because of a need for greater boundary accuracy or because the coastline has changed. Let us then consider the accuracy requirements and means for this mapping.

The survey or mapping of the "normal baseline" involves two principal components: a vertical component and a horizontal component. We must first determine the elevation to recoverable bench-marks on the ground; this is the vertical component. Once the elevation of the tidal datum has been established and referred to recoverable bench-marks, the local surveyor can begin to map the normal baseline. This is the horizontal component.

After the tidal bench-marks are re-covered, a closed line or loop of differential levels is run from the bench-marks to that part of the shore where the boundary is to be located. Levels are run along the shoreline and points are selected at intervals along the shore in such a manner that the ground at each point is at the elevation of the tidal datum. Thus, the boundary is demarcated.

The surveyor then measures the horizontal distances and directions, or bearings, between each of the points and between those points and other features in the area—and/or between the points and horizontal control stations—so that the boundary may be compiled on a plat, or on a map, to an exact scale ratio and in true relation to other boundaries of the property and/or to the international geodetic datum. Tidal bench-marks in the United States are set near the tide stations. It might be quite laborious for a surveyor if he had to run his levels all the way from the tidal bench-marks to the place of his boundary survey where that place may be a number of miles from the tide station. Usually, this is not necessary owing to the connexions already made to many of the tidal bench-marks to the primary level network of the nation. Thus, the surveyor usually can start his survey from the nearest bench-mark of that network.

The primary level network is a United States system of bench-marks established by the Coast and Geodetic Survey. These bench-marks are connected by precise levelling and all are adjusted to one reference surface called the Sea Level Datum of 1929. The last continental adjustment of this network was made in 1929. At that time, the network was connected to some twenty-eight primary tide stations distributed around the coast of the United States to determine the reference surface. Thus, the Sea Level Datum of 1929 is not a tidal datum, but is based on tidal datums at the twenty-eight tide stations. The Sea Level Datum of 1929 will not always be at exactly the same elevation as mean sea level (a tidal datum) determined at any one tide station. For the purpose of boundary surveys, however, the primary level network is important only as an accurate network of bench-marks when a tide station, or the tidal bench-marks for that station, have been connected to the primary network. Every bench-mark in the primary network then has a known elevation in relation to the tidal datums of that particular tide station.

In selecting a chart compilation scale for the mapping of the normal baseline, a scale of 1:20,000 is usually considered adequate, although some areas may require mapping at the larger scale of 1:10,000. The scale 1:20,000 is more than adequate for most practical purposes when one considers the methods that must be used in mapping anything as difficult to reach and to define exactly as the mean low-water line. These lines, marked by the intersection of the surface of the sea with the shore at a specific tide stage, are ordinarily not well defined on the ground because the water surface is seldom calm.

Because the shoreline along tidal waters changes continually in shape and horizontal position owing to the rise and fall of the tide, the vertical datum has special significance. Accuracy is controlled by the number of tide observations that are made and the length of the period the tides are observed. In this connexion, the slope of the foreshore (the area between high water and low water) must be considered. The minimum degree of slope within an area to be mapped is the deciding factor. For example, in Louisiana, there are places where the foreshore is over 1 km wide with a tide range of only about 0.4 m. In this situation, the tides were observed for something over a year to establish the datum within about 0.05 m vertically. On much of the outer coasts of the United States, however, the beaches are much steeper than this. If the foreshore, for example, has a slope of 5 degrees then an error in the tidal datum of 0.06 m will cause a horizontal displacement of the normal baseline of about 0.7 m.

Photogrammetric techniques

The Coast and Geodetic Survey has found that tide-controlled infra-red aerial photography provides an excellent means of mapping the normal baseline. After the tidal datum has been established, observers at the tide stations establish radio communication with the photographic aircraft and can notify the flight crew when the water surface is at the datum elevation. Infra-red photographs are then taken at the correct water level (as, for example, mean low water or mean lower low water). These show the line of intersection of the water with the land very clearly and this line is mapped by photogrammetric methods. The negative scale is 1:30,000.

Infra-red photography utilizes the "near" infra-red portion of the electromagnetic spectrum (wave length range of 700 to 900 millimicrons). It has a special characteristic that water areas are rendered black. This is due to an increase in absorption at 700 millimicrons. Thus, an infra-red photograph shows the water as black, or very dark, in contrast to the shore and provides a sharp, well-defined line of contrast between land and water.

The techniques of obtaining good quality infra-red photography are somewhat different than for panchromatic photography. Special attention must be given to the selection of the camera, the storage of unexposed film, filter, exposure and processing, but these techniques have been quite well worked out at the Coast and Geodetic Survey and are not too difficult.

Although infra-red photography is unsurpassed for mapping a shoreline contour, such as the mean low-water line or the mean high-water line, it is not very suitable for mapping very small, detached features such as small pinnacle rocks. These may be missed on infra-red photography because this photography does not permit any water penetration. If the existence of such features is expected, colour photography should be used to inventory and map them.

For example, at a mapping scale of 1:20,000, the red photographs might be taken at any scale between 1:20,000 and 1:40,000. The larger-scale photographs will, of course, show more detail, and this is necessary on some types of shoreline. The smaller-scale photographs will make the photogrammetric plotting easier and will require less ground control.

Normally, colour photographs are taken simultaneously with a different camera in the same airplane. Also, another set of colour photographs is taken at a smaller scale

(for example, 1:50,000 to 1:80,000) to use for analytic aerotriangulation so as to reduce the amount of geodetic control surveys.

The first step in mapping by means of tide-controlled photography is to re-cover, or establish, the tide stations and to lay out, on the flight maps, the section of coastline controlled by each tide station. Along a generally straight coastline, one tide station will serve to control many miles; for example, four tide stations probably will be adequate to control the photography for the entire outer coast of the State of Texas, a distance of 600 km; on the other hand, it was necessary to use eight tide stations for tide-controlled photography of the outer shoreline of the Mississippi Delta (300 km); and a few years ago, nine stations were used for tide-controlled photography of the shoreline around Nantucket Sound, Massachusetts (160 km).

Adequate tidal datums have already been established for much of the outer coast of the contiguous United States.

Many of the tide stations established in the past have been connected to tidal bench-marks or to the primary level network. Speaking very generally, the datum thus established would be correct within ± 0.06 m, and in the vicinity of primary tide stations, it would be even more accurate.

Tide-controlled aerial photography must be done on days when the tide reaches the proper level during daylight hours and when the sky is cloud-free or nearly so. These are rather difficult conditions to meet, and consequently, tide-controlled photography is more time-consuming and more expensive than normal aerial photography. A special problem is encountered in areas where most of the low tides occur at night; and in some areas low water may occur in daylight hours only during the months of November to late January. In such instances, the tide-controlled photography has to be taken in the winter. Also, the cloud cover has to be considered because cloud-free photographic weather is essential. In other applications, a strong wind holding for some days could change the tides and prevent them from falling as low as mean low water.

Moreover, the period of photography is very short for any one tide (for example, 15 minutes to 1 hour). The tidal datum of mean low water is a mean of all the low waters. On any given day, the low tide will either not get as low as the datum or it will go below the datum. In other words, the low tide rarely goes exactly to the datum level and stops there for a time. As a consequence of this, mean low-water photography is taken when the falling tide crosses the datum level, or when the tide, having fallen below the datum level, crosses that level again on the rise, and these periods are very short.

It is thus very difficult to obtain photographs of all the shoreline at exactly the datum level. Usually it is advisable to take several sets of photographs and endeavour to have these slightly above the datum level and slightly below the datum level. Then if the photography is not at exactly the datum level, an accurate interpolation can be made from the photographs taken just below and just above that level.

Some field examination of the tide-controlled photographs, or of the maps compiled from those photographs, is necessary: to ensure that no small features, such as pinnacle rocks, have failed to show on the photography and have, therefore, been missed; to check the elevations of small off-lying rocks or bars whose tops happen to be at, or very close to, the datum level; and to examine any sections of the datum line that may have been difficult to interpret from the photographs. This field inspection should be made with the tide at, or close to, the datum plane.

Questions often arise regarding the interpretation of the mean high-water line in marsh or swamp areas on our coastal topographic surveys. In marsh or swamp areas, the nautical charts show the offshore edge of vegetation (not the actual mean high-water line) as the shoreline, because this is the line that the mariner sees at high water. Consequently, the topographic surveys of the Coast and Geodetic Survey map the offshore edge of the grass in marsh and the offshore edge of brush and trees in cypress and mangrove swamps; the topographic surveys do not show the actual mean high-water line on the ground in these areas. The mean high-water line on the ground (intersection of plane of mean high water on the ground) often is not along the front or offshore edge of the marsh or at the back limits of the marsh, but meanders around between the front and back limits.

The location of a boundary as it exists sometime prior to the time of the survey is often of interest to property owners. Physical features of boundaries as they existed at some time in the past may be very difficult to determine. The shore often changes because of wave action along the open coast and because of erosion and accretion due to currents. Once a change in the shore has occurred, it is not possible to demarcate or map a tidal boundary as it existed before the change because the old boundary (for example, the mean high-water line) no longer exists and cannot be seen. This fact is readily understood if one considers that the boundary is the line of intersection of the surface of the water with the land. Obviously, if the land changes, this line will be in a different horizontal position, and if the land has changed, we have no ready means of tracing out where the line was before the change. Old maps made before the shoreline change are about the only means of finding where the boundary was in the past, that is, prior to the change. Most places have been mapped several times by C&GS and these repeat surveys serve a useful purpose in this connexion.

Applications

About 10 years ago, our attention was directed to the need for more intensive surveying and charting of the coastal zone. The low-water and high-water lines on existing surveys and depicted on nautical charts, although adequate for navigational purposes, were not, in some instances, in sufficient detail for settling shore and sea boundary disputes because of the small scale of the coastal charts; they did not provide the necessary large-scale accuracy required in boundary litigation matters.

Certain coastal States and concerned agencies of the Federal Government requested assistance through the production of special-purpose shore and sea maps. The request was made in recognition of the C&GS as an authority on tidal datums with long years of experience in charting these lines. Especially important was the modern use of tide-controlled infra-red aerial photographic techniques.

In response to one of these requests, the low-water line mapping of most of the coast of Louisiana was accomplished through a co-operative project between C&GS, the Bureau of Land Management and the State Mineral Board of Louisiana. Through this effort, additional basic

tidal data and up-to-date planimetric maps were provided for revision of C&GS nautical charts. Also, a special set of fifty-four maps was produced showing the mean low-water line and the co-ordinates of baseline points that were especially selected by the State of Louisiana and the Bureau of Land Management for use in establishing an accurate baseline on which to base jurisdictional boundaries essential in leasing extensive offshore oil and gas fields.

Recently, the State of Florida requested the determination of tidal datum planes and the mapping of the mean low-water line and the mean high-water line. It is estimated that the work will be completed in five or six years—the first phase is essentially completed.

A NEW NAUTICAL CHART PRODUCT

A noteworthy by-product has evolved from recent seaward boundary surveys in the form of a nautical chart which includes aerial photographic imagery of the onshore detail. The new chart therefore can now depict the onshore information as it actually appears rather than simply with chart symbols such as swamp, trees and the like. Owing to the new techniques that are applied, the details fall in their correct locations. The compilation of line drawings is greatly reduced and simplified. The new product is both more pleasing in appearance and more meaningful to the user—yet the cost need not be any greater.

The new product has resulted from several factors: (*a*) techniques had been developed for the production of accurate orthophotos; (*b*) several scales of excellent photographs were already available because they had been used for aerotriangulation and for shoreline compilation; and (*c*) a large number of accurately located points had been determined by the aerotriangulation procedure.

Perhaps the term orthophoto map should be defined. In appearance, it resembles an aerial photograph; however, the planimetric positions of features are corrected for the tilt of the aerial camera and for the elevation of the terrain. An orthophoto may be produced photographically from an aerial photograph with a special line-scanning type of printer but, where the terrain is flat, an orthophoto may also be produced with a photogrammetric rectifying printer or by conventional controlled mosaicking. It is significant that an orthophoto map has a planimetric accuracy equal to or better than line-drawn maps.

We expect that eventually all nautical charts may include orthophoto imagery, although it is now being applied only in a limited way for the seaward boundary plans. Moreover, it is also possible to use full-colour orthophotos; before long our charts will probably include this colour material. The colour images aid materially in their identification by the user; for example, trees are green, rooftops are various colours and so on. A further improvement is also available in the form of a photographic screen that eliminates the half-tone screen in chart printing—the photo images themselves perform the printing function of the dots of a screen.

CONCLUSION

It becomes evident that as developments in the coastal zone and the Continental Shelf accelerate, an increasing demand will result for the United States to accelerate its traditional shore and sea programme specifically for boundary purposes. Studies of sea and shore boundaries forcefully indicate the number of technical questions that arise and the extent of judgement required. The most that can be provided are the principles for the delimitation of sea boundaries; answers cannot be provided to every technical or interpretation problem which will arise in laying out sea boundaries in the presence of an almost infinite variety of physical features. This will require agreement and co-operation between the States and the Federal Government and probably some litigation.

ANNEX

Tidal datums: definitions

Several reference planes are derived from tidal data, but only three are of interest here. Tidal datum planes vary somewhat with the type of tide. Along the Atlantic Coast of the United States, where both semidiurnal and diurnal types of tide occur, tidal datum planes are mean high water and mean low water. Along the Pacific Coast, including Alaska and Hawaii, where tides are chiefly of the mixed type, datum planes are mean high water and mean lower low water. Simple definitions of these planes are:

(*a*) Mean high water at any place is the average height of the high waters at that place over a given period of time;

(*b*) Mean low water at any place is the average height of the low waters at that place over a given period of time;

(*c*) Mean lower low water at any place is the average height of the lower low waters at that place over a given period of time.

Although tidal data observed throughout a 19-year period permits the most accurate determination of a tidal datum plane, determinations of acceptable accuracy for many engineering uses can be made from data observed over a much shorter period of time.

REFERENCES

A Study of the U.S. Coast and Geodetic Survey's Products and Services as Related to Economic Activity in the U.S. Continental Shelf Regions, Battelle Memorial Institute, January 1966.

California and Use of the Ocean, University of California, Institute of Marine Resources, October 1965.

Effective Use of the Sea, report of the Panel on Oceanography of the President's Science Advisory Committee, June 1966.

Establishing Tidal Datum Lines for Sea Boundaries, by W. L. Griffin, B. G. Jones, and J. M. McAlinden, paper presented at the Joint American Society of Photogrammetry-American Congress on Surveying and Mapping Convention, March 1967, Washington, D.C.

Man's Geophysical Environment—Its Study from Space, a report to the Administrator of ESSA, March 1968.

"Mapping the Low-Water Line of the Mississippi Delta", by B. G. Jones and W. Shofnos, article in *International Hydrographic Review*, January 1961.

Our Nation and the Sea, report of the Commission on Marine Science, Engineering and Resources, U.S. Government Printing Office, Washington, D.C.

Science and Environment, *Industry and Technology*, and *Marine Resources and Legal-Political Arrangements for Their Development*, in set of three volumes, panel reports of the Commission on Marine Science, Engineering and Resources, U.S. Printing Office, Washington, D.C.

Sea Boundaries and Nautical Charts, by J. C. Tison, Jr., paper presented at the Second Alaska Surveying and Mapping Convention, February 1967, Anchorage, Alaska.

Shore and Sea Boundaries, by A. L. Shalowitz, publication 10-1 in two volumes, U.S. Government Printing Office, Washington, D.C.

The Law of the Sea and the Continental Shelf, by W. L. Griffin, paper presented at the International Academy of Trial Lawyers, February 1967, Mexico City, Mexico.

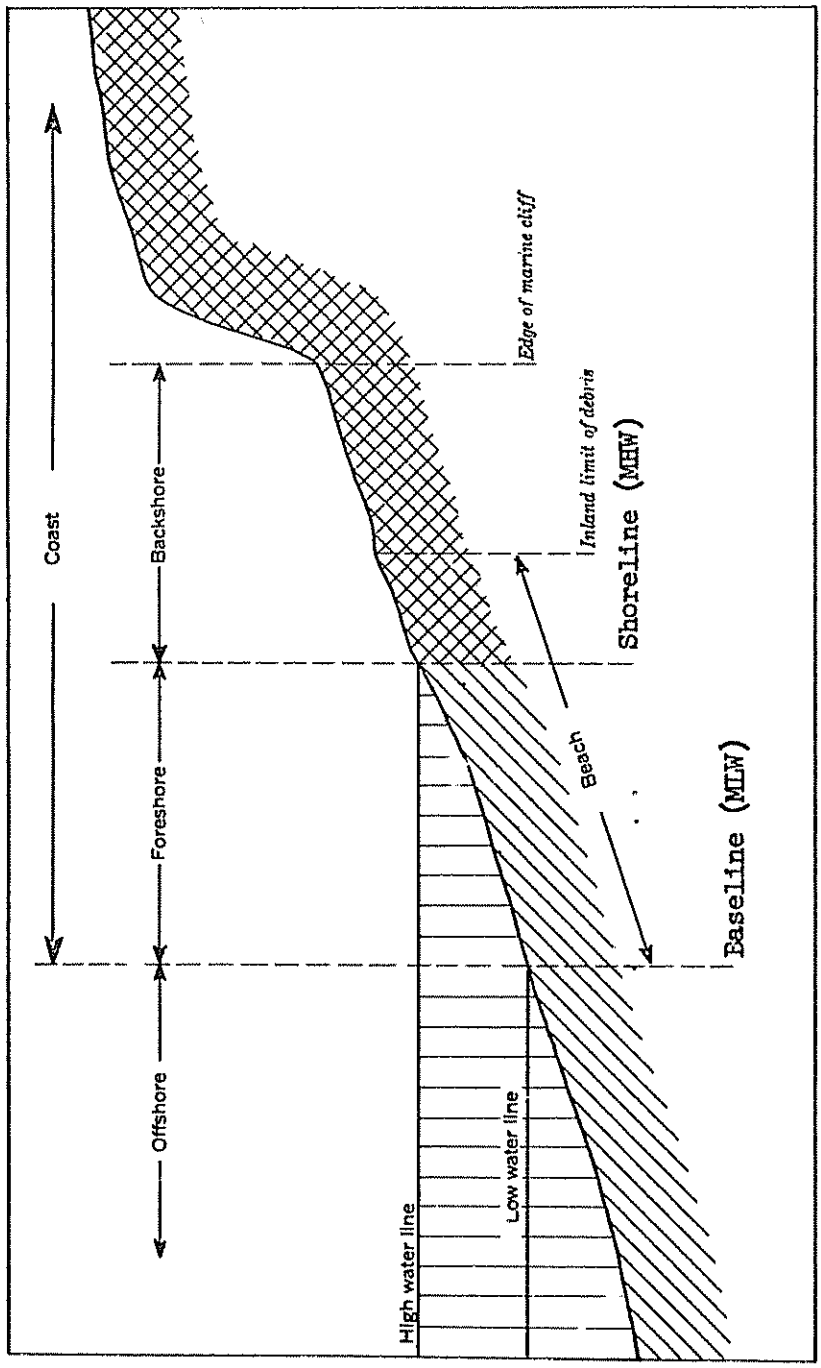


Figure 1. Diagram defining the limits of coastal features

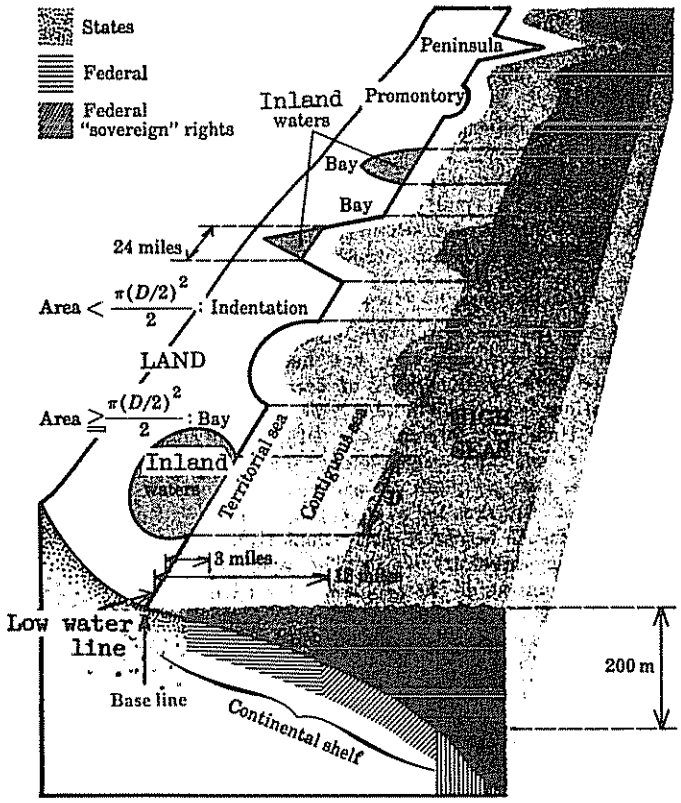


Figure II. Generalized application of the principles of seaward boundaries

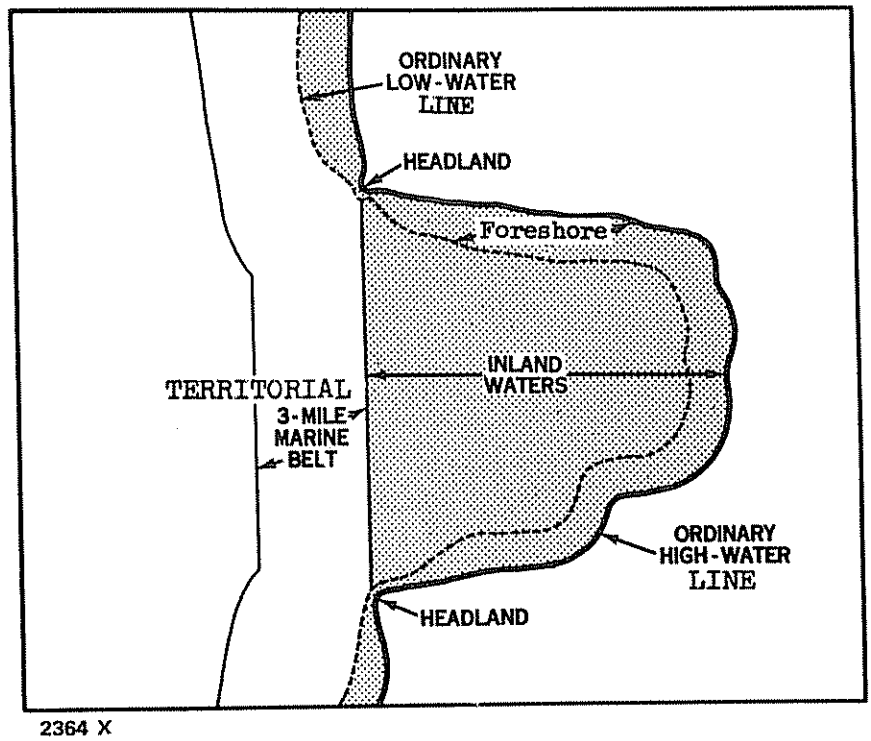


Figure III. The 3-mile territorial zone and its relation to inland waters

OCEANOGRAPHIC MAPPING: THE KEY TO DAVY JONES' LOCKER

Paper presented by the United States of America[1]

Introduction

The question of our use and abuse of the seas has been the subject of progressively more detailed studies by numerous international, national and local commissions over the last decade. The United States Congress has also expressed its interest and concern in this question by legislation establishing the Marine Resources and Engineering Development Act of 1966, which expressed a conviction and defined a national purpose as follows:

"1. A conviction that the time has arrived for this country to give serious and systematic attention to our marine environment and to the potential resources of the oceans; and

"2. A national determination to take the steps necessary to stimulate marine exploration, science, technology and financial investment on a vastly augmented scale."

The act established two complementary bodies: the National Council on Marine Resources and Engineering Development and the Commission on Marine Science, Engineering and Resources. The Commission chairman was Julius A. Stratton of the Ford Foundation, and its membership included distinguished representatives from private industry, academic institutions and Federal and local agencies. In a final report presented to the Congress in January 1969, the Commission observed:

"The nation's interest in the seas, the land beneath and the atmosphere above require that it attains the capability to observe, describe, understand and predict oceanic processes on a global basis. The nation is engaged or must be prepared to engage in operations in all of the world's oceans at increasing depths and in increasingly hostile environments. It has a vital stake in the living and non-living resources of the global seas. Its industry, commerce and agriculture are critically dependent on the weather, controlled in large measure by global ocean conditions. The safety and well-being of its people and their property must be protected against the hazards of air and ocean.

"The environmental information the nation requires for these purposes ranges from descriptions of the topography, geophysics and geological structure of the deep sea floor to the understanding of the normal conditions of the oceans' chemistry, biology, thermal structure and motions, and the prediction of the rapidly changing ocean and atmospheric phenomena recognized as our daily weather and sea state."

The range of tasks suggested above are both numerous and very complex and could hardly be itemized, let alone developed within the limits of a single informal technical programme presentation. This paper will therefore discuss only that portion of the information specifically designated in the report's recommendations as follows:

"The Commission recommends that . . . (ESSA) undertake the systematic mapping of the bathymetry and geophysics of the U.S. nearshore waters and continental shelves and slopes to a depth of 2,500 m. The program should be funded at a level to provide 1:250,000 scale continental shelf and slope maps of bathymetry, magnetics, gravity and sediment depth and type within 10 years. Every effort should be made to declassify existing data which are of mapping accuracy and thereby avoid the need for resurveys."

The United States Coast and Geodetic Survey (C&GS), an integral part of the Environmental Science Services Administration (ESSA), is now engaged in a geophysical mapping programme to implement the above recommendation (figures I and II).

Figures I and II show the 1:125,000 and the 1:250,000 scale map limits for the continental shelf and adjacent slope to a depth of 2,500 m. With variations in the amounts of data required and the complexities encountered with the deeper environment, essentially the same principles apply in deep-sea mapping.

Bathymetric mapping

A bathymetric map is arbitrarily defined as a graphic representation of the relief or topography of a circumscribed portion of the sea floor through the use of contours, depth curves, form lines, hill shading, numbers or any other techniques that can be used to represent relief. As it defines the upper limit of the Earth's crust that is covered with water, it serves as a "base" map for the depiction of parameters that portray geophysical and geological characteristics of the crustal structure and its composition. To this extent it is the water-covered counterpart of the air-covered terrestrial topographic map. Both have essentially the same vertical plane of reference, sea level, and both usually share a common horizontal geographic datum. The analogy stops there, however, because of an obvious difference—the water overlay has an abundant supply of living and mineral resources that are exploitable and therefore require detailed mapping.

Other uses for the bathymetric map are in nautical chart construction, engineering applications, such as pipeline and cable laying, fisheries resource habitat studies and numerous studies dealing with the water mass including estuarine flushing and sediment transport.

The hydrographic source materials for the United States continental margin bathymetric maps are very diverse in quantity and quality. In addition they were conducted over a span of many years, which makes the compilation problem much more difficult than if all the data were acquired over a short and recent time span. They range from accurately controlled large-scale inshore hydrographic surveys in all important harbours and approaches, to random tracklines in the open ocean, with or without supporting information to properly evaluate them. All depth information on basic C&GS hydrographic surveys and tracklines since about 1940 have been compiled from continuous graphic depth profiles. The large-scale C&GS hydrographic surveys, 1:5,000 to 1:40,000 (figure III) were designed to support the C&GS Nautical Charting Program. This use prescribed that the amount of data gathered be sufficient to provide reasonable assurance that no submerged danger to navigation existed in the sampled area. The survey line geometry usually consisted of a series of parallel lines run perpendicular to the major

[1] The original text of this paper, prepared by J. M. McAlinden, Coast and Geodetic Survey, Environmental Science Services Administration, Rockville, Maryland, appeared as document E/CONF. 57/L.14.

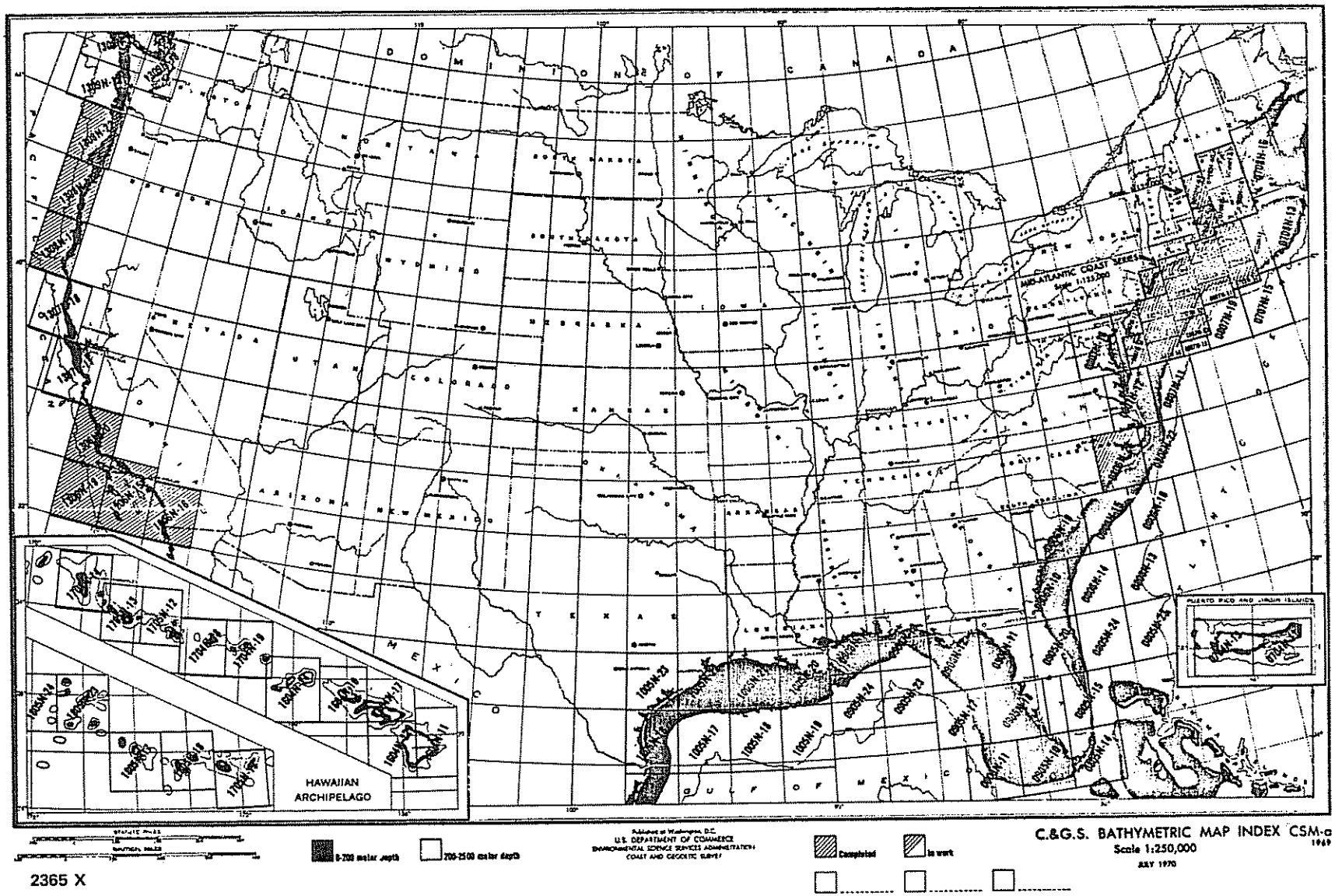


Figure I. United States and adjacent continental shelf

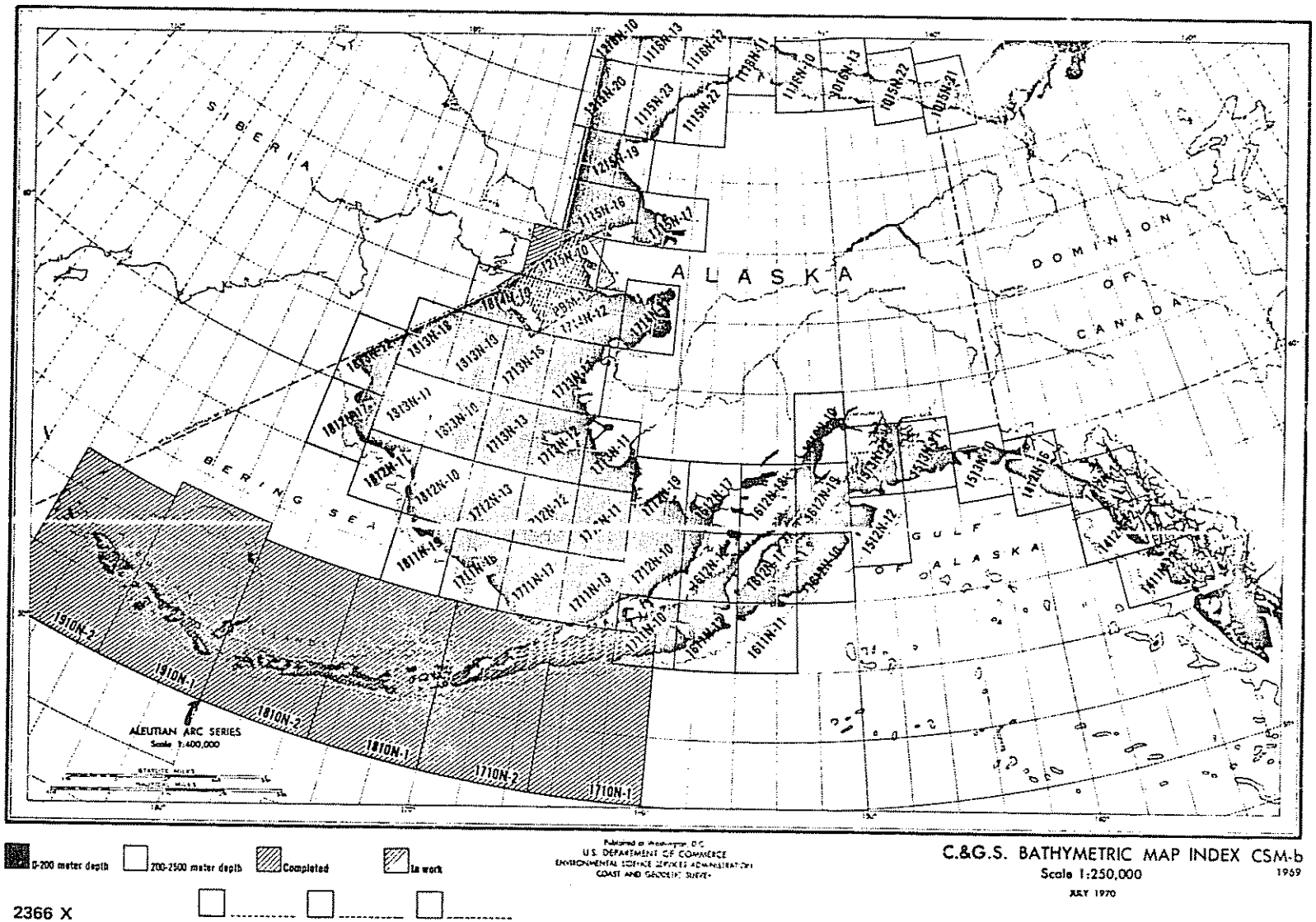


Figure II. United States and adjacent continental shelf

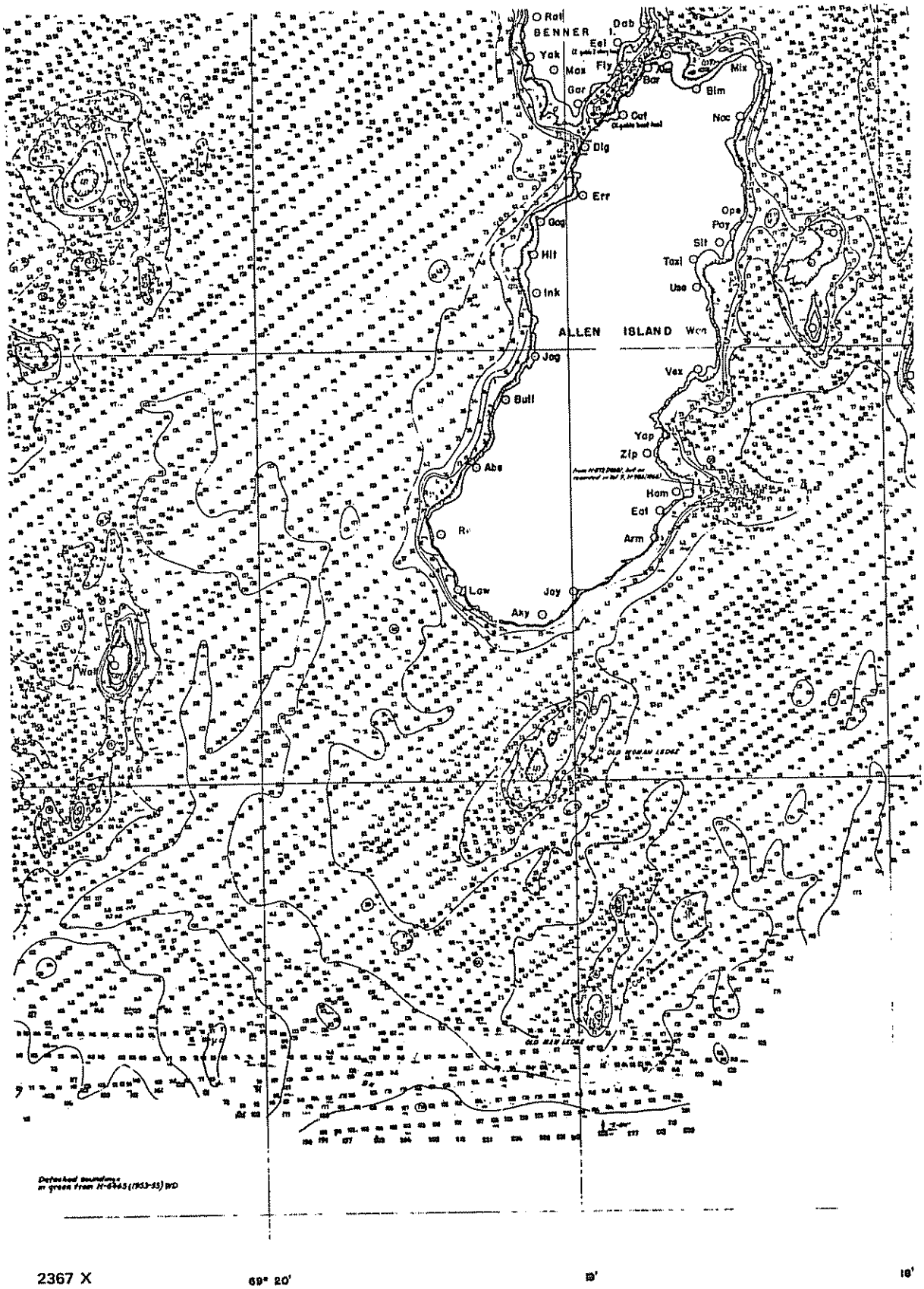


Figure III. Large-scale C&GS hydrographic surveys

topographic features, if possible, and at a prescribed distance apart, say 50 m or less and with additional development for shoal areas, to 5 miles or more in the open ocean. Cross-lines to the extent of from 5 to 10 per cent, were run to disclose any discrepancy from a faulty plane of reference, including effects of wind, sea or current, or operational faults in the sounding apparatus, and also for weaknesses in horizontal control.

It can be correctly surmised from the foregoing statement that in the existing survey information there is an excess of data points in the foreshore areas for detailed bathymetric mapping at a scale of 1:250,000, and a corresponding dearth of points as the water depths increase. In other words the above distribution of data points satisfies very well the requirements for nautical charting, at least as it relates to surface navigation and a general depiction of the sea floor. It does not however offer a desired distribution for detailed bathymetric contouring, which generally requires a more uniform distribution of depth information, to properly delineate significant topographic features. Among those would be submerged canyons, drowned rivers, trapped basins, fault line indications, submerged shore lines and numerous other features of geophysical–geological significance, that would be of little or no importance to the user of a nautical chart.

As an indication of line spacing for a specified programme—in this instance a 1:250,000 scale bathymetric map series of the continental shelf, which is generally defined as the sea floor between the shoreline and the 200 m or 100 fathom curve, the following criteria would apply for a relatively smooth bottom:

(*a*) One mile parallel line spacing, perpendicular to all major topographic features;

(*b*) Ten per cent crosslines at right angles to or at an angle not less than 45° to the basic line spacing;

(*c*) Development of up to 20 per cent of all significant features, as previously indicated, with the further provision that these lines should be run in a cross direction that will better permit the delineation of the actual shape and limits of the feature. This would often require a modified rectangular or isometric grid pattern.

Very complex seafloors, such as the Gulf of Maine, would of course require much closer line spacing and development.

Even with a reduce line spacing, providing continuous vertical profiles at, for example, one-half mile intervals, it must be apparent to both the informed and the casual observer that considerable extrapolation must be performed to fill in the numerical voids between sounding lines. This specialized interpretative skill is usually inherent in a person with a good working knowledge of geomorphology, the study of the characteristics, origin and development of land forms. Contouring cannot be properly delineated by a direct linear extrapolation between adjacent sounding lines. The variables are too erratic to produce an acceptable interpretation. This is a major deficiency in most of the automated computer-plotter contouring programmes known to this writer. A whole area of numbers must be scanned to properly define the details of both major and subordinate features if maximum use is to be made of the source data. This too presumes that a qualitative evaluation of the source data has been made to properly weight all depth values used. Considerably more sophisticated programming would have to be developed to realize the objective of "machine" contouring, but there is a persistent confidence that it will be soon realized. A section of a manually compiled bathymetric map is shown in figure IV.

The very important question of depth accuracy cannot, because of time limitations, be discussed in this paper. It is presumed, however, that all the factors influencing depth determination including astronomic and atmospheric influence on tidal planes, currents, temperature, density, salinity, pressure and all the other factors that inhibit the measurement of a correct depth, including instrumental errors, can be effectively isolated and determined to produce a depth accuracy of considerably less than 1 per cent for all water depths.

The same time restriction applies also to a discussion of all types of horizontal positioning systems for geophysical surveys. However some indication of an order of positional accuracy for our immediate area of interest, the continental margin, is excerpted from the previously cited Stratton Report:

> "The Commission has found, as did the National Academy of Sciences Committee on Oceanography and the President's Science Advisory Committee before it, that the most urgent needs for improved positioning systems are in the zone lying within 200 miles of the U.S. coast but beyond the range of visual navigation. A fully reliable, convenient, and low-cost system which permits fixes within approximately 50 ft is urgently required in this zone for such activities as surveys, traffic control, mineral resource development, salvage and scientific research. Such a system is within the state-of-the-art."

Evaluation techniques have been developed to qualitatively classify all depth information (including position) utilized in Coast and Geodetic Survey bathymetric mapping.

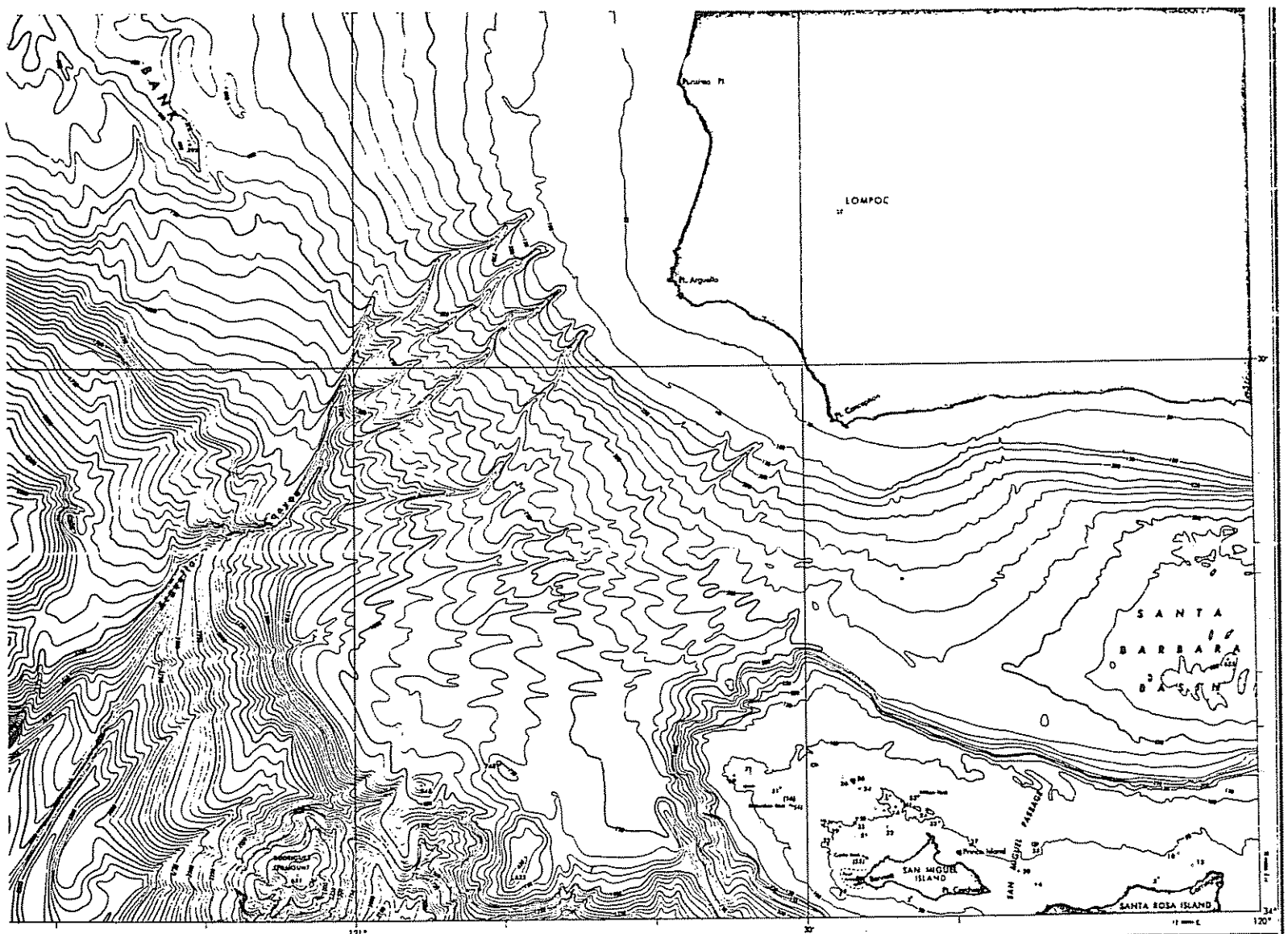
(For additional information on the application of Coast and Geodetic Survey hydrographic surveys in bathymetric mapping, see a paper entitled *Mapping Our New Sea Frontier*, by John M. McAlinden and Dr. Hyman Orlin, obtainable from the Environmental Science Services Administration, Rockville, Maryland 20852.)

Other geophysical mapping

Before discussing other types of geophysical mapping it should be noted that there are numerous methods of displaying the source data to meet the very diverse user needs. There are specific geophysical-geological correlations between all of the disciplines discussed, and this relationship imposes display design criteria that permits many "viewing" combinations. One of those viewing combinations is shown in figures VI, VII, VIII and IX, which illustrate displays of bathymetry, magnetics, gravity and seismic profiling for a common area near Sledge Island in Norton Sound, Alaska, from Coast and Geodetic Survey Preliminary Bathymetric Map (PBM-1), scale 1:250,000.

Figure VI is a bathymetric base map; figure VII is the magnetics overlay printed on a transparent or translucent medium; figure VIII is the gravity overlay printed on a transparent or translucent medium; and figure IX is a $\frac{3}{8}$ scale lithographed reproduction of a section of the original Seismic Reflection Profile (SRP) along the line A–B on figure VI.

The base bathymetric map is usually presented in final contoured form on an appropriate scale, projection and contour interval, and on a printed sheet of paper. How-



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Figure IV. Section of manually compiled bathymetric map



2369 X *Figure V. Residual magnetic anomaly map (USC&GSS Pioneer 1961–1963)*

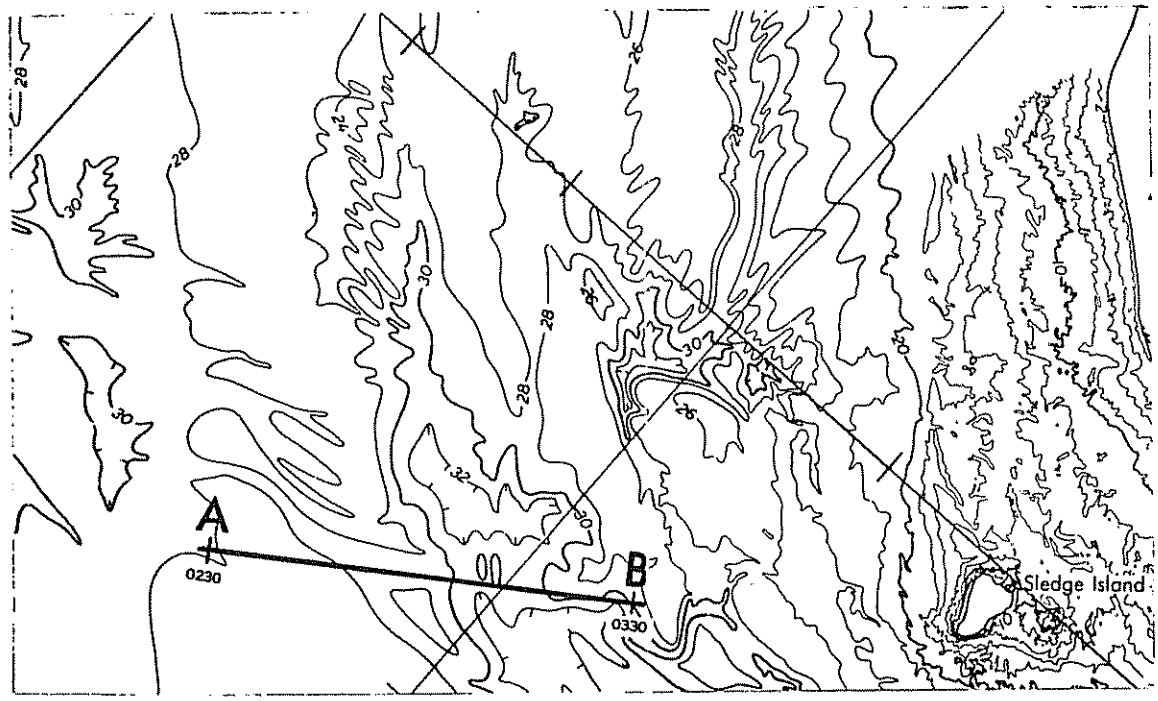


Figure VI. Base bathymetric map

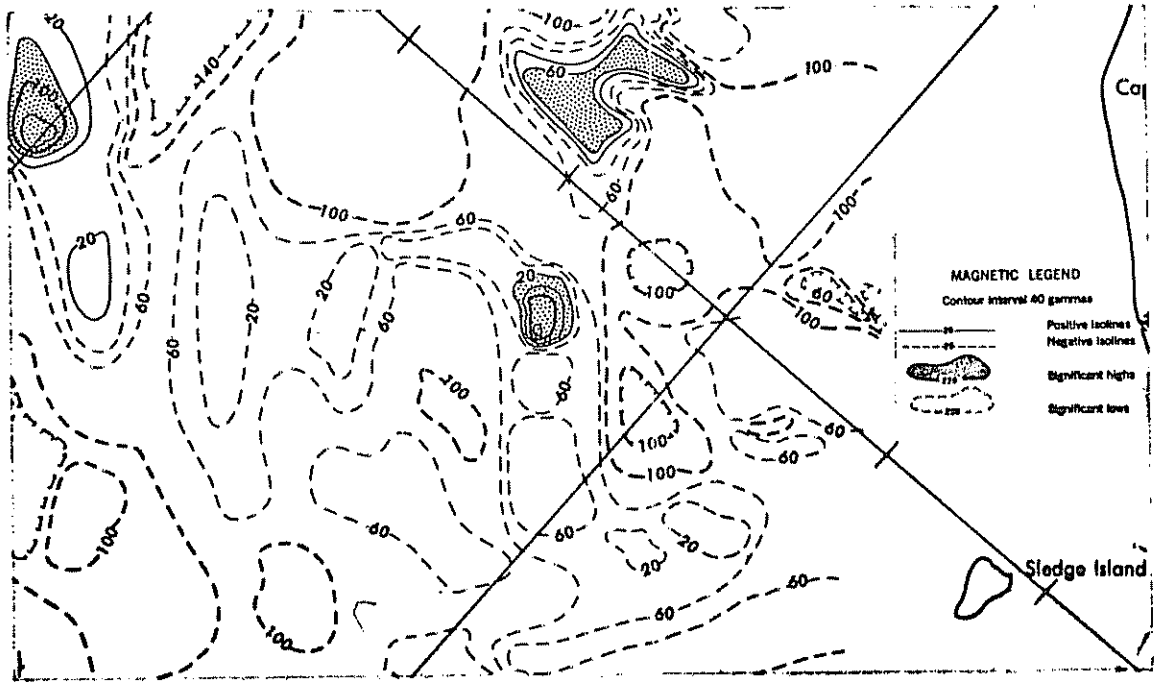


Figure VII. Section of preliminary magnetic map of Norton Sound, Alaska

ever, the numerical source data from which it was compiled could also be presented as a data map of numbers along the ship's tracks, a shaded relief map, a tabular printout, a continuous "stacked" series of vertical profiles, any of which could be displayed on transparent or opaque mediums, photographic film strips for projection, magnetic tape for CRT display and so on. The same reproduction criteria would apply for any or all geophysical displays.

Magnetic displays

Magnetic residual anomaly maps and overlays to base bathymetric maps are derived as an integral part of combined geophysical operations in ocean areas. The anomaly maps at chart scale represent differential magnetic topology, referenced to a standard model field and to a considerable extent (without considering further refinements) reflect the physical pattern and characteristics of crustal sources. In practice, the main field is represented by an analytical expression and the observed data are reduced to residual values using computer techniques.

Regional data files are consolidated and comprise the source material for meaningful data presentation—usually as the earlier noted maps or overlays, exhibiting either systems of contoured isolines or digital data plots, at appropriate scale and projection. Co-ordination with the Bathymetric Mapping Group is stressed to enhance the geophysical value of ESSA products.

Magnetic residual maps are found to have a wide variety of quantitative and qualitative applications. One of the more recent scientific applications of this mapping has been to associate the unique, ribbon-like pattern of anomalies over ocean basins with the sea-floor spreading theory. The patterns are found to parallel mid-oceanic ridge systems and are interpreted to represent magnetization, at the time of extrusion, at the ridge axes. Indeed, by relating the horizontal separation of individual symmetric bands from the ridge axis and historical geomagnetic field reversal data, qualitative estimates of spreading rates are calculated.

Geomagnetic maps are also reconnaissance tools that supply useful information on the ferro-magnetic properties of subsurface materials and provide preliminary estimates on the thickness of sedimentary sections. Where particularly clear anomalies are shown, modelling methods are used to define the physical characteristics of the source body.

A contoured magnetic map can also be of considerable value for determining the seaward extension of local geological structures observed on land.

Two illustrations of magnetic mapping are shown. Figure V is a section of a Residual Magnetic Anomaly Map of the Great Magnetic Bight of the north-east Pacific Ocean. Figure VII is the section of the previously referred to preliminary magnetic map of Norton Sound, Alaska. It is printed (in red) as a transparent overlay to be used in conjunction with Coast and Geodetic Survey Bathymetric Map PBM-1.

Gravity displays

Gravity measurements are of interest to geologists for the determination of crustal densities and structure and to geodesists for obtaining the shape of the Earth. When combined with seismic and magnetic studies, a determination can be made as to the approximate geological structure of the sub-bottom and, when further supplemented by bathymetric maps, will expedite the search for solid minerals as well as oil beneath the sea floor. The Earth's normal gravity field is a function of latitude and ranges from 978 to 983 gals from the equator to the pole with local variations of less than a few hundred milligals. A gal is equivalent to an acceleration of 1 cm/sec^2. In mineral exploration variations of tenths and hundredths of a milligal are sought.

Observations in the marine environment have been made *in situ* on the sea bottom with an accuracy of 0.1 milligal and underway in submarines and on surface ships to better than 3 milligals; accuracies of the order of tenths of milligals have been claimed. In fact, these systems have developed to the stage where accuracies are limited by uncertainties in the corrections which must be applied to the observed data. For interpretive purposes the geophysicists and geodesists reduce the observed data to sea level and compare them with normal gravity data based upon a theory of mass distribution in the crust. This reduction to sea level and the assumed theoretical values are strongly correlated with depths which should be known to better than five metres. Finally, the differences, called anomalies, are interpreted in terms of geoid heights, the distance between the geoid and an adopted surface, and in terms of density contrasts in the crust on a regional basis.

Figure VIII is the section of the previously referred to preliminary gravity map of Norton Sound, Alaska. It is printed (in magenta) as a transparent overlay to be used in conjunction with Coast and Geodetic Survey Bathymetric Map PBM-1.

Seismic profiling

Contrary to popular opinion some of the more valuable heavy heavy minerals (gold, platinum and tin) lie on or just under the surface of the continental shelves. Kenneth O. Emery, the distinguished marine geologist and senior scientist at Woods Hole Oceanographic Institution in Massachusetts, is quoted as follows:

> "... that heavy heavy minerals should be sought along submerged extensions of stream channels or in submerged beaches if they are near primary sources and that light heavy minerals should be sought mainly in submerged beaches of the nearshore zone. Best prospects for all three groups on the sea floor are in areas adjacent to sites of economic placers already mined on land."

The need for all types of minerals is expanding at an accelerated rate. Onshore deposits are decreasing at a corresponding diminishing rate. This condition compels the mining industry to utilize progressively lower grade ores or develop deposits in increasingly remote areas, thereby adding considerably to production costs. Ocean mining is now reaching a stage where the cost of production for some minerals is competitive with conventional land-based mining. Last year's production was valued in excess of $100 million. By the end of this decade the figure is expected to expand to $3 billion. These figures do not include the products of the offshore oil industry which last year had a value of over $2 billion.

It is not economically nor technically feasible at this time to map in detail the entire Earth's crust, so the geophysicist must first select promising locations for more detailed sub-bottom exploratory studies. Bathymetry,

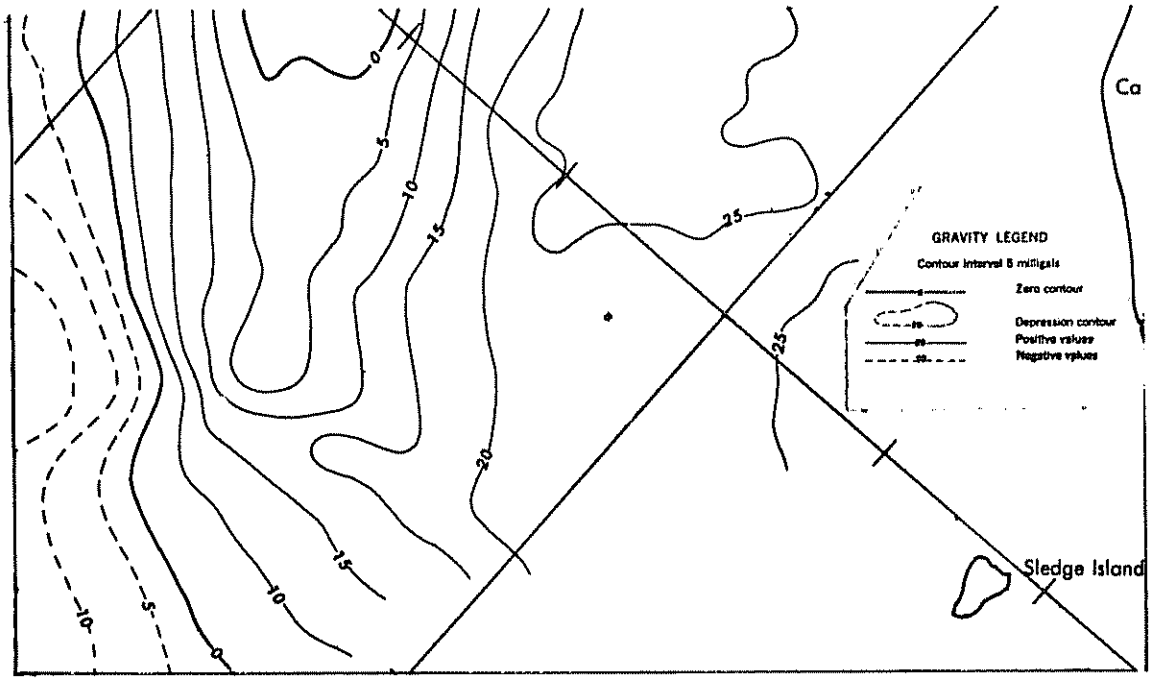


Figure VIII. Section of preliminary gravity map of Norton Sound, Alaska

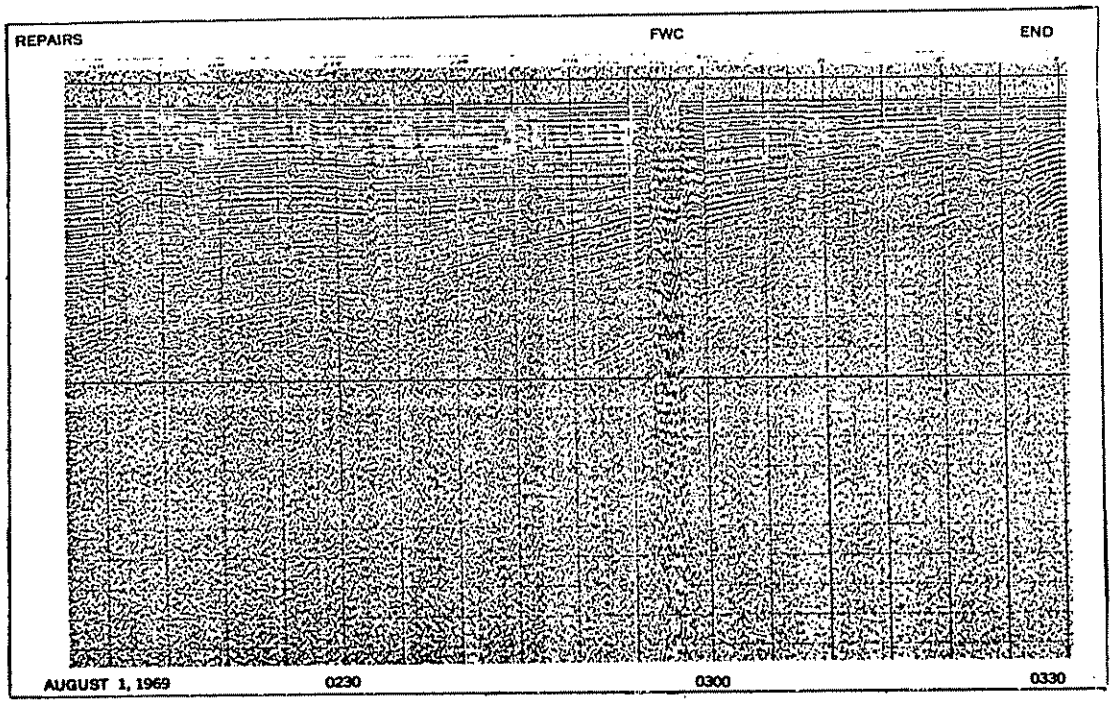


Figure IX. Lithographed reproduction of a section of the original seismic reflection profile along line A–B on figure VI ($\frac{1}{8}$ scale)

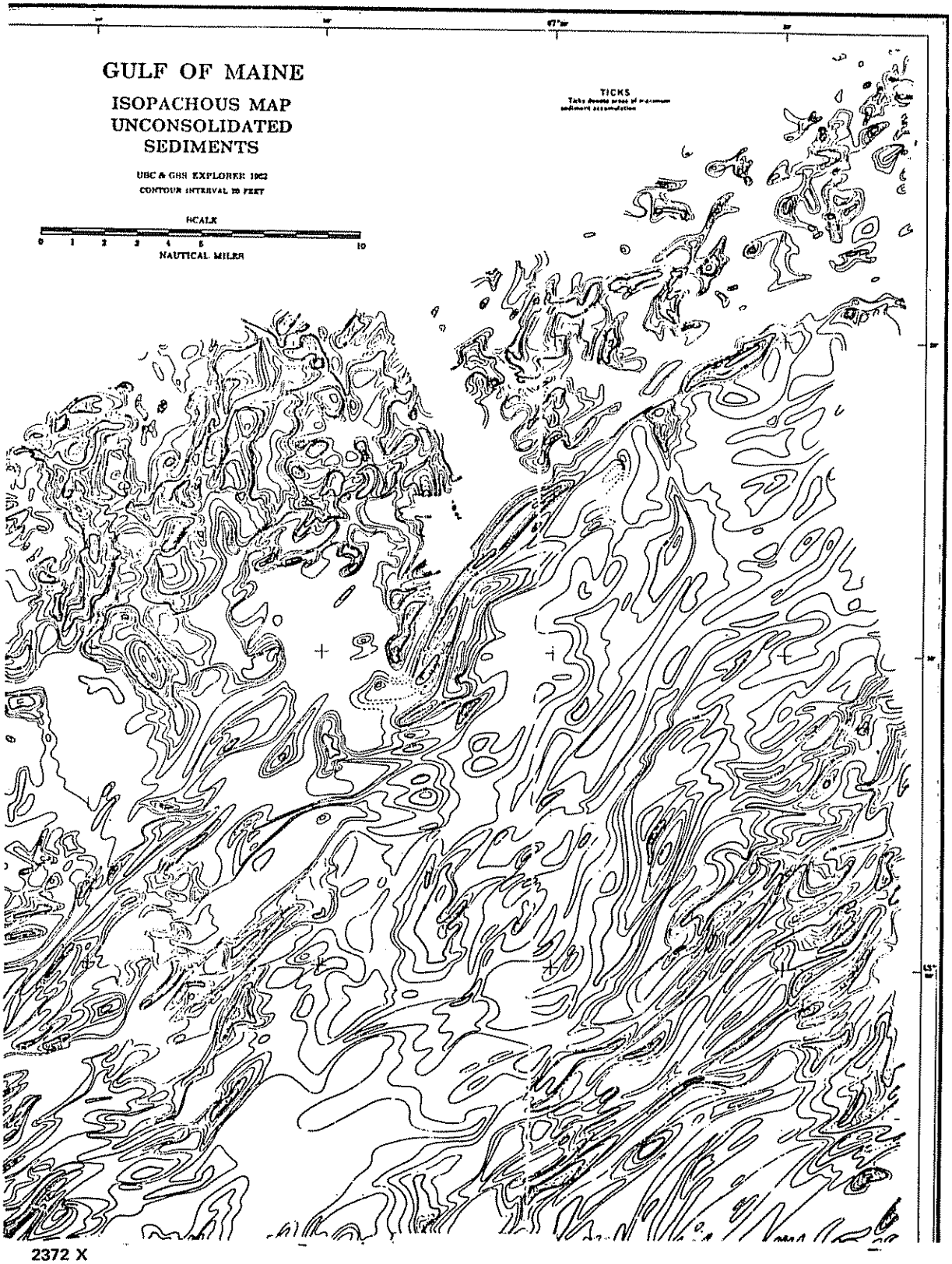


Figure X. Section of isopachous map indicating the depth of unconsolidated sediments in the Gulf of Maine

gravity, and magnetics surveys provide important tools to localize the area of search. But detailed seismic profiling, with selective coring, are indispensable tools for the actual mineral detection. The geophysical-geological information must be complete, but it must also be complemented by proper management controls of all production elements, including mining techniques, if the ecology of the marine environment is to be preserved.

It is evident from the foregoing that seismic profiling, used in conjunction with other geophysical tools, provides invaluable information on the structure of the Earth's crust, including the overlying sediments. (Figure X is a section of an Isopachous Map indicating the "depth" of unconsolidated sediments in the Gulf of Maine.) This knowledge is an absolute prerequisite for the discovery and recovery of the mineral wealth in Davy Jones' Locker. When oil and gas extraction is contemplated, a thorough knowledge of the fault-line indications are also required, especially in an area of seismic activity.

Conclusion

It becomes increasingly apparent that man's survival on this planet is inexorably linked to the proper exploitation of the living and mineral resources in and under the sea. The key word is "proper". Exploration and development must proceed in a manner calculated to produce the maximum benefit for a maximum number of people. Unrestrained or unregulated development can lead to a despoliation of these irreplaceable resources. Geophysical mapping is an indispensable key to that orderly development. We must do more of it—and faster.

The accelerated development of automated procedures to catalogue, store and retrieve all geophysical data in any desired form is an absolute prerequisite if we are to develop a dynamic mapping programme. The tremendous amounts of usable historic data, together with that presently acquired by automated methods, must be integrated in a form that permits "machine manipulation" of all desired data, whether as a graphic computer-plotter display, a visual computer-CRT display or other combinations and methods for the full utilization of usable data.

While machine contouring has not yet been developed to a precise art, there is little doubt that it is well on its way. When that day arrives we will not be too far from an ultimate cartographic goal, "realtime Mapping", concurrent with the gathering of the data, to better serve our users in their quest to efficiently explore and develop the resources of the sea.

References

Our Nation and the Sea, report of the Commission on Marine Science, Engineering and Resources, January 1969.

"Mapping our New Sea Frontier", by John M. McAlinden and Hyman Orlin, *ACSM Journal, Surveying and Mapping*, March 1969.

"Marine Gravity Surveying Instruments and Practice", by Hyman Orlin, *Oceanology and Limnology*.

Marine Geology of the Northeastern Gulf of Maine, ESSA technical bulletin No. 28, February 1966, by R. J. Malloy, R. N. Harbison.

Systematic Ocean Surveys by the USC&GSS Pioneer 1961–1963, ESSA operational data report C&GS DR-1, by D. J. Elvers, C. C. Mathewson, R. E. Kohler and R. L. Moses.

"Economic Placer Deposits of the Continental Shelf", by Kenneth O. Emery, *Offshore*, March 1969.

"Ocean Mining Stimulated by Economic Forces", by John E. Flipse, *UST*, January 1970.

"Offshore Mining to Reach $3 Billion by '79", by J. B. Gustavson, *Offshore*, March 1969.

"Oil Exploration Technology", by Franklyn Levin, *Science and Technology*, February 1969.

"Oilspill", *ESSA World*, July 1969.

"Geology, Petroleum Development, and Seismicity of the Santa Barbara Channel Region, California", United States Geological Survey professional paper 679.

BATHYMETRIC CHARTS: THEIR DEVELOPMENT AND USE

Paper presented by the United States of America[1]

Introduction

The marine navigator's dependence on knowledge of the ocean bottom has been documented back at least as far as 450 B.C., when the historian Herodotus (according to an old English translation) wrote "in voyage to Aegypt, after you come within one day's sayling of the land, at every sounde of the plummet you shall bring up great store of mud and noysome filth, even in such places as the water is eleven ells in depth". Obviously, navigators of 2,400 years ago employed depth soundings as a navigational technique and obtained ocean bottom sediment samples as additional information on which relative ship position might be based.

Despite the early navigators' use of depth sounding, there is little evidence that the depths were recorded or entered on charts for future reference prior to the sixteenth century. Soundings in shallow water, for example, were first drawn on a map by Juan de la Cosa in 1504. Soundings appeared on large-scale nautical charts starting in the latter half of the sixteenth century, particularly in various regional sea atlases. These soundings were of inshore and

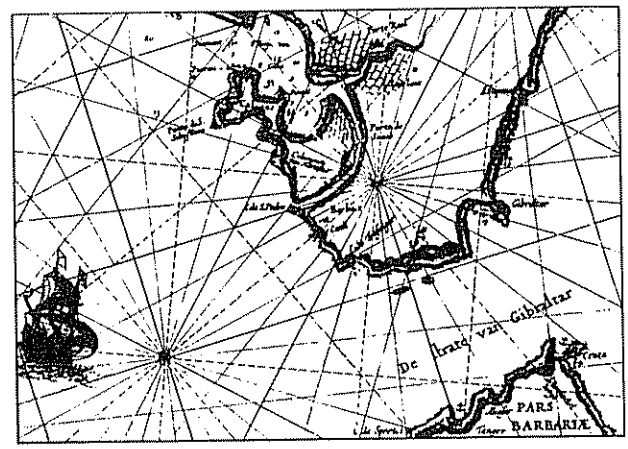


Figure 1. Early marine atlas chart (detail)

[1] The original text of this paper, prepared by F. M. Edvalson, Deputy Director, Bathymetry Division, and V. T. Miscoski, Deputy Director, Nautical Chart Division, United States Naval Oceanographic Office, Washington, D.C., appeared as document E/CONF. 57/L.26.

offshore waters exclusively and were taken by means of the time-honoured sounding lead and handline. They were so sparse, even on the best charts, that it was not possible to delineate the topography of the ocean bottom from them. It was not until 1697 that the first isobaths, or lines of equal depth, were used, when Pierre Ancelin, a surveyor and cartographer of Rotterdam, employed them to show the bottom topography of the Nieuwe Maas. The Dutch engineer N. Cruquius (1728 or 1730) showed the bottom of the Merwede River by contours for the purpose of navigation. And Philip Buache, a Frenchman, also used contours to outline the depths in the English Channel in 1737.

It is obvious, of course, that Columbus had no knowledge of the depths beneath him as he sailed the broad Atlantic on his voyages to the New World. Nor had he the means of measuring ocean depths beyond the continental shelves. As a matter of fact, credit for the first successful "deep-sea" depth measurement and ocean bottom sample beyond the continental shelf is generally given to Captain Constantine John Phipps of the British Navy, who, in 1773, while in command of HMS *Racehorse*, made a sounding of 683 fathoms, using stout hemp line and a lead of 150 pounds, in a basin between Iceland and Norway. Although determination of depths in harbours became fairly common in the eighteenth century, many years were to pass before deep-sea soundings became more than a matter of mere curiosity and were undertaken on a large scale.

Early bathymetric charts

Perhaps the greatest single motivating force for obtaining deep-sea sounding information was the development in the nineteenth century of the submarine telegraph cable. The United States Navy was the first to improve sounding techniques by employing detachable weights and fine-wire lines with steam-powered winches. In the 1850s, surveys of the proposed North Atlantic cable route by United States Navy ships, operating under instructions prepared by Lieutenant Matthew Fontaine Maury of the United States Naval Observatory and Hydrographical Office (forerunner of the Naval Oceanographic Office), resulted in the first chart ever published showing the topography of the North Atlantic Ocean basin. Although much of the information on this chart was conjectural, Maury's chart nevertheless marked the first step in the bathymetric charting of the ocean deeps.

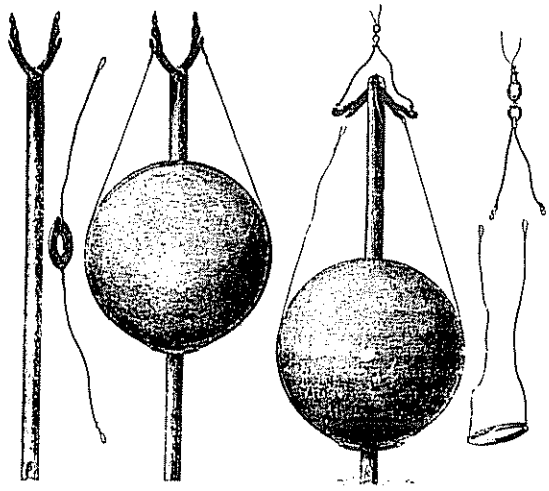


Figure II. Brooke's sounding apparatus

Maury, of course, spent many years in the service of the Navy and was instrumental in stimulating wide scientific interest in the oceans and for initiating vast data collection programmes. As early as 1843, he proposed the use of "blank charts" by all Navy ships as a medium for recording and reporting various marine observations. It was under Maury that Navy Lieutenant J. M. Brooke invented the simple sounding device which proved to be the greatest step forward in deep-sounding technology up to that time. It was also Maury who prepared the specifications which accompanied the Navy's Circular Letter of 1 June 1850, directing Navy men-of-war to take deep-sea soundings on a daily basis when in blue water.

During the latter half of the nineteenth century, the Navy was assigned responsibility by Acts of Congress to carry out deep-sea surveys in support of planned submarine cable installations. By 1885, the number of deep-sea soundings in Navy files had grown so much that a series of plotting charts was prepared by the Navy Hydrographic Office to record the soundings and make them available to navigators of all nations. Although the first charts were limited to six sheets for the North Atlantic, others soon followed for the Pacific Ocean, Caribbean Sea, Gulf of Mexico and the Indian Ocean. These were relatively small-scale sheets, with those of the Indian Ocean being at a scale of one and one-half inches to a degree of longitude. All reported "reliable" deep-sea soundings were plotted on these sheets, which by 1892 had grown to a total of forty-nine sheets.

By 1921, when the sonic-depth finder was invented by Dr. Harvey C. Hayes, of the United States Naval Experimental Station in Annapolis, Maryland, an actual count of all soundings greater than 550 fathoms revealed a total of nearly 15,000. There was an average of only one sounding for each 5,500 square miles in the Atlantic, one for each 10,000 square miles in the Pacific and one for each 10,500 square miles in the Indian Ocean. In spite of such sparsity of data, the first edition of the *General Bathymetric Chart of the Oceans* had already been published by the *Cabinet scientifique* of Monaco, and work on the second edition was well under way to satisfy demands of scientists throughout the world for an improved chart showing the configuration of the ocean basins. Valuable as such charts were, however, they were soon to require even further revision, as more and more deep-sea soundings became available. The development of the sonic depth finder proved to be a major breakthrough in deep-sea sounding technology and ushered in a new era in man's effort to chart the topography of the bottom of the sea.

Hayes' invention, which permitted the taking of soundings in deep water without stopping the ship, was first used successfully on a deep-sea expedition in 1922 by the destroyer USS *Stewart*, which took over 900 deep soundings on a route from Newport, Rhode Island, to Gibraltar. Shortly after the destructive earthquakes in Chile in November 1922, the Carnegie Institution of Washington, knowing of the work of the *Stewart*, asked the Navy Department to run lines of sonic soundings off the United States Pacific Coast to facilitate earthquake investigations. As a result, the destroyers USS *Hull* and USS *Corry* were fitted with sonic depth finders and, in 1923, ran approximately 5,800 miles of sounding lines off the coast between San Diego and San Francisco, California, between the 100-fathom and 2,000-fathom curves. Parallel lines of soundings on headings of 060° and 240° true were run from five to ten miles apart, with an average distance between

soundings in each line of from one to two miles, over an area of approximately 34,000 square miles at a ship speed of 12 knots. These soundings resulted in the publication, in 1923, by the Navy Hydrographic Office of H.O. 5194, the first published bathymetric chart compiled from sonic soundings. *Hull* and *Corry*, in May 1924, executed another sounding mission, of a cable route from Seattle, Washington, to Seward, Alaska, with such accuracy that the percentage of waste cable due to slack was reduced from an expected 10 per cent to only 4 per cent. Also, in 1925 the Coast and Geodetic Survey ship *Lydonia* had installed a sonic depth finder called "Fathometer", which had been developed by the Submarine Signal Company of Boston.

The publication of H.O. chart 5194, primarily for scientific purposes, was soon followed by the issue of similar bathymetric charts intended primarily for surface ship navigation. The United States Coast and Geodetic Survey, for example, published its first chart of this type in 1939. That chart, C&GS 5101A, for coastal waters between San Diego and Santa Rosa Island, California, utilized depth curves in combination with soundings to emphasize submarine configurations. Instead of the many soundings and few depth curves used on the conventional navigational charts of that day, C&GS 5101A made use of many depth curves and fewer soundings, to bring out the ridges, valleys and other characteristic features of the ocean floor. Through the cartographic portrayal of these underwater landmarks, the navigator of a ship equipped with echo-sounding apparatus was assisted in fixing his position at sea by the simple means of comparing his line of echo soundings with the charted depth curves in the area. Charts such as H.O. 5194 and C&GS 5101A could not have been produced before the invention of the sonic depth finder, because it was not previously feasible to obtain the large number of soundings required for accurate depth curve delineation over large ocean areas. During the 1930s, A. C. Veatch and P. A. Smith of the Geological Society of America used Coast and Geodetic Survey data and other sources to develop contoured charts of the Atlantic Submarine Valleys of the United States and the Congo Submarine Valley. European scientists, namely Defant and Stocks, also conducted bathymetric studies during the 1930s, especially on the nature and stratification of the sea bottom.

Depth contours versus soundings

Today, depth contours, or isobaths, are commonly used on all conventional nautical charts to highlight significant navigational features such as shoals and channels. Depth contours may be compared to contours on topographic land maps, on which each curve represents an imaginary line of constant elevation above sea level. On nautical and bathymetric charts, each line represents a contour of the ocean bottom, every point of which is the same depth below the sounding datum or plane of reference to which the soundings have been reduced.

The presence on a navigational chart of a large number of soundings has historically been a criterion of the adequacy or reliability of the chart. On the other hand, the

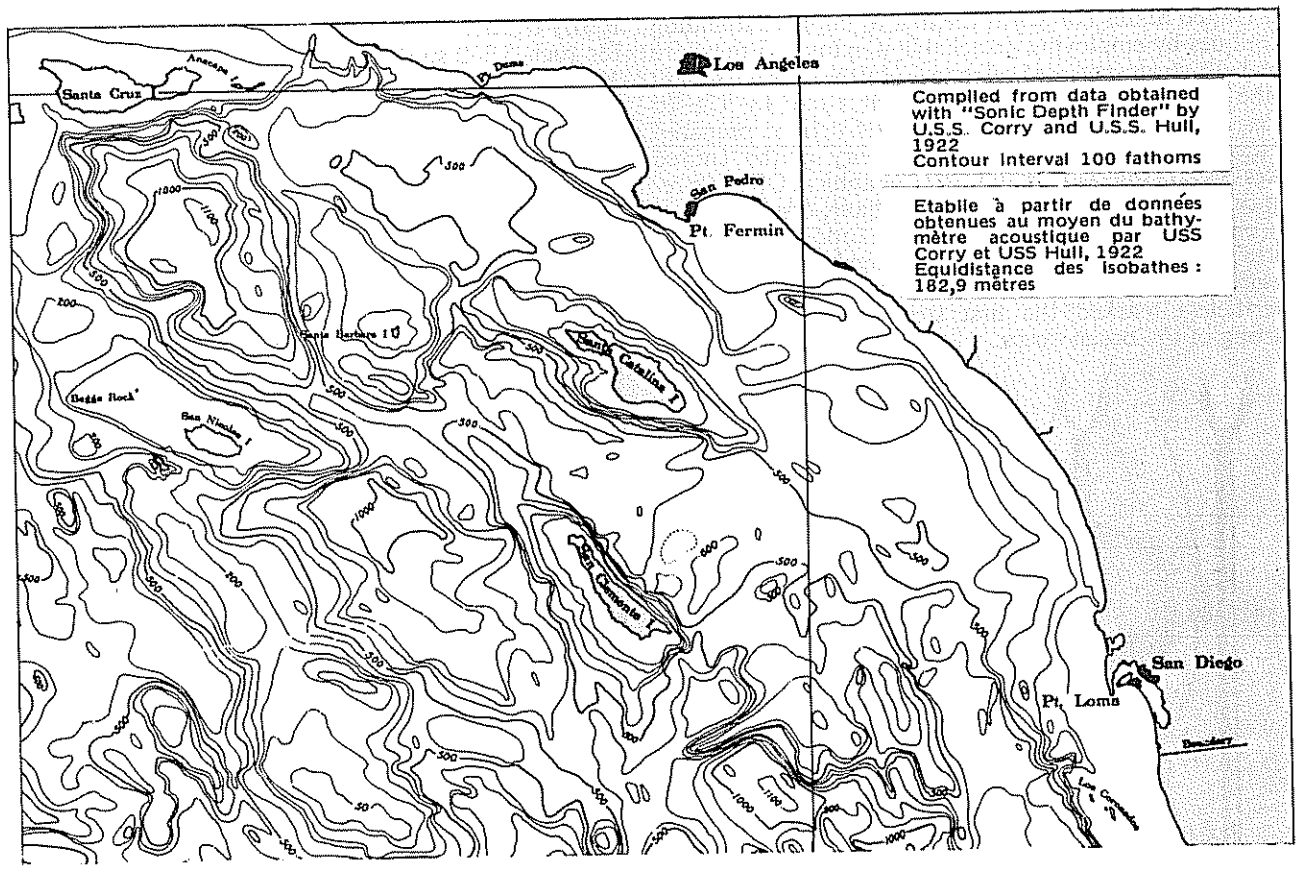


Figure III. Section of H.O. chart 5194, first bathymetric chart compiled from sonic soundings—1923

absence or sparsity of soundings has always been accepted as an indication of an inadequate or unreliable chart. In recent years, the tendency has been to make more use of depth contours and to show fewer soundings on conventional navigational charts of areas for which a wealth of hydrographic information is available. This trend belies the old axiom that depth curves play a subsidiary role on charts used for inshore and offshore navigation. Nevertheless, a judicious selection of soundings continues to be the hallmark of any really adequate large-scale approach or port and harbour chart. It is on large-scale special-purpose charts and on medium- and small-scale general and sailing charts that depth contours, rather than individual soundings, have come to play a primary role in navigation, with the result that most—if not all—such charts will eventually be reissued in bathymetric chart form.

Actually, there are only a few scattered areas in the oceans in which absolute accuracy of bathymetric data has been achieved, thus severely limiting production of truly adequate bathymetric charts. The quantity and quality of sounding data available for most deep-ocean areas makes possible only an approximate delineation of the major features of the submerged topography. Many of the soundings now held in the data bank were taken prior to installation of modern navigation systems and improvements in accuracy of the echo sounder; consequently, they are of questionable reliability, both as to position and depth. In addition, for vast areas of the oceans—in some cases thousands of square miles—there are no soundings whatsoever available.

Origin of the BC chart series

In an effort to make the ocean depth information in its files generally available to the maritime and scientific communities and, at the same time, obtain greater co-operation in the making and reporting of deep-sea soundings, the Navy Hydrographic Office, in 1949, undertook a programme of publishing a co-ordinated series of bathymetric or bottom-contour charts. These were at a scale of four inches per degree of longitude for latitudes lower than 64° and at a scale of two inches per degree of longitude in higher latitudes. The decision to use these scales was influenced by the desire to make the "BC" charts suitable for use as plotting sheets or track charts. A similar plotting series (H.O. 3000) at these scales had already proven their worth, because of the constant longitudes spacing which allow convenient transfer of plotted fixes and tracks from one sheet edge to another.

Officially titled *Contoured Position Plotting Sheets*, charts of the new series quickly took on the appellation "BC", the abbreviation for "bottom contour" or "bathymetric chart". This abbreviation has been continued as both a series identification and an individual sheet number prefix. The BC charts are thus clearly and uniquely distinguished from the many other bathymetric and marine

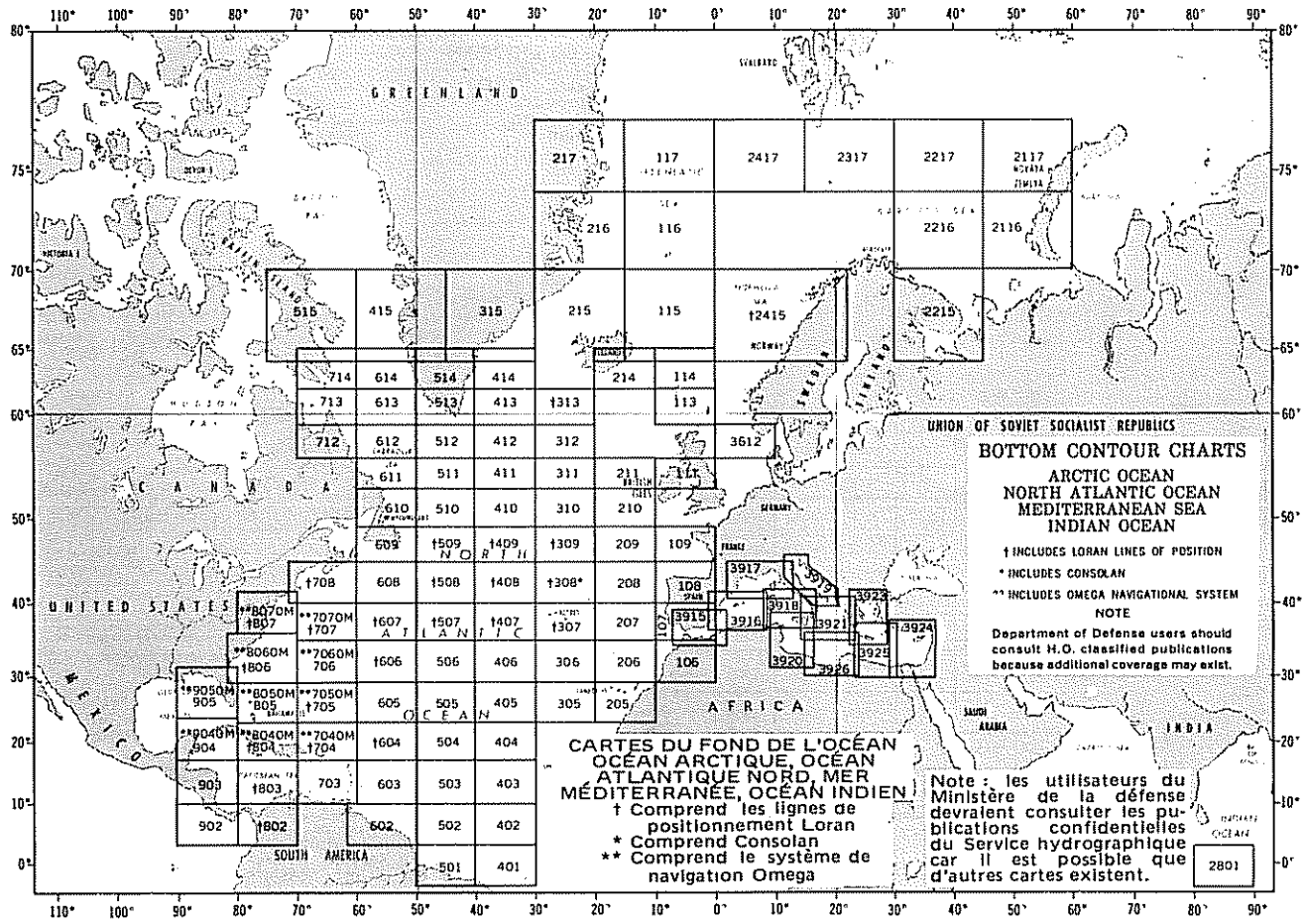


Figure IV. Index of BC charts on issue for the North Atlantic Ocean and Mediterranean Sea

charts which carry the prefix "H.O." and are published by the Naval Oceanographic Office.

Content of the BC chart

The BC chart is designed for navigation, as is the standard nautical chart, but has important differences. On the standard nautical chart the navigator is accustomed to seeing fathom curves and many individual soundings, each of which represents the shoalest sounding in that area. He can assume that a range of mountains does not lie between two depicted soundings, in which case a sounding at the top of the range of mountains would be shown, but he cannot tell whether the ocean bottom is relatively smooth between the two soundings or whether a deep valley exists between them. Danger curves, based upon navigational safety, are placed around shoals, wrecks, rocks and foul areas but are not to be construed as accurately placed depth contours. Danger curves tell the navigator that no depths less than that indicated by the curve are found seaward. Depths in excess of the curve may be found landward of the particular curve. The BC chart, on the other hand, has substituted depth-contour lines for the individual soundings, and the contours have been derived from all existing sounding data available. Such contour lines are scientifically determined from a statistical analysis of all sounding data available. In many cases data from different sources for a particular area will produce a variety of contour lines which may be conflicting. Scientific interpretation is then used to determine the contour line to be portrayed on the basis of bottom topography of logical physiographic size, shape and distribution.

Information shown on the BC series of charts includes: a one-degree graticule on the Mercator projection, subdivided into one-minute intervals on selected parallels and meridians; a generalized shoreline without navigational aids; depth contours at 100-fathom intervals; spot soundings showing minimum and maximum known or reported depths; compass roses; magnetic variation lines and annual change; approved nomenclature, including principal country, port, cape, island, water, and bathymetric feature names; index to sheets in the series; a sounding density diagram supplemented by a reliability note; logarithmic time, speed and distance scales; marginal caution and explanatory notes; wrecks lying in depths between 30 and 500 fathoms; and selected Loran-A curves as well as Consol/Consolan curves for areas of satisfactory reception. Printing colours have been modified from time to time to meet changing needs, with those of the example shown in this article being representative of the most recent charts. Maximum sheet size is 36 × 54 inches. All available charts are indexed in H.O. Pub. 1-N, introduction, part II.

The primary source of data for inclusion in BC charts is that known as "random-track" data, consisting of unadjusted track charts of ship transits between various ports.

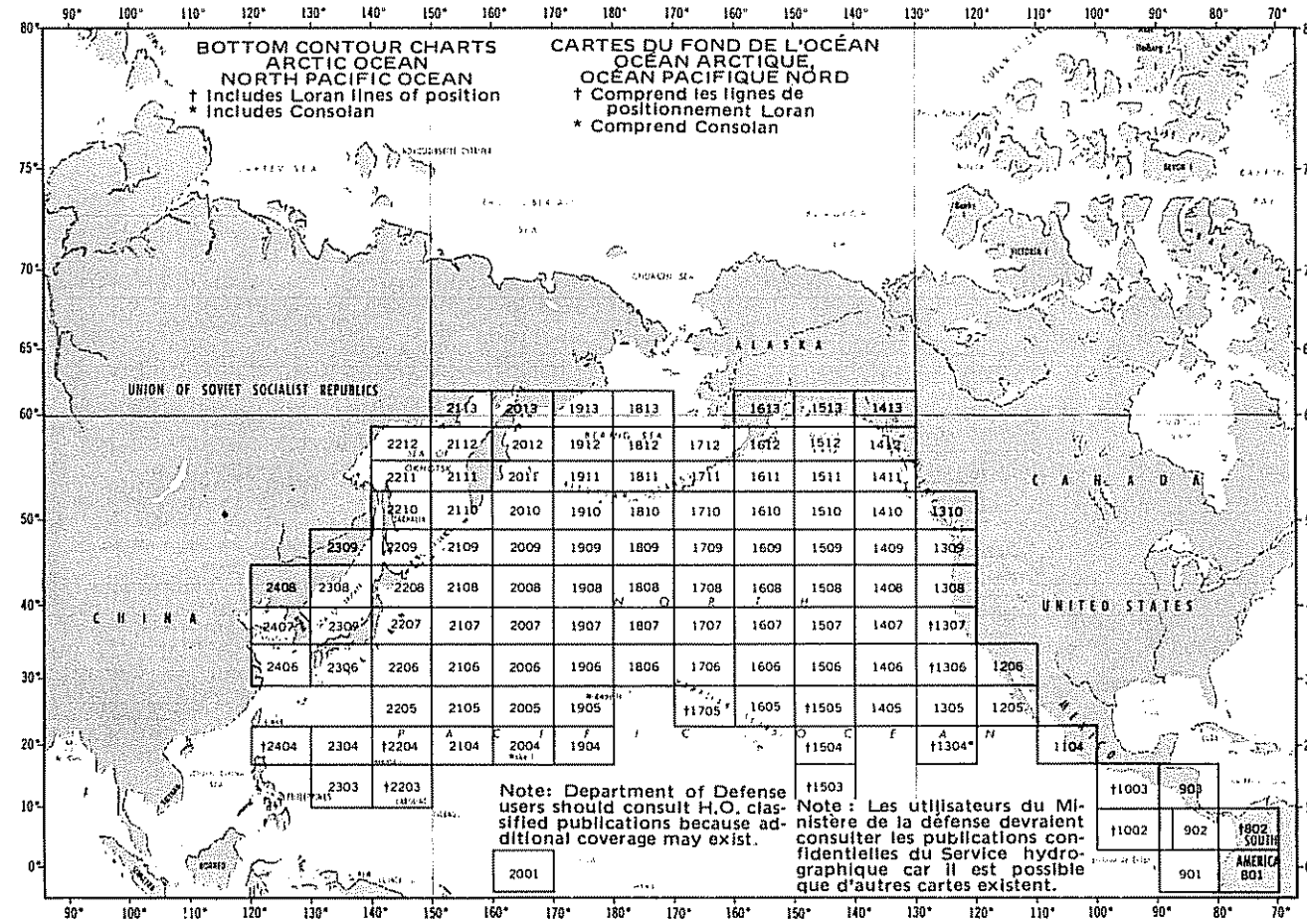


Figure V. Index of BC charts on issue for the North Pacific Ocean

These reports are received from the United States and foreign Merchant Marine, the Navy, Military Sea Transportation Service, the Coast Guard and from foreign and domestic research ships. H.O. Pub. 606b details procedures to be followed in collecting data and submitting reports in order to make the data of the highest possible quality and thus more useful as an addition to the data bank. Knowledge of the area derived through a study of geological, geophysical and oceanographic environment information is used in conjunction with the sounding data as an aid in identifying physiographic trends. The interpretation of this information is greatly enhanced in those regions where a vast volume of data are available.

Compilation of BC chart bathymetry

The compilation of the bathymetry portrayed on BC charts is directly related to the influx of data, and as new and better data are received the existing BC charts become more and more out of date. In spite of the apparently vast amount of data presently held by the Naval Oceanographic Office's Bathymetric Data Library, almost every track line submitted reveals new and valuable information about the sea floor.

Various contributing ships, travelling to all parts of the world, are responsible for many new reports of shoals and dangers of navigation. Many of these ships, however, are restricted in their ability to report depths beyond the continental shelves because their echo-sounding systems have a limited depth-recording capability. As a direct result of the limited capability of the echo-sounding equipment, many of these ships become the source of many doubtful sounding reports. The majority of these ships do not operate their echo sounders continuously and normally turn them on only when shoal waters are expected or when discoloured waters are encountered. As a result of this intermittent operation, the side slopes of bathymetric features, which are vital to correct interpretation, are rarely recorded and only the very shoal depths are reported.

There are three major causes for erroneous shallow depths appearing on recordings in relatively deep water. The first and foremost results from phasing of the echo sounder. Phasing is that recording phenomenon that occurs when the distance between the keel of a ship and the bottom is greater than the scale of the depth recorder being used. A phase represents the time for one sweep of the marking stylus across the recording paper, and the first phase begins with the transmission of the out-going pulse. For instance, the standard Edo deep-sea-echo sounder, model 185 (United States Navy AN/UQN-1 series), has three scales for use in varying depths of water. There is a 600 ft, 600 fathom, and a 6,000 fathom scale, and one sweep of the stylus in each of these depths ranges will represent 100, 600, or 6,000 fathoms. Care must be exercised in selecting the appropriate scale, or erroneous depth information may result. If this echo sounder is operated on the 600 fathom scale in 1,400 fathoms of water, the return will be printed and probably interpreted as 200 fathoms, when in fact it was printed on the third phase. What actually happened was that, after the initial outgoing pulse, the stylus swept across the paper once (600 fathoms), remained off the paper an equal time (600 more fathoms for a total of 1,200), sent out a second pulse and was 200 fathoms into the third phase before the return from the initial pulse was received and recorded. Switching the

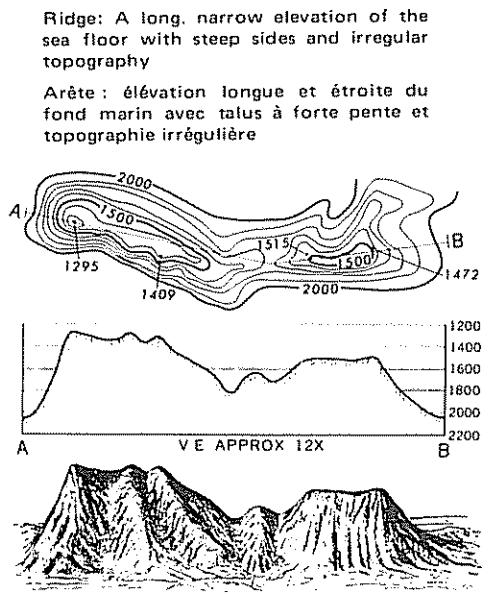


Figure VI. Example of submarine topography as portrayed by bottom contours, profile and plan

recorder to the 6,000-fathom scale would quickly resolve this depth discrepancy. As a matter of practice, whenever the recorded bottom trace disappears or becomes confused for any reason (such as rugged bottom terrain), it should be confirmed as soon as it becomes legible again by switching to a deeper scale until ambiguities are resolved, and then by switching to the shallower scale to obtain better bottom definition.

Shallow-water recorders are even more prone to phasing and operator error than the deep water ones. Most of these recorders have multiple-phase characteristics which make accurate depth determination extremely difficult when the recorders are used only occasionally in oceanic areas. An example would be an echo sounder with a depth range of 720 fathoms divided into nine phases of 80 fathoms each. Phasing is accomplished by manual switching with no indication of phase presented on the recording paper. Thus, unless care is taken to indicate phase during operation, true depth may not be determined with certainty. Under good conditions, a bottom return from depths greater than the listed maximum 720 fathoms is possible. Under these conditions, soundings in error by 720 fathoms may be reported. Suppose a vessel is in 750 fathoms of water with a good reflective bottom present, and the bridge watch activates the depth recorder. A return will print at what appears to be 30 fathoms on the first phase, when actually the return is 30 fathoms into the tenth phase. Since recorders intended to be used in shallow water generally do not have deep scales available, phasing errors are extremely difficult to discover. As a result of phasing errors, shoals are frequently reported when, in fact, no shoal exists. However, these are included on the charts as a safety precaution.

The second major cause of false bottom recording is the Deep-Scattering Layer or phantom bottom. This phenomenon is caused by fish or other small nocturnal marine organisms in the water that are photophobic. In other words, they attempt to avoid the light that penetrates the water to a considerable depth. On a dark cloudy day or at night they move up into the rich surface waters in

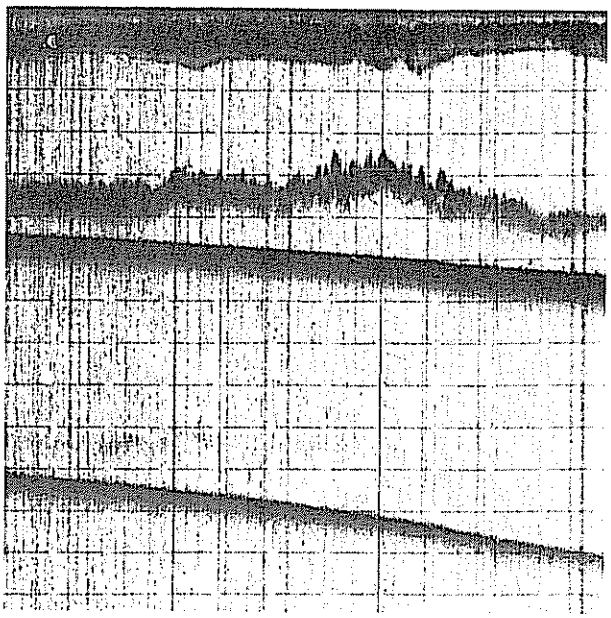


Figure VII. Echogram showing deep-scattering layer

search of food, and when the sun breaks through or daylight approaches they move back into the dark depths of the sea. In many cases, the Deep-Scattering Layer causes a return signal to the echo sounder so strong and regular that it appears shallower but almost the same as the true bottom. With a deep-sea echo sounder and with good acoustic conditions, the bottom can be observed as well as the Deep-Scattering Layer, and problems seldom result. With a shallow-water sounder, though, or with a deep-sea sounder on a shallow scale, the Deep-Scattering Layer may be recorded by itself and interpreted as the bottom. When using a deep-sea sounder with intentional phasing, the bottom sometimes appears to be shoaler than the Deep-Scattering Layer, since the two are received on different phases. It is essential that the operator be alert in order to tell the true bottom from the false return. If the echo sounder being used is equipped so that a single pulse can be transmitted and the return monitored audibly, the true bottom can easily be identified as the last return. Once the bottom is identified, the sounder may be returned to automatic transmission and the gain adjusted so that the true bottom is recorded.

The third cause of incorrect bottom information is interference, either from other echo sounders on the same ship or echo sounders on other ships in the vicinity. On one survey in the South Atlantic, where five ships were steaming in formation with a spacing of 1 mile, the centre ship recorded reflected sound from all five ships. In this case the transmitter was turned off periodically for 4 or 5 seconds, and the return which disappeared was then identified as being associated with the secured transmitter. When two echo sounders are run on the same ship, the transmitted pulse is generally so strong that it is recorded on the other echo sounder even if the frequencies of the acoustic signals are different. If both sounders key at the same rate, the result is a straight line of constant apparent depth. However, if the keying rate is different, as when they are powered from two different generators, the interference pattern appears to change depth.

The bulk of the data used in compiling charts of deep-sea areas comes from Navy and Coast Guard ships. These tracks do not always follow regular shipping lanes and therefore provide useful data in many sparsely travelled parts of the ocean. Most of these tracks have the advantage of continuously recorded echo sounding, but many of them suffer from having been run in a part of the world where navigational aids are substandard. Position accuracy, in areas where electronic navigation is not available, varies to the point where position errors have been estimated to be as high as 30 miles (an extreme case, to be sure).

Other soundings considered in the compilation of BC charts are those that appear on the medium- and small-scale standard nautical charts issued by the maritime nations of the world. Such data are given the least weight in the preparation of BC charts because so little is known about their origin, the navigational control, the method of sounding or the corrections applied. Many of these soundings have been copied from one chart to another, each time with an unavoidable slight change in position. Most were not given a scientific scrutiny before being placed on the charts, and few have been removed because there has been no concentrated effort to verify or disprove the deep soundings reported in years past. It is well appreciated that early cartographers were concerned with filling up the "white spaces" on a chart. Until recent years, all reported deep-sea soundings were readily entered on charts unless there was an obvious conflict with a previously reported sounding in the same area, which was seldom the case. To some extent, this attitude prevails today for those ocean areas devoid of other reported soundings.

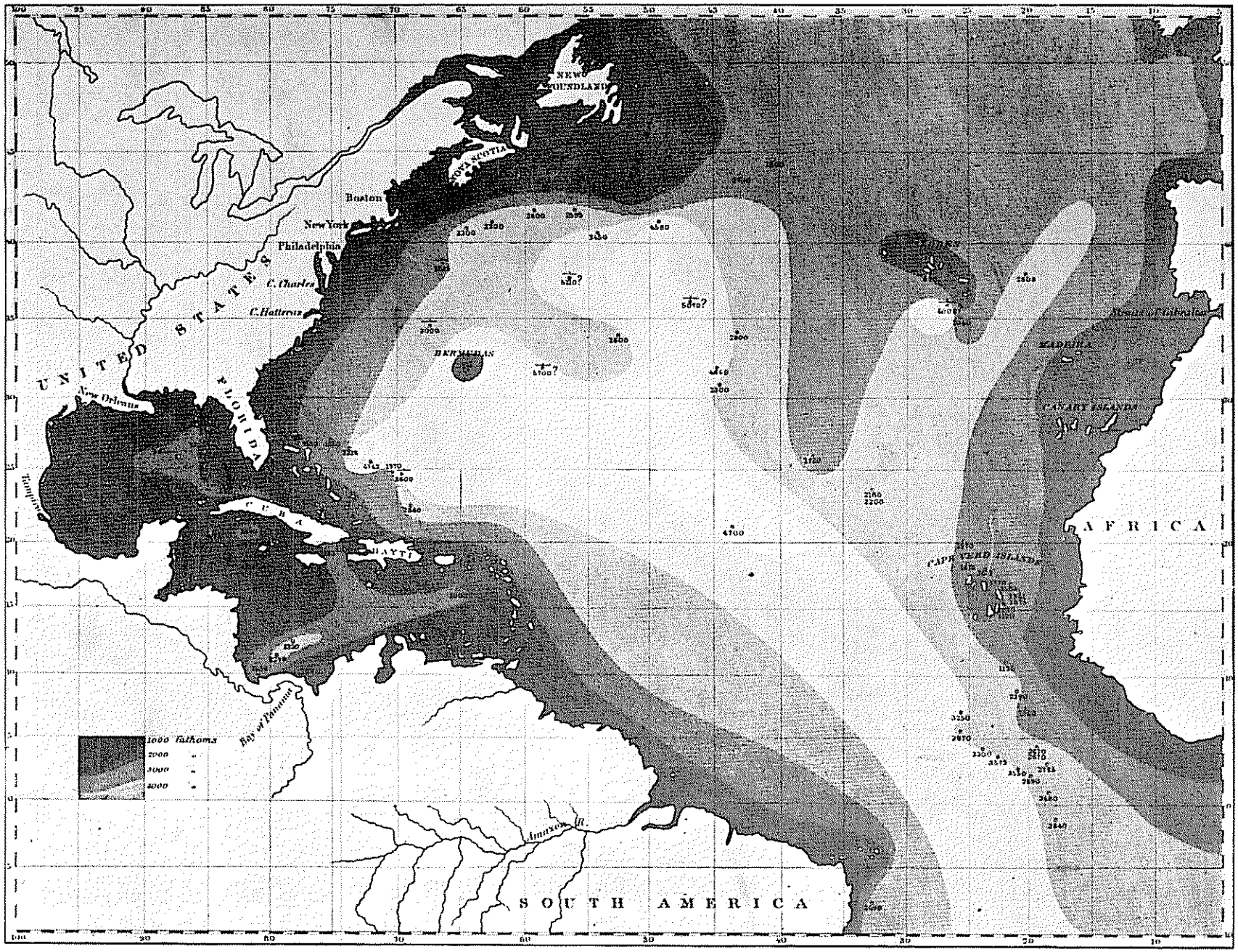
Another small but important source of data for BC charts is used, but the data are available only for limited areas. These are deep-ocean areas for which precise surveys have been conducted by the Navy or the Coast and Geodetic Survey. Although such areas generally cover only small portions of any given BC chart, they are useful in comparing and evaluating other data in the area.

The steps involved in compilation of the BC chart are as follows:

(*a*) All data are given a preliminary evaluation when received. This consists of determining the type of echo sounder, availability of an echo-sounder trace, type of navigational control utilized, adjustment of tracks to position fixes, frequency of fixes, and, finally, scaling of echograms and entering of depths along adjusted tracks. Each report is rated and assigned to a category based on relative accuracy;

(*b*) The next step, which is taken just prior to the scheduled production of a new BC chart, consists of transferring the sounding data to a master plotting sheet. Most of this work is still being done manually; but on a limited basis the data are now being digitized by use of an X–Y co-ordinate scaler, placed on automatic data processing cards or magnetic tape, and plotted with an automatic plotter. Each track is identified so that the original source can be reviewed when discrepancies are detected;

(*c*) Following this, the best data from the multitude of sounding reports plotted are selected and transferred to the master-collection sheet for the area. This sheet, unlike the master plotting sheet, shows no tracks or identification of sources. Therefore, more space is available for sounding data. It is this collection of soundings that is used in interpolating and drawing of contours. The contours



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Figure VIII. Early bathymetric chart of the North Atlantic Ocean (prepared under the direction of Lieut. Matthew Fontaine Maury, United States Navy—1852)

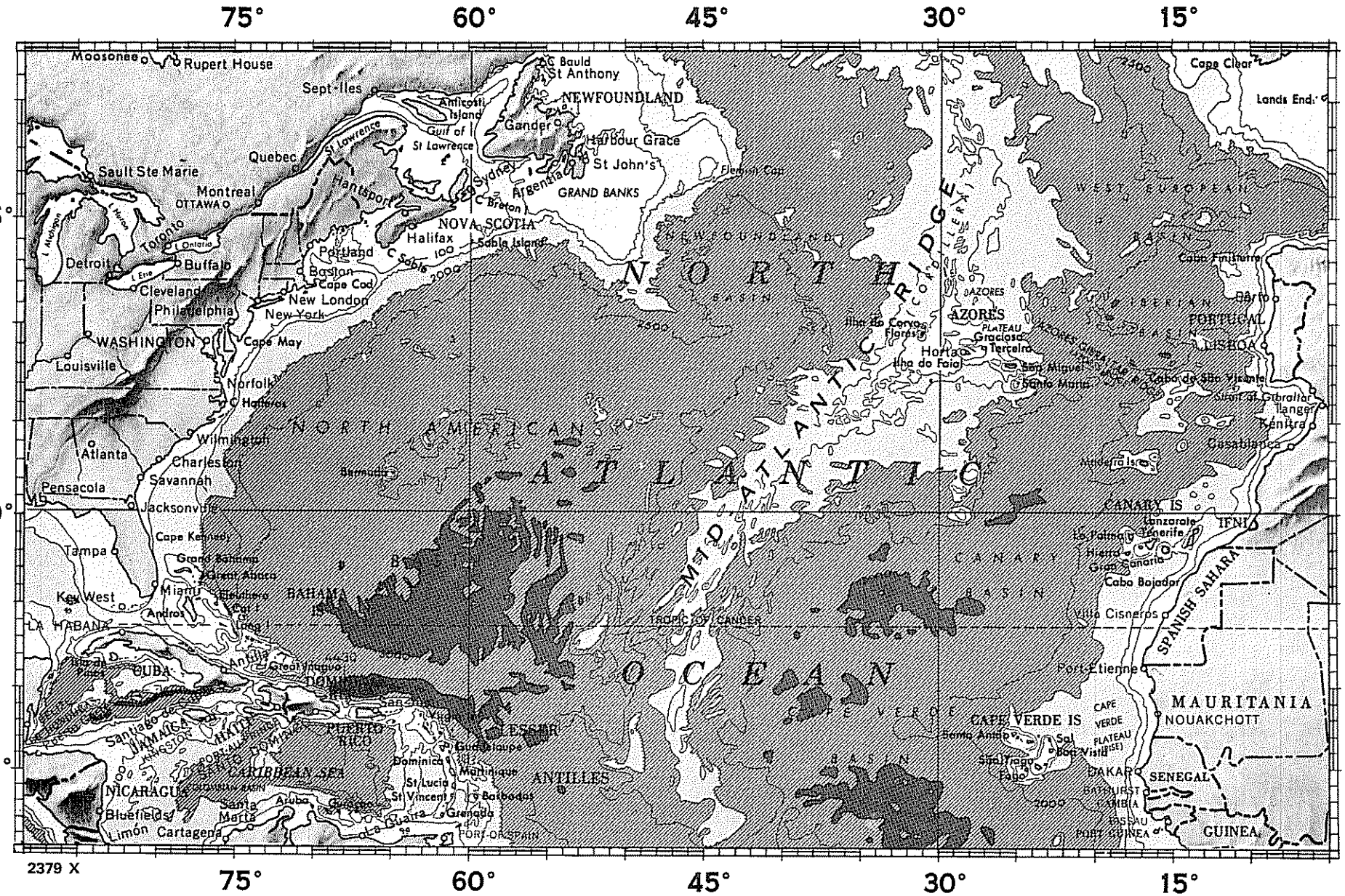


Figure IX. Generalized bathymetry on world chart, North Atlantic area (H.O. chart 1262-A, 1961 edition)

derived from controlled hydrographic surveys are also added to the collection sheet and are, of course, given precedence over random-track data;

(*d*) Finally, the depth contours are drawn. Because of the discrepancies in the positions of many of the random-track soundings, and errors in the soundings themselves caused by poor power regulation aboard ship, the contours developed from these soundings represent the most difficult and exacting task in the compilation of the bathymetry for a BC chart. Each chart comprises an area equal to Utah and Nevada combined, with a topography that may be equally as diversified. An example of the difficulties inherent in the contouring of some BC charts can easily be understood if one will visualize trying to prepare a map showing the topography of these two states by means of contour of 600 ft intervals, with their mountain ranges, basins, valleys and so on, based on elevation readings taken 5 to 10 miles apart, along lines from 2 to 50 miles apart, where the position for each elevation reading could be in error by several miles. This could mean that with two independent observers who thought they both were in the same geographic position but at different times, one could actually be observing the elevation of a peak while the other was observing the elevation in a valley or basin. Plotting the two widely different elevations in the same geographic position makes it impossible to contour the map without some adjustment of the observations. It is readily apparent that absolute accuracy can never be achieved by this means, but the trained geologist or bathymetrist can interpret the combined observed data and come up with a reasonable portrayal of the true land forms. Sizes, shapes and maximum elevations will rarely be completely accurate, but all the major physiographic features will be shown in their correct relative position. The less accuracy exhibited by the original data, of course, the more of the data that must be discarded in the final analysis and the less the reliability of the final BC chart.

Limitations of the BC chart

The use of the BC chart by many navigators has been limited by the lack of descriptive information about the chart. Some users simply do not understand a chart that is made up preponderantly of meandering lines rather than soundings. Others feel that a chart which does not show a high density of individual soundings is based on inadequate data.

Where BC charts exist, they may be considered as representing all available knowledge at the time of their compilation and as presenting more detailed information than a standard navigational chart of the same scale. In general, the BC charts are of a larger scale generally than the standard navigational charts available for the open ocean areas, thus enjoying an additional advantage over the standard charts. A high degree of accuracy has been achieved in interpreting the available sounding data through the scientific approach described under methods of compilation. Despite the accuracy advantages realized by this method of handling data, there are errors in the exact placement of contours. Sometimes errors are caused by utilizing data of a questionable nature, as in the case of reports of non-existent shoals. However, when a shoal sounding has been reported, it must be shown on the chart until such time as its existence can be disproved, in the interest of safe navigation. Such reported dangers are sometimes found to be based on erroneous data, such as

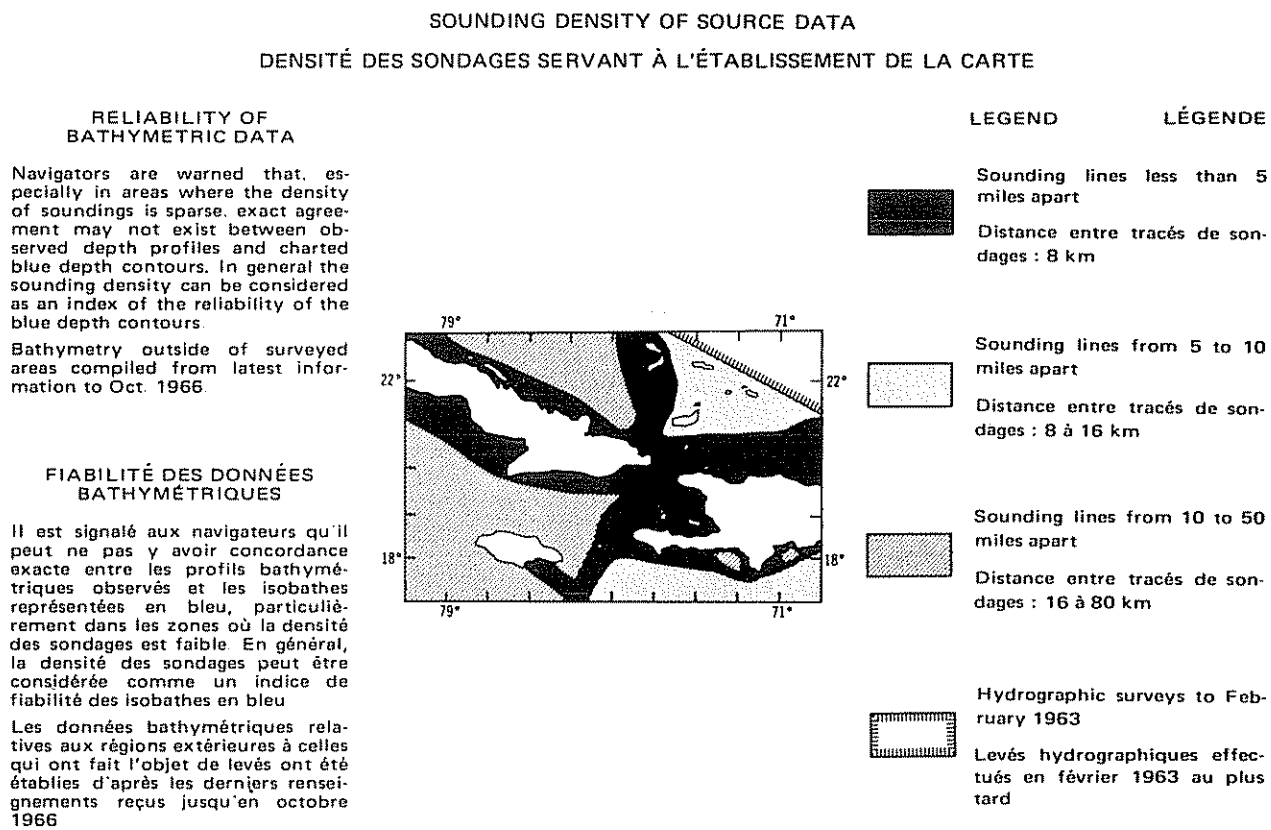


Figure X. Example of sounding density diagram shown on charts of the BC series

phasing errors or interpreting the Deep-Scattering Layer as the bottom.

The sounding-density diagram shown on each BC chart is intended to give an indication of how many soundings exist in an area, and how well the area has been covered. It should be remembered, though, that even where dense coverage has been achieved, many of the data could be in error and thus degrade the accuracy of the resultant chart. The accuracy of the BC chart, while enhanced by the scientific interpretation it has received, is still subject to the vagaries and inaccuracies inherent in the original data. As most of the data and the charts are of the open sea areas, the navigational control in general has not been as precise as navigators desire. Now that sounding tracks run under Loran-C navigational control are becoming available in some ocean areas, it is planned to form a basic network of these lines and use them as a standard in the evaluation of lines which cross them.

Uses of the BC chart

The BC chart is an important adjunct to standard nautical charts of offshore and coastal waters. Where the detail of the ocean bottom on BC charts has been developed from sufficient amounts of accurate data, ships using echo sounders can use the charts to obtain lines of position and running fixes. Other applications include their use for routine dead reckoning and position plotting, for recording tracks and observed depths, for scientific study and use by geophysicists, geologists, and oceanographers, and for operations planning, including the selection of submarine-cable routes and underwater equipment and facility installation sites.

The BC chart can supplant other navigational tools, or at least be used to supplement them. Techniques for use in bathymetric navigation are not new, but obtaining reliable data to present to the navigator is a time-consuming process. If the navigator uses unreliable data in attempting to navigate by bathymetric features, he soon loses confidence in the system and is reluctant to continue using this means of navigation. The best approach to learning bathymetric navigation techniques is to try them under the most favourable conditions first, and then, as familiarity grows, to use them as a standard practice. The installation of echo-sounding equipment has made available a means for using submarine relief features as guide posts in the sea. This means that "Davy Jones' Locker" is no

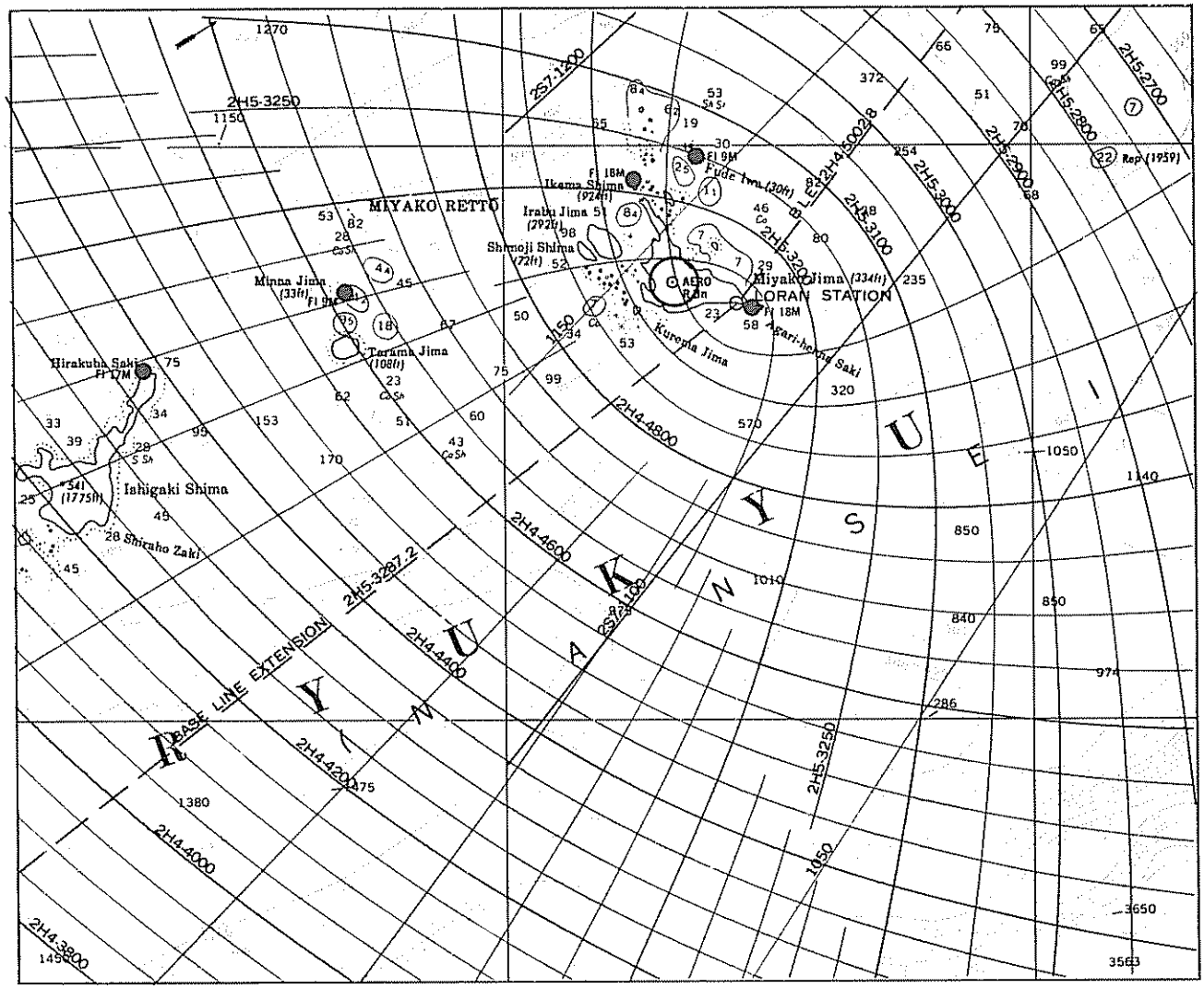


Figure XI. Section of H.O./BC chart 5495 (reduced), 1968 edition

longer an invisible, secretive and mythological place, but, to date, very few navigators have even attempted to utilize the technique of navigating from seamount to escarpment to ridge in the open ocean.

Aside from its basic use as a navigational tool, the BC chart is valuable in further study of the Earth. As over seven-tenths of the Earth's surface is covered by water and cannot be viewed directly by the human eye, the bathymetric chart provides the basic knowledge of the size, shape and distribution of submerged topographic features. The sea floor is as diversified as the land surface. Huge mountainous areas poke their crests up near the surface in many places, large volcanic cones have a wide distribution and canyons comparable to the Grand Canyon course down the continental shelves off almost all the continents.

Upon examining the small-scale nautical charts of the world's oceans, it is no wonder that the true character of the sea floor remains a mystery to many people. The bathymetric chart, on the other hand, gives an immediate and vivid indication of the submarine relief. Close spacing of contours, for example, graphically portrays a steep slope and wide spacing, a relatively flat bottom. Contours help to make the bottom topography stand out in an apparent three dimensions and bring into prominence such navigational landmarks as seamounts, escarpments and canyons. Knowledge of the size, shape and distribution of bathymetric features is, of course, also a requirement for the proper and complete interpretation of gravity and magnetic data.

Future development

The BC charts have now passed through several years of evaluation, and many comments concerning them—both pro and con—have been received by the Naval Oceanographic Office. Obviously, the charting of sea floor topography has come a long way since Maury's chart that utilized fewer than 100 soundings. Whatever success has been realized in this endeavour, as well as the improvements that will surely come, depend to a large degree on the continued close co-operation of many organizations and interested observers. Ships of the Navy, the Military Sea Transportation Service, the Coast Guard, and the Merchant Marine must continue their contributions of reliable sounding data, as the BC chart accuracy is directly dependent on the accuracy of the data used in their construction. Although much better sounding equipment and navigational systems are now available and will result in better data, it is axiomatic that the quality of data collected generally bears a direct relationship to the time and attention given to this task.

In addition to improving the quality of the data collected, better methods of presenting it will no doubt be realized. A new type of sounding density diagram is being planned. It will be supplemented by a reliability diagram, with textual material describing the quality of navigational control and sounding data used on each chart. Other aids to effective utilization of the chart will be a short narrative description of the area, plus the portrayal of selected profiles that can be compared to the echo-sounder trace along the ship's track. Another innovation under consideration is the inclusion of more closely spaced soundings on the chart to assist the mariner accustomed to seeing discrete soundings.

The BC chart is a natural springboard for new products derived from the same basic bathymetric data. One of these already in being is the new HO/BC chart that retains the lights, buoys and other coastal hydrographic and navigational data found on the standard H.O. sailing charts, as well as the deep-water bottom contours and Loran curves found on the BC charts. This marriage of the two types of charts should increase many times the utility of the resulting product. The past practice of adding discrete soundings to small-scale charts from almost any source, and never removing any, has been discontinued. On standard sailing charts, only about 2 per cent of the available data could be shown, leaving 98 per cent not fully utilized. On the new HO/BC charts, 100 per cent of the available data is used to prepare the contours; consequently, they cannot help but contribute to navigational proficiency.

There is every reason to be optimistic concerning our future bathymetric charting efforts. Recent technological advances—such as improved sounding devices and depth recorders, the availability of the Navy Navigation Satellite (TRANSIT) system which for the first time provides suitable worldwide all-weather navigational control, and the increased use of computer technology in collecting and processing data—will permit tremendous advances in our knowledge of the oceans around us in the next decade. Continued emphasis on oceanographic programmes, hopefully including modest precise survey efforts to fill voids and resolve discrepancies in existing bathymetric data holdings, will not only result in better charts for the navigator, but is probably the essential first step toward reaching the goal of "a more effective use of the sea". The BC chart and its successors should continue to play a prominent role in this regard.

THE FUTURE DEVELOPMENT OF NAVY HYDROGRAPHIC SURVEY SYSTEMS

Paper presented by the United States of America[1]

Introduction

The period since World War II has been marked by tremendous advances in technology in every scientific field of endeavour. Very little of this advanced technology has been applied to the problem of collecting hydrographic data on a large scale. Much effort and publicity have been given to advances in the associated science of oceanography. It may be worth while to clearly distinguish between the two disciplines. By hydrographic data, we mean that information which is portrayed on nautical charts, such as soundings, bottom contours, shoreline delineation, navigational hazards and aids, plus tidal data necessary for the establishment of a vertical datum. Oceanography, in an oversimplified view, deals with the physical characteristics of the sea water and its

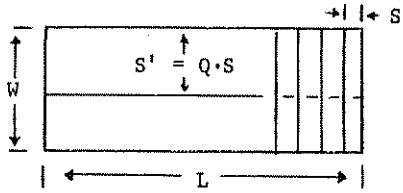
[1] The original text of this paper, prepared by L. I. Sukman, Geodetic Engineer, Advanced Systems Office, Mapping, Charting and Geodesy, Department of Defense, Washington, D.C., appeared as document E/CONF 57/L.29.

inhabitants. As seen from this definition, hydrography is tied to the production of nautical or hydrographic charts, and hydrographic data collection requirements within the Department of Defense are based on the requirements for nautical charts, combat charts and port and harbour charts to support military operations. Considering the global nature of the United States military commitment, there exists a potential requirement for hydrographic surveys covering 5 to 10 million square miles of the Earth's surface. This monumental task would challenge the capacity of the most modern and sophisticated collection system, and our present capability could hardly be called modern or sophisticated. In a report of the Panel on Oceanography of the President's Science Advisory Committee, entitled "Effective Use of the Sea", dated June 1966, the situation is summarized as follows: "The panel gives low priority to continuing hydrographic surveys in their current form. Methods employed are outmoded, slow and are not responsive to user requirements. We believe that high priority should be assigned to development of survey technology." DoD has recognized the need for increased effort in developing these new survey systems and techniques and has helped with two major steps toward the achievement of this increased capability. A research and development organization headed by Dr. Charles C. Bates has been formed at the Naval Oceanographic Office to develop new hydrographic survey systems and a greatly increased funding level was approved for fiscal year 1968.

Analysis

The establishment of a new development programme such as the one for hydrographic surveys requires that specific development objectives be identified at an early stage. To arrive at these development objectives, let us for a moment examine the type of information collected during the performance of hydrographic surveys. The bulk of information collected consists of water depths and the geographic positions associated with these depths. Auxiliary data such as tide records, bottom characteristics, currents, shoreline delineation, hazards to navigation, and beach gradients are collected in numerical or narrative form. For the purpose of this discussion, we will limit ourselves to the collection of sounding data and the related position fixes.

SURVEY OPERATIONS ANALYSIS



$$(1)\quad \text{LIN. TRK. MI.} = D = \frac{L \cdot W}{S}\left(1 + \frac{1}{Q}\right) + 2\,(L + W)$$

$$(2)\quad \approx \frac{L \cdot W}{S} = \frac{A}{S}$$

$$\text{EFF. VEL.} = V = v \cdot n \qquad \begin{cases} n = \#\text{ OF SHIPS/BOATS} \\ v = \text{AVG. SPEED OF THE } \underline{n} \text{ SHIPS/BOATS} \end{cases}$$

$$(3)\quad D = V \cdot T$$

$$(4)\quad \boxed{T = \frac{A}{S \cdot V \cdot n}} \qquad (5)\quad \boxed{A/T = S \cdot v \cdot n}$$

Simple calculation to determine the critical parameters affecting hydrographic survey efficiency

The rectangle in the figure represents an idealized survey area of length L and width W. S represents the sound line spacing and S' the spacing of cross check lines. Expression (1) represents the total linear track miles of sounding to survey the area. Assuming that L, W and $1/Q$ are small compared to the rest of the expression, we arrive at the simplified form $D = A/S$. Using the simple relationship that distance equals velocity times time, we arrive at equation (5). This expression tells us that the area to be surveyed per unit of time is dependent on three factors; the line spacing, average velocity of the sounding platforms and the number of sounding platforms in use. It is obvious that a twofold improvement in any one of these factors will double the productivity of the survey task force. Let us therefore examine these three factors to see how performance can be improved.

Sound line spacing

The spacing of the sound lines is dependent on the density of coverage desired, the depth of the water and the characteristics of the fathometer used. The first two factors are tied to the scale of the chart to be produced and the bottom configuration of the survey area. With the fathometers in use today, about 90 per cent of the area in coastal surveys is covered at a line spacing of a third of a mile and 10 per cent at a spacing of 100 yards. The development of new fathometers which would enable a wide swath of the bottom to be surveyed, instead of a single line of soundings, would result in wider line spacing. The use of fathometer arrays for wide swath coverage is a technique which should be investigated. However, it should be recognized that in shallow waters only a narrow swath would be covered by the subtended angle of the array. The maximum array angle would also be limited by lack of echo return as the angle gets larger.

Velocity of sounding platform

The second area for consideration is the velocity of the sounding platforms. In general, the speed with which sound boats operate is limited by these five factors:

(*a*) Weather conditions, including sea state and visibility;

(*b*) Hazards to navigation, natural, man-made and boat traffic;

(*c*) Design of the craft's hull and propulsion system;

(*d*) Ability of the navigational positioning system to provide fixes;

(*e*) Ability of the fathometer to keep up with the speed of the craft.

The ability of survey craft to operate under adverse weather conditions can be enhanced in several ways. Vertically stabilized transducers would enable operation in rough water and the addition of radar would assure the safety of the craft under conditions of limited visibility.

Since most hydrographic surveys are conducted in unsurveyed or poorly surveyed areas, the problem of navigational hazards slowing down sound boats is a serious one. The obvious solution is to get the sounding platform out of the water. This can be done by using helicopters or ground effects machines as sounding platforms. This approach provides us with vehicles of high speed which are less subject to surface conditions and navigational hazards.

The design of high-speed craft which can be used as sounding platforms is far ahead of our ability to use these craft. A great deal of experience has been gained in using hydrofoils, ground effects machines and helicopters for other purposes. However, a large number of operational and technical problems will have to be solved before these vehicles can be effectively used for the collection of hydrographic data. One of these problems is the development of navigational aids which can provide continuous position fixing. Optical techniques such as sextants and theodolites will obviously not be adequate, and total reliance will be on electronic systems. These electronic systems fall into two general categories, ranging and hyperbolic, and in themselves present a number of support problems. This rather complex set of electronic devices requires skilled maintenance personnel to keep the equipment running. Prior to commencement of survey operations, it is necessary that the geodetic positions of the transmitter sites be determined and that permission be obtained to occupy the transmitter sites for the period of the survey. After the transmitter sites have been positioned, special electronic charts which show electronic lines of position for the survey area, at the scale of the survey are then produced, usually back at the base plant. It is important that these functions be performed prior to the arrival of the survey task force or expensive delays in commencement of the survey may result.

A great deal of work needs to be done to provide adequate depth sensors for the high-speed vehicles which are available today. Some experimental work has been done in the use of FM sonar as a sounding device mounted on a hydrofoil craft. The results of this test have been encouraging. However, the development of a depth-sensing device for use with helicopters and ground effects machines has not yet begun. Preliminary investigations indicate that it will not be practical to lower the sensors into the water from these vehicles, so that in a limited way these will be remote sensors. The most promising approach at this time seems to be the use of a pulsed green laser. Green lasers have demonstrated ability to measure water depths in static tests, under ideal conditions of water clarity. Many basic questions still need to be answered before an operational laser fathometer can be developed. Some of these are: the effect of various bottom materials on laser reflectance; the range of water turbidity in which laser fathometers can be successfully operated; practical limits to the depths at which they can be used under operational conditions; and power requirements and maintainability. It is possible that other types of sensors can be developed for use with these high-speed sounding vehicles of the future.

High-speed vehicles mean high data acquisition rates and this means data-recording equipment which can keep pace with the vehicle. The automatic recording of time correlated, sounding data and position fixes, in digital form seems to be a necessity. In addition, there will be a requirement for display of the vehicles track and sounding information, so that the predetermined line spacing can be accurately followed and uncharted shoals can be quickly identified for navigational safety. The collection of data in digital form at the source will also pay dividends in the automation of the data-reduction process.

Number of Platforms

The third major factor affecting the productivity of a hydrographic survey task force is the number of sounding platforms employed in a survey. Assuming an average velocity for each vehicle, it is obvious that we can double productivity by doubling the number of sound boats we use without any advance in technology. However, the use of a large number of sounding platforms presents its own set of special problems. The large ship, or mother ship, as we like to think of it, must first of all have the capacity to carry these sounding platforms to the survey area. Secondly, she must be capable of efficiently launching and recovering these vehicles, even under adverse weather conditions. She must provide maintenance and logistical support for the craft in the form of technicians to keep equipment running, spare parts and fuel. The crews must also be berthed and fed by the support vessel. All this points to a slightly different concept in large hydrographic survey vessels. They must be thought of less as survey platforms and more as support vessels which can assure the efficient utilization of a large number of sounding platforms.

Providing positional fixes for a large number of sounding craft may also present a problem. Some of the electronic navigational aids in use today limit the number of simultaneous users. These are primarily the range-measuring types which employ active transponders aboard the survey craft. Hyperbolic systems are passive from the users' viewpoint and do not limit the number of users. However, the technology in electronic-ranging systems has progressed to the point where the development of a system which could accommodate a reasonable number of users can be easily achieved.

As in the case of high-speed vehicles, the collection of data by a large number of vehicles would soon swamp our capacity to process the data. It will be necessary to develop equipment to automatically reduce and plot the data during the progress of the survey so that the status of the data-collection effort can be monitored.

In order to efficiently use a large number of sounding platforms operating simultaneously, the Navy will have to develop new operating procedures to assure that there is maximum utilization of the entire capability. As the survey task force becomes more complex, the job of planning the survey becomes more important. The responsibility for keeping all that expensive equipment moving in a co-ordinated effort rests squarely on the shoulders of the survey planners.

On the subject of collecting auxiliary hydrographic data, thought should be given to the collection of tidal information by a more efficient method. The use of remote, pressure-type tide gauges which telemeter their information back to the mother ship could lead to the ability to correct sounding data for tides in real time.

Future Development

In looking at the parameters which affect the productivity of hydrographic surveys conducted on a large scale,

we have identified six areas which should be considered in a development programme.

(1) Fathometer technology. There is a need to develop depth sensors which can operate from a variety of high-speed vehicles such as hydrofoils, ground effects machines and helicopters. These sensors should be able to operate from above the water's surface, and it may be desirable to have the pulse rate variable as a function of water depth. In deeper water, fathometer arrays which can cover a wide swath of the bottom at one pass should be developed. The advantages which can be achieved by vertically stabilizing these sensors should also be investigated.

(2) Navigational aids. Electronic navigational aids which can accommodate a large number of high-speed vehicles will be needed. Serious consideration should be given to the development of a system which operates untended, from moored buoys in both deep and shallow water. In addition, the system should have the ability to determine the relative positions of its transmitter stations so that the survey can start prior to the completion of geodetic operations. The system development should emphasize compactness, reliability, freedom from ambiguities, adequate range and untended operation for long periods. Receiver equipment should be compact enough to allow operation on small craft with minimum power requirements.

(3) Data recording. Emphasis should be on recording data in a form which lends itself to automatic data processing. Track plotters and visual displays will also be required to monitor progress of the survey and permit immediate recognition of navigational hazards.

(4) Data handling. A large number of high-speed vehicles operating simultaneously will result in a huge volume of data which should be at least partially processed during the course of the survey. Data links between the sounding platforms and the mother ship would provide real time data for input to automatic plotting devices which could plot the survey as it progresses. These same automatic plotters could be used to produce electronic positioning charts based on the relative positions of the electronic navaid transmitters.

(5) Tide sensors. Pressure-type tide sensors which could be lowered to the bottom with self-contained power supplies should be developed. The information could be telemetered back to the mother ship for real time corrections to soundings.

(6) Mother ship concept. The development of a highly efficient hydrographic survey capability should follow the same approach used in developing other integrated systems. This approach emphasizes the compatibility between system components. Following the concept that the data collection should be done by a large number of high-speed vehicles, the role of the mother ship within the system becomes one of support, maintenance, communications and data reduction. The important point to be emphasized about this vessel is that it should be designed as an integral part of a system and not merely as a ship which will carry certain specialized equipment. All of the other component developments, if successfully achieved, would lose a certain measure of effectiveness if the system is not integrated through a properly designed support vessel.

In closing, it should be noted that the final decisions for systems design in the development of hydrographic survey systems, as in any system, should be based on an analysis of cost per unit of data collected and the ability of the system to meet the quantity requirements within a specified time frame.

Since the original presentation of this paper, the U.S. Naval Oceanographic Office has undertaken the development of a Hydrographic Survey and Charting System (HYSURCH). It is anticipated that a system which incorporates many of the ideas presented in this paper will be ready for testing by mid-1972.

BASIC MAP OF THE SEA AROUND JAPAN

Paper presented by Japan[1]

In order to cope with the recent growing need for general maps for the ocean, owing to the nation's expanding activities in oceanographic development and exploitation of continental shelves around Japan, the Hydrographic Department worked out a scheme to produce a detailed "Basic Map of the Sea" series to cover waters adjacent to Japan, and started the work in 1967. Due consideration was also given to resolutions 24 and 25 of the Fifth Conference in supporting the scheme. The scheme is scheduled to be completed by publishing sixty-two sets of the Basic Map of the Sea over the continental shelves by 1976. Four sets have been published to date and two sets will soon follow. The figure shows the survey and publication project for the Map series.

For planning and operation of oceanographic development or exploitation of continental shelves, it is necessary to grasp not only the configuration of the bottom, but also geological structure, magnetic intensity, gravity anomaly and so on. It was therefore decided that the Basic Map of the Sea should consist of four different specific charts compiled from data obtained simultaneously, i.e. a bathymetric chart, a submarine structural chart, a total magnetic intensity chart and a gravity anomaly chart.

Each type of chart is compiled at 1:200,000, 63 × 46 cm, half the size of ordinary nautical charts. The Lambert's conformal conic projection is adopted so that the actual shape and configurations can be represented, neighbouring maps can continue with one another and continuation to land maps at 1:200,000 can be taken into account.

The Bathymetric chart represents the bottom topography by blue isobaths drawn at a depth interval of 20 m to a depth of 200 m, and every 100 m for deeper areas. Proper

[1] The original text of this paper appeared as document E/CONF. 57/L. 54.

geographical names for the main sea bottom features are labelled.

The submarine structural chart represents the positions of faults, anticlines and synclines, as well as configuration of the basement. Sub-bottom geological profiles are also shown.

The total magnetic intensity chart represents the total magnetic intensity by means of isopleths every 50 gammas, the pattern of which is directly connected with the base rocks.

The gravity anomaly chart represents the free air gravity anomalies by means of equal difference curves every 10 mgal, as well as the location of gravity measurements, thus enabling an analysis of geological structure below the sea floor to a depth of about 20 km.

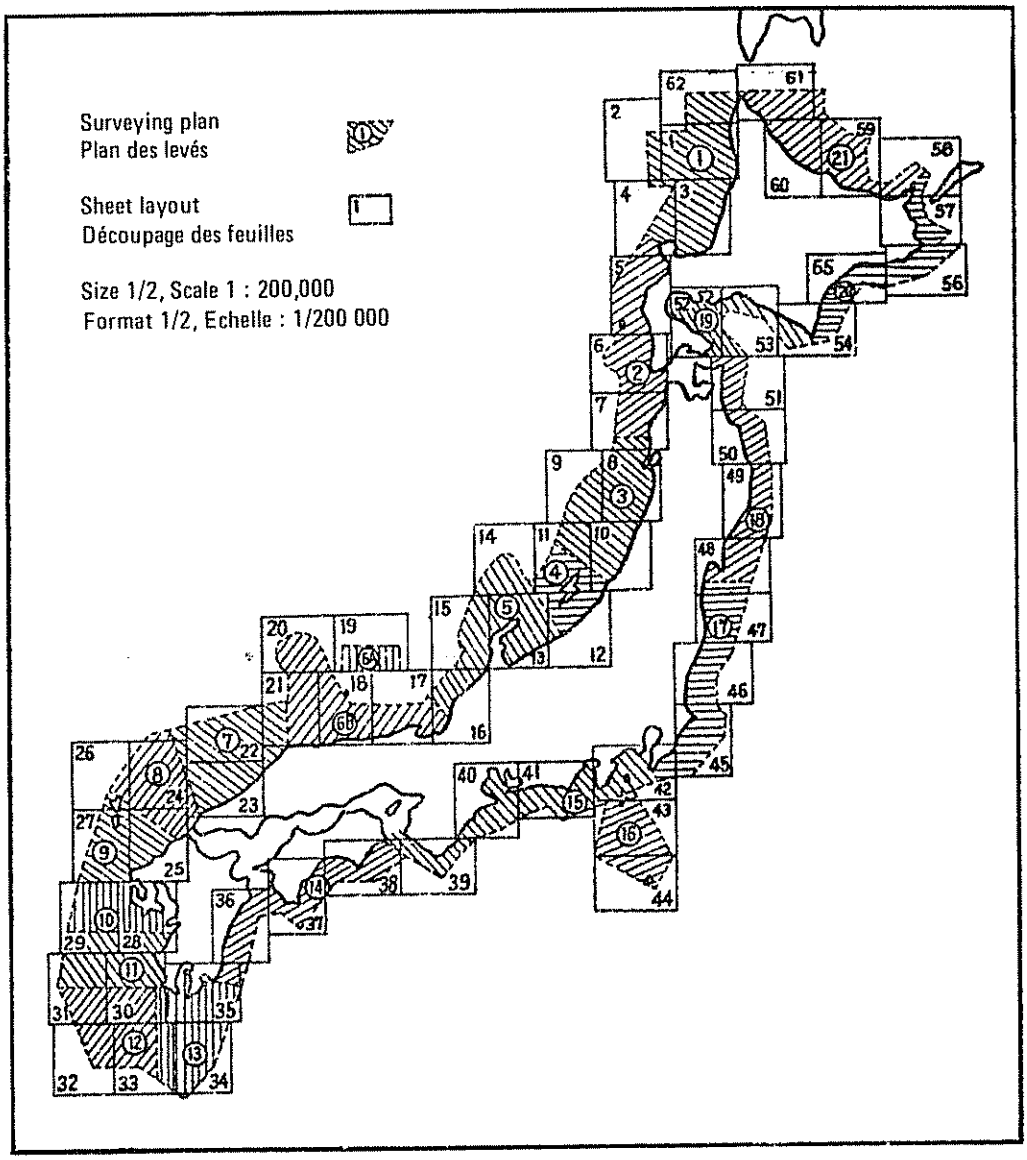
A SCHEME OF THE BASIC MAP OF THE SEA FOR COASTAL AREAS

Paper presented by Japan[1]

In regard to submarine topography in the coastal areas of Japan, thus far bathymetric surveys have been completed only for ports and harbours at 1:10,000 for the purpose of preparing nautical charts; and for the rest of the coastal waters only surveys at 1:50,000 or smaller have been carried out. As for submarine geological data in those areas, information on the geological structure is scarce except for that relating to the surface of the bottom.

It was therefore felt necessary to produce bathymetric charts and submarine structural charts anew at 1:10,000 as

[1] The original text of this paper appeared as document E/CONF. 57/L.112.



Basic map of the sea around Japan (publication project)

the "Basic Map of the Sea for Coastal Areas" series; these charts will now be indispensable tools for the exploitation and utilization of coastal areas. The Hydrographic Department of Japan is planning to prepare these charts starting in 1971.

This series will cover all the coastal waters of Japan as far as 10 km from the coast, or the waters down to a depth of 50 m. About 2,000 charts will eventually be published.

The bathymetric chart will represent the bottom topography by means of isobaths at 1 m intervals, and the submarine structural chart will show the location of strata as well as faults and folds of the sub-soil down to a depth of about 50 m below the sea bottom.

It is expected that the planned survey operations will require a lot of work. Accordingly, thought is being given to using the survey capabilities of private enterprises in the country to complete the scheme within a reasonable period of time. Survey areas will be decided annually upon consultation with the participating organizations.

(a) *Report of the corresponding committee on the oceanographic survey of a portion of the South China Sea*

REPORT ON THE CONCLUSION OF THE CORRESPONDING WORKING GROUP ON THE CO-OPERATIVE OCEANOGRAPHIC SURVEY OF A PORTION OF THE SOUTH CHINA SEA

Paper presented by the Chairman of the Corresponding Working Group

During the three years since the start of the work of the Working Group, the Chairman sent out six circulars to the members for suggestions and comments on the working plan and various aspects of the Group's work. Replies were received from most of the members of the Group, IHB and IOC, although some members failed to respond to many of the circulars.

Under the circumstances, the Chairman formulated the following conclusions based on the suggestions and comments received, on the study of the plotting sheets compiled from the existing bathymetric data and from discussions at the meeting held in Tokyo from 22 to 23 July 1970.

AREA TO BE SURVEYED

After collating sounding data supplied from various countries to compile the plotting sheets covering the "dangerous ground" of the South China Sea, it was found that sounding lines are very sparse in most places and that even in those places where the sounding-lines cross or run close together, big discrepancies are observed between sounding values from different sources. In fact, virtually none of the approximately 246,000 square miles of the area was sounded at the density recommended by the IHB.

The area has greatly varying depths and includes many known dangers and extensive shallow areas. Adopting the principle as stated by the IHB that the spacing of sounding lines should not exceed twice the mean depth, tremendous mileage would be required to complete the survey. While the IHB standards are not in question, it is obvious that if the survey is to achieve its object within a reasonable time, a system of priorities must be adopted. It is suggested that an exploratory survey with 6-mile spacing of sounding lines should first be carried out in the general area, followed by a more intensive survey in areas of particular interest.

The following tasks are seen as main priorities:

An exploratory survey with 6-mile spacing of sounding lines in the entire area;

Correct positioning of the isolated navigational dangers in otherwise deep water. Most of the area south of 10° north falls into this category, and if the comparatively quickly performed task of positioning the known dangers were completed, the southern portion of the South China Sea could be charted. Such a chart could be used with a reasonable degree of confidence;

A survey of the Reed Bank area between 12° and 10° north and 116° and 118° east. This area is mostly shallow, contains many known dangers and may contain as yet undiscovered dangers.

More intensive survey of areas of particular interest.

SURVEY STANDARDS

It is difficult to maintain position fixing over the area in question, since it is extensive and far removed from land. It was also found that positions of identical reefs or shoals do not always coincide on the plotting sheets supplied by different countries.

As for geodetic operations and positioning of survey ships, it is considered advisable to make use of those systems currently employed by the participating countries or those systems which will be in use by the time the survey is started.

Although the Working Group considered this subject to some extent, it is felt that the systems to be employed will eventually be those which are available to the countries that participate in the survey. Accordingly, the degree of accuracy to be required in the survey is not definitely described in this report. It is sufficient to mention that the highest possible degree of accuracy is desirable in geodetic control surveys and ship position fixing.

DATA TO BE COLLECTED OTHER THAN HYDROGRAPHIC

Since the whole object of the survey is the preparation of nautical charts, every effort should be concentrated on obtaining bathymetric data together with other data useful to the preparation of nautical charts. Collection of other data, if required, such as oceanographical, geological, geophysical and biological data, should not retard hydro-

[1] The original text of this paper appeared as document E/CONF. 57/L 50.

graphic surveying. In any case the object of the present survey is to enable the other data to be collected later.

Execution of the survey and financial assistance

It is desirable that a regional project be established under the sponsorship of one of the participating countries with the assistance of the United Nations Development Programme for active co-ordination of the international co-operative hydrographic survey as well as of the publication of its results.

Updating of nautical charts

The co-ordinator of the regional project should disseminate the survey data to the IHO as well as to those countries which have navigational chart coverage of the South China Sea so that national coverage of the existing charts may be updated.

Information to other organizations

The IOC and IHO will be kept informed of the progress of the regional project by its co-ordinator.

AGENDA ITEM 14

Geographical names

UNITED NATIONS SUPPORT OF GEOGRAPHICAL NAME STANDARDIZATION

Paper presented by the United States of America[1]

The development of international co-operation in geographical name standardization owes much to the support provided by the United Nations. The first United Nations Conference on Standardization of Geographical Names, held in 1967 in Geneva, was a particularly important milestone in this field. Representatives of fifty-four countries sought and found a better understanding of problems and points of view, reached some specific agreements, laid out some lines of further joint study and proposed some new machinery for exchange of information. The formal United Nations report of the Conference (in two volumes, E/CONF.53/3 and E/CONF. 53/4, issued in 1968 and 1969, respectively) contains the details of actions and proceedings and the technical papers.

In 1871, almost 100 years ago, geographers in their first international congress recognized the existence of a problem and made some useful observations. Subsequently, interest in geographical names and the need to know and use them grew steadily but slowly until World War II, and then spectacularly under the spur of vastly increased map coverage on larger and larger scales and with new orders of accuracy first for defence and then for economic development. The war brought suddenly a requirement of rendering millions of names into Latin alphabet letters from other writing systems. This presented both a challenge and an opportunity. If the need had come gradually, names would probably have been done a few at a time with compromises to accommodate the idiosyncrasies of both people and names. Faced with a task of unprecedented size and complexity, there was no acceptable alternative to mass production by standard treatment. Nor was it possible to indulge those who might have liked some familiar spellings better than those that resulted from standard processing. Furthermore, while every country had a stock of conventional names for foreign entities, these generally covered only the names of countries, principal cities and some other well-known entities. The vast bulk of lesser places and features had only local names. These had to be accepted, and the less they were modified the better.

The wartime and postwar experience in name processing made it abundantly clear that there is no acceptable alternative to standardization of local names by the country having sovereignty. At the same time, national standardization programmes encounter similar problems everywhere and experience in one country is likely to be applicable in another. Furthermore, the assimilation of nationally standardized names by another country may be far easier if the problems of transfer have been anticipated at the time of standardizing. In this kind of situation, the United Nations is a particularly appropriate instrument for extending mutual understanding and developing ways and means of co-operation.

First, a draft general programme looking for progressive steps toward such understanding and co-operation was circulated by the Secretary-General of the United Nations to all Member States for comment. Next, the Economic and Social Council of the United Nations convened the first Group of Experts in 1960 to explore the problems to be expected in national standardization programmes. The report of that group was also circulated and commented upon. The Council then authorized the first International Conference on Standardization of Geographical Names to be held in Geneva in 1967, and recalled the Group of Experts in 1966 to help organize it.

The Geneva Conference thus took place under highly favourable circumstances. The Conference was devoted entirely to exploration of the subject; most of the participants were technically competent and associated with geographical name standardizing; every country had had ample time to study and experiment with the recommendations in the 1960 report of experts; and the Conference was deliberately structured to facilitate the exchange of information and views and to develop the machinery for international co-operation.

It is indicative of the enthusiastic spirit of co-operation generated at the Conference that the two resolutions considered most important related to the continuance of the momentum that had been gained. The first resolution called for establishment of a United Nations permanent committee of geographical name experts "to provide for continuous co-ordination and liaison among nations to further the standardization of geographical names and to encourage the formation and work of regional groups . . .". An *ad hoc* group was set up to function *ad interim*. The second resolution recommended convening of a second conference not later than 1970. These two resolutions duly came before the Council at its spring meeting in May 1968, and were approved in slightly altered form. The

[1] The original text of this paper, prepared by M. F. Burril, Geographer, Department of Defense, Washington, D C., and Chairman of the United Nations *Ad Hoc* Group of Experts on Geographical Names, appeared as document E/CONF.57/L.25.

Group of Experts set up at Geneva was asked to continue to carry out the functions proposed, and the Secretary General was asked to consult with the Group relative to holding the second conference in 1971.

A second session of the Group of Experts was convened by the Council in March 1970, the first session having been the one in Geneva at which officers were elected and general plans were made. It had been agreed at Geneva that the experts would come from fourteen major linguistic/geographical divisions of the world. However, since many of these who were present in Geneva could not on their own authority commit their Governments to making their services available as experts, and since no one was present from one of the divisions, it was not possible to fix the composition of the group definitely at that time. Subsequently, it developed that, without proper mailing addresses for people who could serve as experts from these regions, it was not possible to complete the organizational structure prior to the second session. The United Nations invitation to countries to send experts to the March 1970 meeting was therefore made general and any country wishing to do so was free to send an expert or experts. Sixteen countries sent twenty-five people and all but two of the divisions were represented, the missing ones being Europe—east, central and south-east, and Asia—south-east.

The report of the second session has been issued by the United Nations as document ESA/RT/C/GN/1, dated 29 April 1970. The charge to the Group of Experts, essentially that proposed by the Geneva Conference for a permanent commission, was to provide continuous co-ordination and liaison among countries, to further the standardization of geographical names, and to encourage the formation and work of linguistic/geographical divisions. The Conference undertook immediately to remedy the communication problem that had been encountered, starting by providing their own addresses. Countries in which there is no designated recipient for United Nations names materials are being asked to provide the name and address of such a person.

After considerable discussion of the organization and *modus operandi* of the Group of Experts, it was decided to leave the divisional breakdown essentially as defined at Geneva with one or two changes in name, and to try to find out the divisional affiliation preferred by those countries that might logically go in one or another.

Reports were presented by the representatives of the various divisions on activities since the Geneva Conference, and by the chairman of the Group on his contacts and activities. Of special interest was the report on the regional conference in Central America, held under the auspices of the Organización des Estados Centroamericanos (ODECA) in Guatemala in 1968. At this conference, as at the first Group of Experts meeting and the Geneva Conference itself, experience with the national standardization programmes was discussed in terms of applicability in other countries, particularly in those where programmes had not been begun or had not been carried far. The regional conference was attended by persons who were expected to lead the programmes in their respective countries and was a profitable experience for all concerned.

Here, as in some other parts of the world, some countries had yet to establish names authorities and begin their governmental programme, and the conference was structured to help them get started. Another area where this approach could be of particular value is in the Africa south of the Sahara division, but some preliminary establishing of contacts needs to be done. It was agreed that the expert from Kenya should explore the possibilities of co-operative action within his region, beginning with a tour of the countries and should prepare a comprehensive report on needs and resources within each country. Since financial aid would be necessary to do this, it was suggested that the Ford Foundation should be approached. The experts reiterated the view of the Geneva Conference that regional activities can be highly useful. Since the problems within the different regions are quite different, the programmes should be tailored specifically to each situation.

The expert representing a division is expected to exercise leadership and provide liaison within his region. Until a country starts a national name standardization programme, it may not by itself see that it needs one. The divisional expert should be in a position to help a country identify and analyse its need, and will of course increase his expertise by doing so. As divisional activities grow, the full-scale international conferences will be structured to take them into account.

Three working groups were set up to work on, respectively, a comparative study of romanization systems; policy on extraterrestrial topographic naming; and international co-operation in the field of maritime and undersea naming. These working groups will report at the fourth meeting of the Group of Experts before the next conference in 1972.

It is indicative of the interest in the activities and programme of the Group that the problem of membership in the Group is not one of getting enough people to serve, but rather of keeping it small enough to function effectively. The specific recommendations on the aims, functions and *modus operandi* of the Group were arrived at and they appear to take care of the problems for the time being.

The second Geneva recommendation was that the United Nations convene a second conference on the standardization of geographical names. The Council received the recommendation and requested the Secretary-General to consult with the Group of Experts on the scheduling of the conference. This consultation was in effect accomplished at the March 1970 meeting, with the experts recommending that the conferences on this subject be held at intervals of three or four years. The Secretary-General took the larger figure, four years, and the Council concurred. Shortly before the Experts' session, Canada had decided that since it will be host to four other major international meetings in 1972, it should not be host to the second names conference. The experts from several other countries thereupon expressed interest in extending an invitation and consulted their Governments. The United Kingdom has now formally offered to be host to the Second United Nations Conference on the Standardization of Geographical Names in the second quarter of 1972, and the invitation has been accepted.

The Group will convene in New York in February 1971 to assist in planning the conference organization, and then will hold its fourth session just before the Second Conference to receive the reports it has provided for. Immediately after the Conference, it will hold its fifth session

to elect officers and plan its interim programme in accordance with the actions and instructions of the Conference.

There was general agreement at the March session that the experts should apply their special expertise to identification and enunciation of general principles and criteria of usefulness, and should not attempt to prescribe solutions for every problem. Some pertinent papers were distributed and others are in preparation for study before the Second Conference.

GEOGRAPHICAL NAMES

Paper presented by the United Nations Secretariat[1]

Since the United Nations Conference on the Standardization of Geographical Names which was held in Geneva, Switzerland, from 3 to 22 September 1967, the Group of Experts on Geographical Names has had two sessions. The first session immediately followed the Geneva Conference.

The Group of Experts met from 3 to 13 March for their second session at United Nations Headquarters in New York. At this session the group considered its aims and *modus operandi* and, in addition, created three working groups to study the following topics: the naming of undersea features; extraterrestrial topographic names; and a working group on a single romanization system. In addition the Group of Experts placed particular emphasis on the importance of regional activities. As requested by the Group, a circular letter was sent by the United Nations to all the countries of Africa south of the Sahara. Activities of the above-mentioned working groups and the replies to the circular letter sent to the African countries will be reported to the group during their forthcoming session.

On the basis of a decision by the Economic and Social Council at its 1,676th meeting of its resumed forty-eighth session that a second United Nations Conference on the Standardization of Geographical Names be held during the first half of 1972, the experts will also prepare, during their third session, this second Conference, which will be held in London for three weeks during the first half of 1972. The Expert Group will also plan for its fourth session to take place before the Conference, as well as a fifth session, immediately following the second Conference, in order to elect their officers and prepare a future programme of work on the basis of the results of the second Conference.

The provisional agenda of the third session follows:

1. Opening of the meeting.
2. Adoption of the agenda.
3. Adoption of the rules of procedure.
4. Review of progress since the Second Session:
   (*a*) Reports of three working groups set up during the Second Session;
      (i) Undersea features;
      (ii) Extraterrestrial topographic names;
      (iii) Working group on a single romanization system;
   (*b*) Reports on regional activities;
      (i) Africa south of the Sahara (Loxton);
      (ii) Latin America (Gall and Burrill);
      (iii) Other;
   (*c*) Reports of the experts on their activities.
5. Preparation for the Second Conference:
   (*a*) Agenda;
   (*b*) Organization;
   (*c*) Documentation.
6. Arrangements for the Fourth Session and schedule of activities before the Second Conference.
7. Arrangements for the Fifth Session immediately following the Second Conference.
8. Adoption of the report of the Third Session.

[1] The original text of this paper appeared as document E/CONF. 57/L.45.

GEOGRAPHICAL NAMES FOR INDONESIAN MAPS

Paper presented by Indonesia[1]

Political instability is not only bad for the stock market and for a few politicians, it is just as disturbing for mapmakers. This is especially true in developing countries, where change seems to be the only thing that is permanent. Too frequent changes in administrative boundaries and names render maps outdated too soon. This factor of change together with other factors mentioned below are the technical problems faced by Indonesian mapmakers at present.

OTHER DIFFICULTIES

The early surveyors

Systematic mapping in Indonesia was started by the Dutch Government as soon as a certain measure of political stability prevailed in the country. These early surveyors were trained primarily as topographers and knew little about other specialities. It is therefore not surprising that their maps were excellent, except for the names. Cases of carelessness in spelling are apparent and seem to be rather consistent. The names tend to be written in accordance with their Dutch pronunciation, not their true pronunciation. For example, we find "Ajer Item" instead of Air Hitan; "Denpasser" instead of Denpasar; and "Tandjong Priok" instead of Tandjung Periuk.

Places renamed

At one time, several places were renamed by the Dutch. As a result, these places are known by two names, although maps usually carry only the names given by the Dutch. Such places are, for example: Batavia for Djakarta, Buitenzorg for Bogor, Fort de Kock for Bukittinggi,

[1] The original text of this paper, prepared by I. M. Sandy, Direktorat Land Use, Department of the Interior, Djakarta, appeared as document E/CONF.57/L.76.

Fort van der Capellen for Batusangkar, and several others. Since the Dutch left, these places are known only by their original names, although the names given by the Dutch still remain written on the maps.

Alien names

Aside from the places renamed by the Dutch, there are other places whose names are alien to the native ear and tongue. A small volcanic island north of Flores carries the impressive name of "The Emperor of China". Except for some vulcanologists and a few other interested persons such as mapmakers, no one, including the local administrative officer, would have known that this name is the name of a tiny island somewhere in the Flores Sea. Similar names are, for example, Glenmore, a tiny estate town in East Java, established originally by a Scottish rubber planter; the Schwaner and Muller ranges in Kalimantan; and the Paternoster islands in the strait of Macassar. Alien though they may sound, these names will still appear on the maps, at least for some time in the future; replacement is impossible since local names never existed.

The problem of vernacular

In spite of a centralized form of government and the existence of a *lingua franca*, Indonesia is essentially a nation of diversity with regard to race, culture and language.

Although the *bahasa Indonesia* (the *lingua franca*) is taught in the schools and is officially used and understood almost everywhere in the country, especially by the younger generation, its systematic use on maps seems to add to the confusion and so tends to reduce the effectiveness of the map as an orientation tool. The retention of local terminologies for certain physical features is therefore to be preferred, such as for the terms "river", "lake", "island", "hill" or "mountain", "range" and so on. Moreover, some areas in the Republic tend to spell their place names with double consonants, contrary to the common practice in the Indonesian language. Makassar, Watansoppeng and Rappang are examples of such names, found primarily in southern Sulawesi.

In western Djawa, place names and river names are usually confusing to anyone not familiar with the area. It is hard to distinguish from the name whether it is a river or a place name. Tjiandjur is a place name, and Tjitarum is a river name; but Tjimanuk indicates both a river and a place.

Policy for the future

There is no official policy from the Government on geographical names. But mapmakers are aware of the problem and are determined to take steps towards its solution. For future maps, attempts will be made to write down the right spelling of those names which were misspelled on previous maps. Tandjung Periuk will be written in lieu of Tandjong Priok; Denpasar instead of Denpasser, and so on. The alien names will still appear on future maps when the local name is not known or where it does not exist. On the other hand, local names will replace names of Dutch origin. In case of anticipated confusion, both names will appear temporarily. The retention of local terms will be advocated for physical features and ways will be sought to differentiate between the writing of place names and other physical features.

PROGRESS OF WORK

At present, compilation of geographical names is under way. The *Direktorat Hydrografi* of the Navy managed to compile about 13,000 island names, and the geographical location of each has been checked by the *Badan Atlas Nasional*. Geographical names on land are also being compiled. Progress has been slow because of the nature of the work.

PROBLEMS OF GEOGRAPHICAL NAMES IN THE REPUBLIC OF VIET-NAM

Paper presented by the Republic of Viet-Nam[1]

INTRODUCTION

For the past two years, the National Geographic Department of the Republic of Viet-Nam has given particular attention to the problem of compiling and transcribing place names. This is a very puzzling and complex problem, owing to the newness of our establishment and the state of war that has existed ever since the three countries of former French Indo-China acceded to independence. Our technicians do not find it easy to venture very far into the countryside for the purpose of making a complete compilation and faithful transcription of geographical names. In particular, their task is made difficult by the lack of a "National Toponymic Commission" responsible for verifying geographical names before their definitive adoption.

The problem is further complicated by the fact that, in addition to the pure Viet-Namese, the population of Viet-Nam includes such heterogeneous races as the *montagnards* of the high plateaus, Viet-Namese of Khmer origin, and that in addition to the everyday language, which is Viet-Namese, each ethnic minority has its own dialect, and some of them have only recently adopted a romanized transcription. Clear evidence of these difficulties is provided by the many errors in place names found on published maps, even recent ones. As every place name in our country generally has a meaning and an origin, the best policy is to agree on a method for complete compilation and for a single, logical and appropriate transcription, while respecting the accuracy of the name.

However, some of the pitfalls which have so far been met with are worth mentioning.

Compilation

Official names

These are names of political subdivisions such as municipalities, provinces, districts (*délégations*) and communes. These alone are names which have an official character either because they were first used in an official

[1] The original text of this paper appeared as document E/CONF. 57/L.85.

document which created the subdivision in question, or, if they existed previously, because they have been confirmed by such official publications as the *Periodical Population Census* of the Ministry of the Interior or the *Statistical Bulletin* of the National Statistical Institute. Changes in such names (which are rare) can only be made and subsequently rendered official by a decree or an order.

In this category, the problem of compilation would no longer seem to arise. The authenticity of these names can be easily verified from the official documents or from inquiries to the competent regional authorities. However, some difficulties such as the following, persist:

The existence of numerous accents (a, á, à, ả, ã, ạ, ă, â) in our written and spoken language is often a source of hopeless confusion and frequent distortions due to ignorance or caprice. For example, a commune in the province of Gia-Dịnh having the correct official name of Hanh-Thông-Tây is distorted into Hạnh-Thông-Tây (with the unfortunate addition of a dot below the letter "a").

In the absence of a "National Toponymic Commission", there have been no checks, corrections or even official censure. Errors, already frequent, are becoming more and more numerous, distorting the meaning of place names and increasingly obscuring their historical, popular or etymological origins.

One strange idea, which started to be applied during the First Republic (1955–1963), is to change existing, ill-sounding names of provinces, districts and even communes (with the creation of rural centres and strategic hamlets) into new, purely Viet-Namese names which bear not even a remote relation to the actual names.

Thus, Sóc-Trăng, which comes from the old Khmer name Srok Khléang meaning "granary village" and Cà-Mau, from Túk Khmau meaning "black waters", have become Ba-Xuyên and An-Xuyên.

This name revolution encounters obstinacy or ill-feeling on the part of the local population who oppose or disregard all kinds of changes. Thus, if one travelled in some remote corner of the Republic of Viet-Nam with a recent map and asked directions from a native by the new name officially given to some administrative entity, one would be met with bewilderment and astonishment.

Names having no administrative standing

These are old-time folk names of small inhabited localities, other places, mountains, streams and the like, which are still used and are still very familiar to the local inhabitants. These names vary from one government body to another, and even from one document to another, depending on the personal knowledge of its author. Being of uncertain form, they often lead to tedious exchanges and prolonged polemics, which are further embittered by an ignorant and incompetent local press. In this situation, the Viet-Namese geographer limits himself to obtaining information directly from inhabitants of the area and local scholars. The definitive form of each name is only decided upon after very detailed analysis and painstaking checking. The geographer's task, however, would not be easy in the following cases: when there is a difference between a usual popular appellation and a name given "solemn" christening after a corner-stone laying or other ceremony, the local population seems to ignore the new, given name, while the administrative authorities, for their part, continue to use it. Streams, when they exceed a certain length may undergo a change of name from one area to another under the influence of other local names, especially where the adjoining areas are populated by tribes speaking different dialects.

Transcription

A problem arises only for geographical names having no administrative status. Names of purely Viet-Namese origin can be transcribed with a high degree of accuracy, without any danger of error, if use is made of the customary accent marks of our script. (Examples: Rạch Đủóc, Núi Chúa, Của Đại.)

Since Viet-Namese is monosyllabic and every word has its own meaning, while composite words, on the contrary, might have a different meaning, the specialist, by exercising a little care, finds his work greatly facilitated.

The problem, however, becomes more complicated in the case of names of non-Viet-Namese origin. The ethnic minorities are for the most part concentrated on the high plateaus, e.g. the Thais and the Meos in the north, and the Rhades, the Ko-Hos and the Bahnars in the south.

Explorers and ethnographers, often Catholic missionaries, have adopted the method of a phonetic romanized transcription based on the pronunciation of the local inhabitants. As there is always a difference in pronunciation between the dialect in question and the French they speak, and as they are seldom linguistic scholars, the transcription is never perfect and subject to certain increasingly serious distortions due to the absence of sufficient accent marks in the French. Thus, the old maps published by the former Service géographique de l'Indochine show names without any accent marks, and this distorts the pronunciation and sometimes the meaning of the names. For example:

Montagnard dialect	*Meaning*	*French transcription*
Chư M'ta	M'ta Mountain	*Chu* M'ta
Dak *Dăm*	Dăm River	Dak *Dăm*

An attempt was at first made to replace certain original orographical terms such as Chư, Êa and Krông by their Viet-Namese equivalents, while correcting the transcription of the name itself wherever possible.

Original transcription	*Meaning*	*Transcription with substituted term*
Chư Nam Ka	Nam Ka Mountain	*Núi* Nam Ka
Dak Dăm	Dăm River	*Sông* Dăm

Another tendency is to add the corresponding Viet-Namese orographical term before each already complete *Montagnard* geographical name, while correcting the transcription wherever possible.

Original transcription	*Meaning*	*Corrected transcription*
Chư Nam Ka	Nam Ka Mountain	*Nui Chư* Nam Ka
Dak Dăm	Dăm River	*Sông Dak* Dăm

This gives rise to inadmissible pleonasms, for if the last column is translated word for word, it gives:

Nam Ka Mountain Mountain
Dam River River

The present policy of the National Geographic Department of the Republic of Viet-Nam is to standardize the transcription, and to revert, after meticulous corrections, to the original *montagnard* orographical terms of origin.

Adopted transcription	*Meaning*
Dak Dăm	Dăm River
Chư M'ta	M'ta Mountain
Preck Chieu	Chieu River

These are explained by a marginal glossary in the map legend.

Geographical names of Khmer origin still give rise to many difficulties. Here it would not be beside the point to mention some historical details which may help to shed light on the problem of transcription. The history of Viet-Nam shows that in very ancient times the southern part of the Indo-Chinese peninsula, the lower Mekong Basin, including the Plaine des Joncs (10,000 km²), belonged first to the Fou-Nan Kingdom, then in the sixth century to the Khmer Kingdom, and finally, starting with the sixteenth century, to the old Empire of Viet-Nam. That is why there are still many Viet-Namese of Khmer origin in the southern provinces (104,000 persons in the Province of Vĩnh-Bình alone).

Formerly French subjects of Cochin-China under the French occupation and now Viet-Namese citizens, they form separate colonies, speak their own language (Khmer), have their own schools, which are often situated in pagodas, continue to promote their written language as best they can, maintain their own customs and way of life, and exercise a more or less dominant influence on the toponymy of the region. It is a curious fact that in the many centuries of co-existence, the Viet-Namese, instead of imposing new Viet-Namese geographical names, have been content to adopt the names of Khmer origin while more or less distorting their pronunciation, owing to the irreconcilable differences in pronunciation which have always existed between the two languages.

Khmer names (romanized form)	*Meaning*	*Viet-Namese distortion*
Ksach	Sand	Kẻ Sách
Srok Khléang	Granary village	Sóc Trăng
My Sor or Mê Sor	Pretty girl	Mỹ Tho
Túk Khmau	Black waters	Cà Mau
Phsar Dek	Market with a metal roof	Sa Đéc
Prêk Lôp	Lop Canal	Rạch Lộp

These few examples show that each geographical name has its meaning and its origin. Although their phonetic transcription into Viet-Namese is meaningless, the more or less correct pronunciation of these names vaguely recalls their origin; and this is to some extent helpful to those who want to study the toponymic, archaeological and ethnological problems of the area.

Before the arrival of the French, the emperors of Viet-Nam, desirous of promoting elegance in the language, departed from the popular phonetic transcriptions, which were already not too faithful, and ordered the adoption of Sino-Viet-Namese geographical names, which in their opinion had a more literary flavour.

Khmer name	*Phonetic transcription*	*Sino-Viet-Namese name*
Srok Khléang (granary village)	Sók Trăng	Nguyệt-Giang (river of the moon)
Srok Prah Trapăn	Trà Văn	Trà-Vinh

In spite of the doubly illogical nature of this distortion, it gave rise to geographical names which have been universally adopted by official bodies as well as by the people over a fairly long period. Yet it makes more difficult the task of those who wish to trace certain geographical names to their origin.

Conclusion

The preceding analysis shows that, while the National Geographic Department is paying particular attention to the problem of place names in the Republic of Viet-Nam, this is a problem of considerable dimensions which goes beyond the competence of a small Toponymic Section and even of the National Geographic Department as a whole. In spite of all our efforts, the present situation in the country does not make it easy to check each place name on the spot. We must accept that there are still numerous gaps in our recently published maps, for the geographical names are nearly always based on those shown on the maps previously prepared by the old *Service géographique d'Indochine*.

We hope that in the future we will have a "National Place Names Commission", composed of specialists who will be qualified to provide a complete solution to the problem of place names in our country.

REPORT ON THE STANDARDIZATION OF THE USE OF GEOGRAPHICAL NAMES IN HUNGARY

Paper presented by Hungary[1]

In the matter of standardization of geographical names in Hungary distinction is to be made between the group of names of localities and that of other geographical names. The standardization of names of localities took place at the end of the last century, in accordance with the requirements of the public administration, and was adopted in regularly issued directories of administrative names. These directories contain the official names of all the independent municipalities and of their suburbs. Moreover, the new names are indicated together with their old names. In this group of names the main task consists in applying the new spelling called for by the reforms introduced since the beginning of the century.

In addition to the standardization of administrative names, the problem of standardization of other—Hungarian and foreign—geographical names acquired importance in recent years. This is the responsibility of the Committee on Geographical Names, established in 1964 within the system of the national cartographic organization.

The first activity of the Committee consisted in the standardization of the spelling, which was a prerequisite to all subsequent standardizations. In the course of this work, the Committee compiled and published in 1965 very detailed spelling rules for Hungarian geographical names, including a large number of name types. In the course of establishment of these rules and during its subsequent activities the Committee closely co-operated with linguistics representatives.

One of the main objectives of the Committee was the fullest possible standardization of Hungarian (non-administrative) geographical names and their official publication. The first phase of this work started in 1966 with the compilation of a list of geographical names indicated on a map of Hungary at 1:500,000. This list was first compiled in the form of a draft and submitted to all organizations (public administration, water conservation, forest services, linguistic and geographical institutes, high schools and the like) which played an important part in the usage of geographical names. On the basis of the comments received, some changes were made in the draft, in accordance with the principle that in the case of small places the names generally in usage on the spot should be adopted. Naturally this principle cannot be applied in all cases, for example, when a river has different local names. In such cases the local names must be neglected. The names included in the modified and approved list are already uniformly applied in Hungarian cartographic practice.

With regard to the more detailed standardization of geographical names, a list is drawn up of names which appear in large-scale (1:25,000 and 1:10,000), and so they come into official use. This work is closely related with the collection of names which started in Hungary in 1965. In accordance with this programme, under the direction of linguists, all the existing geographical names are registered by county.

In mapping, the uniform usage of foreign geographical names also plays an important part. The Committee has therefore developed guide-lines for the collection and uniform usage of these names. A list of names will therefore be compiled indicating when and to what extent foreign geographical names should be used in Hungarian. At the same time, the official foreign forms of the names will also be indicated. The largest group of this type of names comprises the names of various countries, the list of which has already been compiled. In the interest of fuller information, the abbreviated and complete names of countries are included in this list, as well as their adjectival forms and their names in the original language; the names of the countries are also given in English, French, German, Russian and Spanish.

The Committee on Geographical Names also deals with the development of rules of transliteration and transcription of foreign geographical names in Hungarian, in accordance with the principle that, in Hungarian publications, the names which are not romanized must be transliterated in Hungarian in a form corresponding to their pronunciation.

The activity of the Committee on Geographical Names in the matter of international standardization of geographical names should also be mentioned. The results of this work appeared for the first time in a guide to the writing of geographical names in the World Map at 1:2,500,000. (The first edition of this guide appeared in 1959; the second, in 1962.) In it an attempt was made to establish uniform principles for the international standardization of geographical names in letters of the Latin alphabet. With regard to the transliteration or transcription of non-romanized geographical names, the official system of transliteration in use in the particular country should be preferred. In this activity may be included the compilation of the full or partial list of names in such important works as the Map of China at 1:5,500,000 (Esselte, Stockholm, 1967) and the Rand McNally International Atlas (Chicago, 1969).

[1] The original text of this paper, prepared by E. Foldi, Geocartographic Research Department, Hungarian Geodetic Institute, Budapest, appeared as document E/CONF.57/L.93.

Department of Geographical Names, is a division of the Central Research Institute of Geodesy, Aerial Survey and Cartography.

Special commissions on geographical names have been set up in most Soviet Republics. This organization of work makes it possible to take into account both the Federal and national interests of all the Soviet peoples, which completely conforms with the Soviet national policy.

Although this brief report does not give a full account of the Soviet experience in the standardization of geographical names, it may be of some interest to other countries with multinational populations.

EXPERIENCE IN THE DOMESTIC STANDARDIZATION OF GEOGRAPHICAL NAMES IN THE UNION OF SOVIET SOCIALIST REPUBLICS

Paper presented by the Union of Soviet Socialist Republics[1]

The correct and fixed spelling of geographical names on maps and other publications, as well as in official documents, is a matter of considerable interest for all the countries of the world. All countries are faced with the need to standardize geographical names.

The problem of systematization and standardization of geographical names at the national and international levels attracted the attention of the United Nations, and was included in the agenda of all the United Nations regional cartographic conferences for Asia and Africa. The first United Nations International Conference on the standardization of geographical names was held in 1967. Official representatives of fifty-three States and several international organizations participated in the Conference. At present the *ad hoc* United Nations Group of Experts on geographical names functions, and representatives of a number of countries—participants of the present Conference, for example, India, Iran, the Soviet Union and others—take an active part in its work.

The complete and well-conceived programme for the standardization of geographical names carried out in many countries includes four main groups of problems: (*a*) investigation and elaboration of a general methodological framework and specific rules for rendering national names (in multinational countries) and foreign names in the official language or languages of a given country; (*b*) development of methods for the collection of names, collection operations and concentration of initial data on place names of one's native country and foreign countries; (*c*) cataloguing and scientific processing of the data collected and, as a result, the establishment of a final and mandatory form for each name; (*d*) introduction of the standard names into mandatory use for a given country with the help of available means and methods of information.

The standardization of geographical names in a multinational socialist State is an extremely complicated task. The Union of Soviet Socialist Republics comprises 130 nationalities each of which enjoys equal rights and has its own language. More than fifty of them acquired a written language and, consequently, the possibility of school education in the native language only during the Soviet period.

In the Soviet Union, books, magazines, newspapers, journals, geographical maps and atlases are issued in sixty-two national languages. Therefore the standardization of geographical names in our country cannot be confined to the establishment of a compulsory spelling of names in one of the official languages of the Soviet State. The problems of standardization in this case are much broader and more complicated because they involve the elaboration of methods and rules of standard rendition of domestic national and foreign names into all the official languages of the Soviet Union, for example, Azerbaijani, Armenian, Georgian, Kazakh, Kirghiz, Russian, Tajik, Turkman and many others.

Since the Russian language holds a special place among all the national languages of our country, it serves as the main means of international communication and gives each one of the Soviet peoples the possibility to take advantage of the science and culture of all the others; for this reason, we started with the scientific elaboration of rules for rendering names into Russian.

During the last few years, a series of instructions for rendering geographical names from sixty-two national languages of the Soviet Union and from forty-eight foreign languages were worked out and published thanks to the joint efforts of Soviet linguists, cartographers and geographers.

Since 1968 these instructions are mandatory only for the cartographic organizations. At the present time, they are given the status of a State document, that is, they are mandatory for all the organizations of the Soviet Union dealing with the publication of books, newspapers, magazines, journals, maps, atlases and so forth. In this connexion they are being revised and republished. The drafts of new instructions containing rules for rendering the national names of our Union and Autonomous Republics into Russian are scrutinized in the scientific organizations of the Republics concerned and co-ordinated with the supreme legislative bodies (Supreme Soviets) of the Republics.

Along with the preparation of new instructions regulating Russian spelling of national and foreign place names, a great deal of work is being done on the compilation of glossaries of local geographical terms throughout the national territories of the Soviet Union and foreign countries. Fifteen glossaries of this kind have been published.

The standardization of geographical names in the Soviet Union is not confined to the elaboration of rules for rendering non-Russian place names into Russian. Similar work is now under way in several Republics of the Union where rules for transcribing geographical names into their national languages are being worked out. Thus, for example, a series of special reference books containing rules for the rendition into Lettish of proper names belonging to other languages (Russian, Lithuanian Estonian, Finnish, English, Italian and others) has been published.

Many different organizations—central (all-union) and local (republican and regional), legislative and executive (administrative), scientific and industrial—are directly interested in the domestic standardization of geographical names in the Soviet Union. The Permanent Joint Commission on Geographical Names under the auspices of the State cartographic service is the central national names authority that co-ordinates the entire work on the standardization of geographical names in the Soviet Union. The Permanent Commission is composed of official representatives of all the ministries, agencies and scientific organizations interested in the problem. The executive body of the Permanent Commission, the

[1] The original text of this paper, prepared by the Central Scientific Research Institute of Geodesy, Aerial Photography and Cartography, Moscow, appeared as document E/CONF.57/L.111.

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