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

20 October — 1 November 1958, Tokyo, Japan

Vol. 2 - Proceedings of the Conference and Technical Papers

UNITED NATIONS
New York

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

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UNITED NATIONS
Department of Economic and Social Affairs
New York, 1961

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E/CONF.25/4

UNITED NATIONS PUBLICATION

Sales No.: 61.I.8

Price: $U.S. 3.00 ; 21/- stg.; Sw. fr. 13.00
(or equivalent in other currencies)

FOREWORD

In accordance with the procedure followed for the previous conference, the official records for the Second United Nations Regional Cartographic Conference for Asia and the Far East, held in Tokyo, Japan, from 20 October to 1 November 1958, are issued in two volumes: Volume 1, *Report of the Conference*,[1] and the present publication, Volume 2, *Proceedings of the Conference and Technical Papers*.

Part I of the present volume contains the summary records of seven plenary meetings and Part II contains the text of studies, reports and communications submitted to the Conference by participating Governments and the Secretariat of the United Nations.

These technical papers are grouped by item and are presented in the order of the items as indicated in the agenda of the Conference. The papers have been edited or consolidated in accordance with United Nations practices and requirements. One paper [2] and parts of another paper [3] which have already appeared in other United Nations publications have not been reproduced in this volume.

The report of the Conference was submitted to the Economic and Social Council at its twenty-seventh session, held in Mexico City in April 1959. The resolution adopted by the Council in concluding its consideration of the report is given in the annex to Volume 2. This resolution contains provisions for convening a Third United Nations Regional Cartographic Conference for Asia and the Far East.

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[1] *Second United Nations Regional Cartographic Conference for Asia and the Far East*: Volume 1, *Report of the Conference*, E/CONF.25/3 (Sales No.: 59.I.9).

[2] *See* "Standard Cartographic Practices for Land Maps" in United Nations, *World Cartography*, Volume VI, 1958 (Sales No.: 60.I.10).

[3] *See* footnote 9 (page 152) to "Automation in Geodesy, Photogrammetry and Cartography" in the present volume.

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[1] Including only documents presented under substantive items 6 to 15 of the agenda, reproduced in this volume and arranged in the following manner: (1) by item or sub-item; (2) by country in alphabetical order; (3) in cases where more than one document was presented under a single item by the same country, by document symbol in numerical sequence. *See* Volume I, *Report of the Conference*, E/CONF.25/3 (Sales No.: 59.I.9), pages 5 and 6, for a complete list of agenda items, and pages 14 to 17 for a complete list of documents issued for the Conference. A paper prepared by the Institut géographique national, " Standard Cartographic Practices recommended for International Use for Land Maps ", submitted by France under sub-item 10(*b*) and issued as document E/CONF.25/L.57, was published in United Nations, *World Cartography*, Volume VI, 1958 (Sales No.: 60.I.10) and has, therefore, been omitted from the present publication.

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Part I

PROCEEDINGS OF THE CONFERENCE

SUMMARY RECORD OF FIRST PLENARY MEETING[1]

Held at Sankei Kaikan, Tokyo, Japan, on Monday, 20 October 1958, at 10.30 a.m.

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Temporary Chairman: **Dr. Te-Lou TCHANG, Chief of the Cartographic Section of the Department of Economic and Social Affairs of the United Nations.**

Present:

The representatives[2] of the following countries: Australia, Burma, Cambodia, Canada, Ceylon, China, Federal Republic of Germany, France, India, Indonesia, Iran, Israel, Japan, Netherlands, Portugal, Republic of Korea, Switzerland, Thailand, Turkey, United Arab Republic, United Kingdom of Great Britain and Northern Ireland, United States of America and Vatican City.

Observers from the following countries: Brazil, Dominican Republic, Ecuador, Philippines and Peru.

Observers from the following organizations: International Hydrographic Bureau, Pan American Institute of Geography and History, International Geographical Union, International Organization for Standardization and International Union of Geodesy and Geophysics.

Statement by the Temporary Chairman

The TEMPORARY CHAIRMAN, speaking on behalf of the Secretary-General of the United Nations, was honoured to welcome the delegates to this important inter-governmental conference, which had been called by the United Nations in pursuance of resolution 600 (XXI) of the Economic and Social Council, and to thank the Government of Japan, as the host Government, for its cordial reception and for the excellent arrangements which had been made.

He said that it might be of interest to recall that the first Regional Cartographic Conference had been held in Mussoorie, India, three years ago. During that conference, effective collaboration had been initiated among the cartographic services represented. Up-to-date technical information had been exchanged among cartographically advanced countries and countries of the region, to their mutual benefit. It was expected that similar exchanges would take place at the present conference.

There was no need to stress the important role played by cartography in modern society, particularly in the development of resources, transportation, navigation and public administration; it was especially important in economic planning and programming.

Since the Mussoorie Conference, every country in this region had studied plans or launched new projects to accelerate development. At the national level, these projects ranged from exploration for and exploitation of mineral resources and appraisal of water resources to execution of specific projects in the fields of irrigation and construction of roads, airports, seaports and dams and reservoirs for hydroelectric stations. At the international level, integrated projects were envisaged, such as the development of the Mekong River.

Cartographic data were required not only for planning and facilitating technical construction of these projects, but also for selecting the most suitable sites, as well as the most economic methods of construction. Unfortunately, in many countries of this region, basic cartographic coverage for general planning was not yet available, and facilities for carrying out specific mapping projects were inadequate. In the past few years, considerable efforts had been made by several Governments to improve the level of cartographic techniques and achievements by the establishment of cartographic services, improvement of existing technical facilities and methods of work, and the training of technicians. Technical assistance, rendered either through the United Nations or through bilateral and other arrangements, also helped substantially in this respect. Such aid included provision of experts in geodesy, photogrammetry, topography, aerial survey and map reproduction; training of local staff in the country and abroad; supply of equipment and instruments; carrying out of aerial photographic surveys for urgent projects, and publication of preliminary maps.

However, the gap between the need for cartographic data and the facilities for fulfilling this need was still great and constituted an acute problem for many countries.

Newly developing countries, which lacked either adequate basic surveys and maps, or trained and experienced technical staff, faced the problem of providing essential data in order to avoid long delays in carrying out urgent projects. It was thus necessary to consider temporary short-cut methods involving simpler procedures and less expensive instruments

[1] Issued as E/CONF 25/SR.1.

[2] For a list of representatives and United Nations staff who attended all plenary meetings, see *Second United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 1, *Report of the Conference* (Sales No.: 59 I.9), pages 1 to 4.

to provide maps accurate enough for this purpose. It might be mentioned in this connexion that such short-cut solutions were also considered by highly developed countries in view of their significant economic advantages.

Another problem which deserved consideration at this point was the fact that planners, administrators and engineering designers of economic projects frequently lacked relevant cartographic data at the time of their study. In some cases crude data—photographs, draft sketches, map-minutes—would be sufficient for their purpose. Experience had shown that it was highly desirable, both from the technical and the economic points of view, that such users should be able to obtain easily and quickly existing crude data in whatever form of presentation they might be available. Information on the availability of such material would be a great help in reducing delays in policy-making decisions and in avoiding an unrealistic approach to certain technical questions. There had been too many instances, in recent times, where initial failure to obtain even the simplest cartographic data had led to a complete failure of important projects.

The need for various kinds of maps dealing with different subjects and on different scales, relating to one area, could be met by co-operation and co-ordination among the various agencies concerned with mapping activity, both at the national and international levels. Co-operation was particularly required not only in international projects, such as the International Map of the World on the Millionth Scale (IMW) and the World Aeronautical Chart (WAC), but also in national projects using standard procedures and techniques. Such co-operation could provide proper solutions to technical problems. Appropriate co-ordination in this field and an up-to-date exchange of information would eliminate unnecessary duplication of tests and studies and increase the over-all efficiency of cartographic work.

The deliberations and accomplishments of this conference might thus be expected to have an immediate bearing, not only on the improvement of cartographic work, but also on the economic and social development of the region.

In conclusion, he conveyed to all participants the Secretary-General's best wishes for the success of this work. He also expressed his gratitude to His Excellency the Vice-Minister of Construction of Japan for agreeing to inaugurate the Conference.

Address by His Excellency Dr. Masafumi Yoneda, Vice-Minister of Construction of Japan

His Excellency Dr. MASAFUMI YONEDA felt highly honoured to have this opportunity of expressing sincere greetings to the delegates who had come from various parts of the world to attend the Second United Nations Regional Cartographic Conference for Asia and the Far East.

He pointed out that accurate maps were indispensable for proper programming of land development and improvement of the social environment. Now that international co-operation was becoming closer in these fields, such co-operation in the field of standardization and the introduction of new techniques was a pressing need in this region.

Recent developments in electronics engineering and optical instruments had been remarkable. They had brought about revolutionary improvement in surveying techniques—namely, the invention of the geodimeter and the tellurometer, th application of such electronic devices as Shoran and Decca and the rapid advancement in photogrammetry. It was highl desirable that maps of the countries in Asia be systematicall developed by applying adequately these newly develope methods through international co-operation. It was essentia for that purpose to have as many opportunities as possible t exchange knowledge on surveying techniques. In this sense, h was sure that this Conference would be fruitful and successfu

As to the necessity for the standardization of maps, it migh not be necessary to elaborate now on the subject, inasmuch a the publication of the International Map of the World on th Millionth Scale had been put into operation. A map can b called a picture of the face of the earth. Our faces, in spite c their different appearances, were composed of commo elements, namely eyes, ears, nose and so on. With regard t maps, the matter was quite similar. In other words, in map making, common scales and symbols might be used fo depicting different areas and various phases on the earth. H believed that once the standardization of methods and pro cedures was realized, it would not only be a big step forwar in the field of cartography, but would also prove a great con tribution to the planning of international co-operatio programmes.

This problem would be discussed in detail during the preser Conference. He took this opportunity to express his earnes desire that the participants here would deepen mutual friend ship and understanding and make the Conference a forur for the exchange of technical knowledge and experience i order to further the standardization of maps and map-makin techniques.

In closing, he hoped that in spite of the unfamiliar climati conditions, delegates would find time to see the life in Japa and would fully enjoy their stay there.

Message of welcome from the Governor of Tokyo Metropolis

Mr. NISSI SATO, representative of the Governor of Toky Metropolis, read the following message from the Governo Mr. Seiichiro Yasui:

" It is my distinct pleasure to extend, on behalf of th citizens of Tokyo, my heartiest welcome to you distinguishe delegates to the Second United Nations Regional Carto graphic Conference for Asia and the Far East.

" Much has been attained by the United Nations in th field of technical co-operation since its establishment i 1945. Even the most exacting critic of the United Natior will readily admit the great progress that has been made i international co-operation through the United Nations fo the economic and social welfare of man.

" This outstanding achievement has not only made a gre contribution to the betterment of living conditions, but ha offered invaluable opportunities for promoting a bett understanding among different peoples of the world. An I am sure you will agree that mutual understanding is th only way to lasting international peace.

" In this region of Asia and the Far East, there is a gre deal to be done in the way of international co-operation fo economic development and especially for improvement o living standards. It is my expectation that this Conferenc

will mark another great step forward in the prosperity of this area so that we may live in peace as good neighbours. I sincerely hope also that the distinguished delegates assembled here this morning will gain a better understanding of the people and the country of Japan, and that your stay in Tokyo, with its autumnal beauty, will be a most enjoyable one."

Vote of thanks to the Government of Japan

Lieutenant-General DURA (Turkey), speaking on behalf of all delegations, thanked the Government of Japan for the excellent organization of this Second United Nations Regional Cartographic Conference. He moved the adoption of the following resolution:

"The Second United Nations Regional Cartographic Conference for Asia and the Far East wishes to convey its warm thanks to the Government of Japan for the excellent organization of this Conference."

The resolution was adopted unanimously.

His Excellency Dr. Masafumi Yoneda, Vice-Minister of Construction, and Mr. Nissi Sato, Representative of the Governor of Tokyo Metropolis, withdrew.

Adoption of the rules of procedure

[Item 1 of the agenda]

The TEMPORARY CHAIRMAN submitted to the Conference the draft rules of procedure, which appeared on page 130 of the Proceedings of the First Regional Cartographic Conference for Asia and the Far East.[3] These were standard rules of procedure as followed by meetings of this kind called by the United Nations.

Dr. Chūji TSUBOI (Japan), supported by Colonel KALHA (India), moved the adoption of the rules of procedure.

The rules of procedure were adopted.

Election of officers

[Item 2 of the agenda]

Colonel SHAHBANDER (Iran) nominated as President the head of the Japanese Delegation.

Colonel KAZEM (United Arab Republic) seconded this nomination.

Dr. Chūji Tsuboi (Japan) was unanimously elected President and took the Chair.

The PRESIDENT thanked the Conference for the honour it had bestowed upon him in electing him; he considered that this move reflected the participants' confidence in his country. He promised that he would spare no effort in the discharge of his duty.

Dr. TCHANG (Executive Secretary) wished to thank all representatives for their co-operation, which had enabled him to conduct this meeting efficiently.

The meeting rose at 11.15 a.m.

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[3] *United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 2, *Proceedings of the Conference and Technical Papers* (Sales No.: 56.I.23), pages 130 to 132.

SUMMARY RECORD OF SECOND PLENARY MEETING[1]

Held at Sankei Kaikan, Tokyo, Japan, on Monday, 20 October 1958, at 2.30 p.m.

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President: **Dr. Chūji TSUBOI (Japan)**

Election of officers (*continued*)

[Item 2 of the agenda]

Mr. CHIN (Republic of Korea) nominated Lieutenant-General Dura, Chief of the Turkish Delegation, to be First Vice-President.

Mr. TSAO (China) seconded the nomination.

Lieutenant-General Dura (Turkey) was unanimously elected First Vice-President.

Colonel KALHA (India) nominated Mr. Rasaretnam (Ceylon) as Second Vice-President.

Mr. LACLAVÈRE (France) seconded the nomination.

Mr. Rasaretnam (Ceylon) was unanimously elected Second Vice-President.

Mr. Wilson (India), nominated by Mr. Elster (Israel) and seconded by Mr. Laclavère (France), was unanimously elected Rapporteur.

Adoption of the agenda

[Item 3 of the agenda]

Dr. TCHANG (Executive Secretary) introduced the provisional agenda.[2] He pointed out that as the additional items were included in the order in which they had been received, the arrangement of these items, if adopted, might have to be streamlined in the final agenda. He also referred to document E/CONF.25/L.43 containing information on the status of papers received for each item, together with some remarks.

The PRESIDENT suggested that the provisional agenda could be considered item by item.

It was so agreed.

Mr. LACLAVÈRE (France), speaking about item 6 of the provisional agenda, wondered whether the reports asked for should be submitted orally or in written form, and whether they should cover the work achieved in this region only or, more generally, all technical developments everywhere in the world; the latter would seem too wide a scope.

Dr. MUTO (Japan) proposed that oral reports be made only when written reports were not available.

Professor SCHERMERHORN (Netherlands) pointed out that, since this conference was a regional one, it would be advisable to put the emphasis on experience gained by countries of this area.

Dr. TCHANG (Executive Secretary) drew to the attention of the Conference the procedure followed for the adoption of the agenda at the first Regional Cartographic Conference.

The PRESIDENT ruled that the exact scope of various items on the agenda would not be determined at the present stage.

Mr. LACLAVÈRE (France), dealing with sub-item 8 (*c*) of the provisional agenda, felt that it would not be advisable for the Conference to deal with magnetism and gravimetry which concerned geophysics rather than cartography. The field covered by the Conference should be clearly defined.

Dr. RANDALL (United States of America) pointed out that since 1953 the magnetic and gravimetric aspects of mapping had been included in the technical agenda of the Pan American Consultation on Cartography organized by the Pan American Institute of Geography and History. He also called the attention of the meeting to the intentionally broad definition of cartography adopted by the Committee of Experts on Cartography called by the Secretary-General of the United Nations in 1949.

Mr. LACLAVÈRE (France) stated that the Conference should decide whether it intended to limit itself to topographic maps or whether it also wanted to take up other topical maps such as geomagnetic and gravimetric ones. In his opinion, it would be unwise for the Conference to tackle these subjects which were already extensively studied by technical commissions of specialized bodies, such as the International Union of Geodesy and Geophysics and the Pacific Scientific Association. The Conference should simply inquire about the needs of countries in these different fields and refer them to the specialized bodies concerned.

Professor SCHERMERHORN (Netherlands) agreed with the representative of France. It would be better for a conference on cartography to limit its scope and not to try to deal with too specialized techniques.

Mr. MILLER (Canada) disagreed. Meetings such as this Conference did not need to go into details of every technique discussed. On the contrary, their coverage should be as large as possible, even if some highly specialized techniques were to be dealt with rather briefly.

Colonel KALHA (India) supported Mr. Miller's point of view. The countries of the region should be informed, even though summarily, of all of the latest progress in the field

[1] Issued as E/CONF.25/SR.2.

[2] E/CONF.25/1 and Add. 1 and 2.

of cartography. Besides, geodesy, gravimetry and other subjects of cartography had already been discussed at the first Regional Conference.

Mr. LACLAVÈRE (France) had no objection to the inclusion of sub-item 8 (*c*) in the agenda.

Dr. TCHANG (Executive Secretary) said that as no papers had been received on sub-items 8 (*e*) and 8 (*f*), he proposed to delete these two sub-items if no country represented at the Conference wished to sponsor them.

It was so agreed.

Mr. LACLAVÈRE (France) suggested the addition of a new sub-item 8 (*b*) entitled " Geomagnetism ", since the subject covered by sub-items 8 (*c*) and 8 (*i*) could hardly be put under " Geodesy ". The subject of geomagnetism was a very important one and well deserved to be considered here.

Rear Admiral KARO (United States of America) contended that magnetism and gravity were part of geodesy; to some extent both belonged to cartography.

Dr. TCHANG (Executive Secretary) wished to point out that at this stage the classification of items and sub-items was a difficult task since many questions overlapped several fields and not all the papers were available. However, it was more important to know what should be discussed under each item than how to classify the items.

Professor SCHERMERHORN (Netherlands) considered that sub-item 8 (*j*) of the provisional agenda could be deleted; the matter could conveniently be discussed under sub-item 10 (*a*) (*v*).

It was so agreed.

Professor SCHERMERHORN (Netherlands) felt that the subject covered by sub-item 10 (*c*) could be grouped together with 9 (*b*) and 9 (*c*).

Dr. GERKE (Federal Republic of Germany) agreed with this arrangement.

It was so decided.

Concerning sub-item 10 (*d*), Dr. TCHANG (Executive Secretary) pointed out that the sponsor country was not represented and had not submitted a background paper; a technical paper had been received, however, from another country.

Rear Admiral KARO (United States of America) stated that electronic control was becoming more and more important for the preparation of maps. He was sure that a discussion of such methods would be interesting and useful. He moved the inclusion of the item.

It was so agreed.

The PRESIDENT stated that agreement had been reached on each item of the provisional agenda.

Dr. TCHANG (Executive Secretary) understood that the meeting had adopted the spirit of the agenda and the re-arrangement of some items would be made on the basis of their actual content. Such rearrangement would aim at eliminating duplication and confusion. He would suggest that for practical convenience the Conference should continue to use document E/CONF.25/1 and Add.1 with appropriate deletions. The agenda as adopted would be issued when all details had been finalized by the Conference.

On this understanding, the agenda as a whole was unanimously adopted.

The meeting rose at 4.5 p.m.

SUMMARY RECORD OF THIRD PLENARY MEETING[1]

Held at Sankei Kaikan, Tokyo, Japan, on Tuesday, 21 October 1958, at 9.30 a.m.

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President: **Dr. Chūji TSUBOI (Japan)**

Brief reports by Governments on the cartographic activities of the respective countries, outlining work achieved, technical developments and difficulties encountered in technical work since the Mussoorie Conference

[Item 6 of the agenda]

The PRESIDENT proposed that item 6 of the agenda be taken up.

It was so agreed.

Mr. LAMBERT (Australia) said that in Australia the survey and mapping activities of the Federal and State Governments were co-ordinated through a National Mapping Council, and that national standards had been set up for geodetic and topographic surveys, including aerial photography.

In geodetic work, priority was being given to the immediate establishment over the whole country of a sparse network to which all specific surveys could be rapidly connected by traverse, using one of the recently developed electronic distance measuring instruments such as the geodimeter and the tellurometer. For horizontal control, there had been an almost universal adoption of first-order traversing.

The National Mapping Council had under way a programme aimed at completing by the end of 1959 a geodetic survey around the continent, the central north-south cross tie and certain additional surveys required for particular projects. It looked as though 3,000 to 4,000 miles of first-order traversing would be completed this year and a greater amount was likely next year.

The National Geodetic Survey was being organized. Two Markowitz Moon cameras and a Baker Nunn satellite tracking camera were already in operation.

Preliminary consultations had been held with the Survey Authority of Portuguese Timor regarding the use of Hiran or Shoran for connecting geodetically that country and Australia. Such a project appeared practicable and Australia was favourably disposed towards it, although Australia would prefer to see the work carried out as a part of a more ambitious scheme of geodetic connexion within the ECAFE (Economi Commission for Asia and the Far East) region.

The basic cartographic programme provided for contou mapping on the scales 1 : 31,680 and 1 : 63,360 in the mo developed and fertile areas, while mapping at 1 : 500,000 ar 1 : 1,000,000 scales was intended in the central dese areas.

He then outlined the procedure followed by both the Con monwealth Government and the State Survey Department pointing out that a considerable amount of aerial photograph had been carried out prior to 1953 by the Royal Australia Air Force and, since then, by private contractors.

Colonel KARET (Cambodia) said that his country's top graphic service had existed only since 1954. Its main tas included the training of qualified personnel and the provisic of adequate modern instruments and equipment. Cambod already had maps on the scales 1 : 100,000 and 1 : 400,00 It had greatly benefited from the help of the United Stat Army Map Service. A 1 : 50,000 series had been undertake to cover the whole country; in the most densely populate areas, however, maps on the scale 1 : 20,000 and even 1 : 10,0 were being prepared.

Mr. MILLER (Canada) stated that his country's geodet service had completed coverage of 3,800,000 square mile for mapping on the scale 1 : 50,000. About 50 per cent the national territory was covered on the scale 1 : 250,00 while several places were being mapped on the scale 1 : 50,00 However, the current task was a tremendous one because the great expanse of land to be surveyed.

He reported the usefulness of the tellurometer which l considered to be the greatest step forward in cartograph development since the introduction of aerial photograph

Mr. RASARETNAM (Ceylon) said that there had been very precise survey of his country about eight hundred yea ago. Indeed, even approximate methods gave good resul owing to excellent controls available. The island was cover with a network of primary, secondary and tertiary levelli with a break-down into grades, so that the planning office of the Irrigation Department or the town planners had perfect base for their work. Photography was taken at t scales 1 : 40,000 and 1 : 20,000, and sometimes at 1 : 10,00 In this connexion Ceylon had the assistance of the Unit Kingdom and of Canada, especially for aerial photograph and had also been able to obtain some assistance from t United States, especially in the supply of aircraft and mode instruments.

Mr. TSAO (China) outlined the work done in his count since 1955. In the field of topographic mapping, more th 700 sheets at scales from 1 : 50,000 and 1 : 250,000 had be revised and produced in colour. In the field of geodet

[1] Issued as E/CONF 25/SR.3.

research, a preliminary investigation had been undertaken utilizing the existing data relating to the south-western part of the country for the determination of the Figure of the Earth.

Aerial photography was the responsibility of the Chinese Survey Bureau, but part of the technical work was done by some private organizations, such as the Chinese Society of Photogrammetry. Aerial photogrammetric techniques had been applied to different mapping projects, such as the cadastral survey, water conservation and the railroad survey; the results obtained had been satisfactory.

With a view to utilizing to the maximum efficiency all manpower and material and financial means, the Chinese authorities intended to establish a unified mapping organization and to use electronic equipment in photogrammetric work.

A programme for recompiling medium-scale maps in China had been set up and was expected to be completed in 1963; it would be based on international standards, a few aspects of which would, however, have to be modified to suit the local conditions in China.

Mr. LACLAVÈRE (France) stated that the Institut géographique national was a very powerful cartographic organization in his country, with a staff of about three thousand which included 145 highly qualified engineers. The territories to be mapped by the French Government differed very much in character and included densely populated areas and semi-desert regions, such as the Sahara and French Antarctica. The cartographic programme was carried out by two agencies: the Institut géographique national, which had the responsibility of producing maps at the scale of 1 : 40,000 and smaller, including those covering the very densely inhabited areas, and the Service de cadastre, which produced larger-scale maps and plans. The two agencies worked in close co-operation.

He pointed out that, among the new series of maps in production a map on the scale 1 : 100,000 was being prepared with standards already used by many other countries, for the sake of uniformity.

In the Asian region, France had had, up to 1954, the responsibility for the territories of Viet-Nam, Cambodia and Laos for which the Institut géographique national had prepared, by means of aerial photography, good maps on the scale 1 : 40,000, together with a number of other maps at various scales. When the Governments of these countries took over the responsibility of mapping work in 1955, maps on scales from 1 : 25,000 to 1 : 2,000,000 were already in existence and a 1 : 100,000 map covering almost the entire area of these three countries was in preparation. The Institut géographique national had recently completed a 1 : 20,000 map of the Nam-Theun basin in Laos, in connexion with a United Nations technical assistance project.

In New Caledonia, the New Hebrides and Oceania, aerial surveys of the various islands had been made in 1954 and 1955.

Dr. GERKE (Federal Republic of Germany) gave a detailed report of the activities in his country, where the first phase of the geodetic and cartographic work was now finished. The main task had been to revise and improve what had been done previously in the geodetic and cartographic fields.

With regard to triangulation, a first-order net had been undertaken for practical projects. For scientific research, a network would be produced with measurements of various Laplace stations and geodetic base lines. The whole network would be readjusted as part of the European first-order triangulation network. A Väisälä standard base line of 864 metres, together with a test net for electronic distance measurement devices, had been established. The base line would be used for calibration of invar wires employed for the measurement of other geodetic base lines.

As regards levelling, the measurements of the first-order network, including additional gravity measurements, had been completed. A new adjustment of the German part of the European levelling network had been made which took into account geo-potential data.

In the field of gravity, a European gravity calibration base had been set up for the European pendulum and gravimeter networks. A new procedure had been developed which combined the pendulum and gravimeter networks of Germany as a part of the European networks.

As far as hydrography was concerned, nautical charts were being prepared or revised with the use of electronic surveying devices. Scientific research was being continued in oceanography, magnetism, tides and time determination.

In photogrammetry, large-scale plans were being drawn up in connexion with reallotment, cadastre, forestry and mining, and a basic map on the scale 1 : 5,000 was in preparation. Large-scale and small-scale photographs were used for revising topographical maps. Research work was being continued in various branches of photogrammetry.

In cartography, work was continuing on a new edition of a three-colour map of the whole country on the scale 1 : 25,000. A new 1 : 50,000 map would be completed in about five years. The old 1 : 100,000 map was being revised with the addition of contour lines. A topographical map on the scale 1 : 200,000 and another on the scale 1 : 500,000 were being prepared. The recommendations of the United Nations would be applied for the revision of the IMW series.

Finally, the following topical maps were also being prepared: soil and soil conservation maps on scales from 1 : 2,000 to 1 : 100,000; geological maps on scales from 1 : 25,000 to 1 : 1,000,000; maps at various scales for forestry, agriculture, hydrography, regional planning and administration. In pursuance of recommendations by the International Civil Aviation Organization, various aeronautical charts had been undertaken.

Colonel KALHA (India) said that, with the rapid economic development of India, the demand for maps on scales varying from 1 : 25,000 to 1 : 1,000,000 for multi-purpose projects had greatly increased and the Survey of India had had to be expanded. With effect from 1 October 1958 new surveys and mapping work were to use the metric system. The new policy involved a tremendous task and the process would necessarily be a slow one. The contour intervals adopted for the various Indian standard series maps were: (*a*) 10 metres for the 1 : 25,000 series; (*b*) 20 metres for the 1 : 50,000 series; (*c*) 50 metres for the 1 : 100,000 series, and (*d*) 100 metres for the 1 : 250,000 series.

He then outlined the organization and tasks of the Geodetic and Research Branch of the Survey of India, in particular its International Geophysical Year programme.

About photogrammetry, he said that shortly before the First United Nations Regional Cartographic Conference for Asia and the Far East stereoplotting machines had been introduced

in India to speed up the production of topographical maps, particularly those on large scales, which were required in connexion with the various development projects.

India had been fortunate in receiving substantial assistance in the form of machines under the Indo-United States Technical Co-operation Programme. An intensive training programme in photogrammetry had been carried out and a certain amount of productive work had also been taken up. It had been proved that the introduction of modern photogrammetric plotting methods had been a step in the right direction: output had increased by 100 per cent in most cases and greater accuracy had been achieved.

With regard to the preparation of maps, India was following either the interim specifications based on the resolutions of the international conferences on the International Map of the World on the Millionth Scale, held in 1913 and 1928, with certain modifications, or on the specifications framed by the International Civil Aviation Organization. As regards the International Map of the World on the Millionth Scale, the Indian delegation still recommended the adoption of the interim specifications for international use presented by India to the Mussoorie Conference. They should of course allow sufficient flexibility so that no change in the existing sheets would be required and countries would not be prevented from producing, for their local requirements, maps not meeting the specifications. Appreciable progress had been achieved: out of a total allotment of twenty-three sheets, five had been printed, a sixth was being printed and it was hoped to publish another six sheets within the next twelve to eighteen months.

For hydrographic surveys, India had three ships and a fourth was under construction and due to be launched by January 1959. The situation regarding the survey personnel, however, was still not satisfactory, especially in so far as trained cartographic personnel were concerned. The Hydrographic Department of the British Admiralty was very helpful in this respect.

The first navigational chart to be produced in India was already in print; two others were in the stage of compilation. Indian Notices to Mariners had been published by the Naval Hydrographic Office. An Indian list of lights was in preparation.

The hydrographic expert from the Netherlands whose services had been made available under the United Nations technical assistance scheme had left India in 1955 after having trained a group of surveyors for the Marine Division of the Public Works Department of Bombay. After the Mussoorie Conference, India had become a member of the International Hydrographic Bureau in 1956, and had attended the Seventh International Hydrographic Conference at Monaco in 1957.

The meeting adjourned at 10.44 a.m. and resumed at 11 a.m.

Mr. EBRAHIMI (Iran) said that in Iran cartographic activities for economic development had started in 1945 on a small scale. The aerial photographs covering about 1,500,000 square kilometres, on a scale of 1 : 50,000, were completed in 1957. These activities were developed gradually through the various services concerned with mapping and in particular through the National Cartographic Centre, which largely used the photogrammetric method. A British aerial survey firm was training the technical personnel required for this kind of work. Now the National Cartographic Centre had a plan to install a special camera for taking aerial photographs and it photographic laboratories were equipped with up-to-dat modern machines, which made it possible to prepare map photo enlargements and photo rectifications. Private photo grammetric firms also existed in Iran which used specialize equipment of American, Italian or German makes.

Iran had benefited from the United Nations technica assistance in the form of experts and scholarships; moreove trainees were sent by national services to several Europea countries.

Mr. ELSTER (Israel) said that it was the task of the Surve of Israel to carry out the work connected with all the stages c the production of maps, from the initial geodetic survey– triangulation, precise levelling, gravimetry, magnetometry—t their final reproduction. The programme included topographi mapping, as well as cadastral survey.

During the last few years angular measurements in th southern part of the country's network had been carried ou in rather unfavourable conditions. A re-observation of angle in certain triangles would be necessary in the future. Bas measurement for the astrogeodetic network had been done.

As regards precise geodetic levelling, about 400 kilometre of lines had been levelled in the period from 1955 to 195 The network was based on eight fundamental precise bench marks, two of which had recently been constructed. He als referred to the work accomplished in astronomy, gravimetr and magnetic observations.

Concerning cartography, the basic topographic map of th country was on the scale 1 : 20,000, with the present coverag extended only to the developed part of the country; that of th undeveloped part was still on the scale 1 : 50,000. A numbe of maps had been published or were being prepared by mean of aerial photographs on the scales of 1 : 50,000, 1 : 100,0 and 1 : 250,000. A new series on the scale 1 : 10,000 had als been started. Moreover, many topical maps had been publishe and the work was being continued. The Cadastral Surve had been started under the British Mandatory Power in 192

Owing to the extensive changes in the country, considerab areas had had to be resettled in connexion with the reparcellin of land and the establishment of many new settlement During the past three years an area of approximately 3(square kilometres had been covered. Some experiments ha been carried out in the use of photogrammetry for cadastr purposes; this experimental work was being continued.

Mr. INOUE (Japan) said that, since a full report on carto graphic work in Japan during the past three years had alread been given in document E/CONF.25/L.68, he would on point out a few important items in the field of mapping.

Photogrammetry and other uses of aerial photographs f various studies had been remarkably developed in his countr The areas where the aerial photographs had been taken durin the three-year period amounted to 100,000 square kilometre The land area of the country was completely covered by 1,2(topographic maps on the scale 1 : 50,000, while about on fourth of it was covered on the scale 1 : 25,000. The activi of the Topographic Survey had been so highly centred on th preparation of 1 : 25,000 maps that 300 sheets had been cor pleted during the past three years.

The Japanese Antarctic Research Expedition Party 1956, in which a photogrammetrist of the Geographical Surve Institute (GSI) had participated, had taken a series of aeri

photographs of Ongul Island and its environs, where the base camp of the Party had been established. From these aerial photographs a map of East Ongul Island had been plotted on the scale of 1 : 5,000.

Application of aerial photogrammetry had been extended over wide fields of civil and agricultural engineering by making topographic maps on the scales 1 : 5,000 to 1 : 10,000 which were of basic importance for planning public works. The compilation of the land use maps on the scale 1 : 50,000 had commenced in 1952 and since then 300 sheets had been completed. Several sheets of land classification maps on the scale 1 : 50,000 had also been published.

Mr. CHIN (Republic of Korea) stated that, owing to the destruction of equipment, maps and control work during the recent conflict, and to the shortage of cartographic technicians as well as to difficulties regarding the availability of finances, no great progress had been achieved in his country in the past few years. However, maps on the scales of 1 : 10,000 and 1 : 50,000 were expected to be completed by the end of 1958 and sheets of the map on the scale 1 : 25,000 were ready for distribution. Moreover, the Meteorological Bureau had carried out hydrographic survey work; the Ministry of Finance had issued city planning and cadastral maps, and the Ministry of Transport had prepared traffic maps. At the present time Korean authorities were working on the standardization of geographical names.

In concluding, he stressed that his country was among those which would need technical and financial assistance to speed up their cartographic work.

Professor SCHERMERHORN (Netherlands) stated that, since the most important part of the Netherlands territories lay in Europe and South America, he would confine himself to brief remarks about the work done in these two regions. A country as easily flooded as the Netherlands had to resort to hydrostatic levelling. Between three and four miles of new underground tubes had been constructed for that purpose. In the field of map-making, the cartographic service had undertaken the revision of maps—or points on maps—on the scale 1 : 25,000 as well as the production of new maps on the scale 1 : 100,000.

In South America, mention could be made of the survey of Surinam covering an area of 60,000 square kilometres.

Regarding New Guinea, one of the most under-developed territories of the world, topographic surveys were being carried out with the equipment available.

The meeting rose at 11.55 a.m.

SUMMARY RECORD OF FOURTH PLENARY MEETING [1]

Held at Sankei Kaikan, Tokyo, Japan, on Tuesday, 21 October 1958, at 2.30 p.m.

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President: **Dr. Chūji TSUBOI (Japan)**

Brief reports by Governments on the cartographic activities of the respective countries, outlining work achieved, technical developments and difficulties encountered in technical work since the Mussoorie Conference (*concluded*)

[Item 6 of the agenda]

Mr. CLEMENTE (Portugal) recalled that the cartographic work done in the Portuguese territories in Africa, Asia and the Madeira Archipelago had been reported on in detail at various international meetings in the field of photogrammetry and geography. He therefore wished to refer to the work undertaken in Timor and Macau only.

In Timor, a modern map prepared by photogrammetric methods had replaced the old one. Concerning hydrography, a mission had been established which had started its work this year, particularly in Macau Port. Another survey was being carried out on the scale 1 : 15,000 by photogrammetric methods and should be completed soon. The same mission had already surveyed Macau in order to complete a map to replace the existing one which was very old.

Mr. SCHOLL (Switzerland) said that two federal survey departments, namely, the Swiss Topographic Survey and the Swiss Directorate of Cadastral Surveys, both located in Berne, were responsible for the mapping work in his country. The Swiss Topographic Survey was responsible for first-order, second-order and third-order triangulations which had now been completed, for first-order levelling and for the production of maps at small scales.

New series of maps were being produced on the scales 1 : 25,000, 1 : 50,000 and 1 : 100,000, covering all of Switzerland. They were compiled wherever possible by the reduction of the basic maps on the scales 1 : 10,000 or 1 : 15,000. A large part of the country had been mapped by ground methods and aerial photogrammetry. Reproduction of these maps had been made in colour, using the glass scribing method. All maps were available to the public with or without shading, but experience had shown that more than 90 per cent of th buyers preferred shaded maps.

The main task of the Directorate of Cadastral Surveys wa to co-ordinate and supervise the work done by a large numbe of private surveyors; it did not engage in actual mapping Shading at various scales was produced for agricultural an other purposes. Basic topographic maps on the scales 1 : 5,00 and 1 : 10,000 were produced.

Major PACHIMKUL (Thailand) summarized the worl accomplished in his country in the fields of geodesy, topo graphy and map publication from 1909 to 1958. Thailand an neighbouring countries had agreed to extend their respectiv systems of triangulation up to their frontiers and to connec them for their mutual benefit. It was expected that suc connexions would be extended to Australia as well as to th Philippine Islands. Sporadic work had also been done i the fields of astronomy, gravimetry and magnetic obser ation.

Concerning topography, aerial photography and photo grammetric plotting had been used in Thailand for severa years; the major series of topographic maps were on the scale 1 : 25,000, 1 : 50,000, 1 : 100,000 and 1 : 200,000. In 1952 bilateral agreement had been signed with the United States fc a co-operative mapping programme which had recently bee completed. As a result, practically all of Thailand had bee covered by aerial photography at the 1 : 50,000 scale, an large-scale photography had also been obtained in 1953 an 1954, resulting in a good horizontal and vertical picture of th country. All geodetic data had been adjusted with the assis ance of the United States Army Map Service. It was expecte that, with the same assistance, all of Thailand would be mappe on the scale 1 : 50,000 in about five years.

During the past few years, the main task of the Surve Department had been to set up a modern mapping organiza tion equipped with first-order machines and second-orde plotting instruments at a ratio of about 1 to 6. The training c staff was an urgent task. Considerable progress had been mad but it would still take at least two more years to complete th programme.

Colonel ATES (Turkey) said that, since his delegation ha circulated a very detailed report, he wished only to point ou that his country's General Directorate of Geodesy and Carto graphy was able to prepare every type of map needed by th country. For example, in revising the map on the scal 1 : 25,000, it was able to issue about ninety sheets a yea Maps for irrigation purposes and forestry were being prepare and a cadastral service was being organized. Large-scale map were being established by modern photogrammetric apparatu which had recently been acquired. Maps on the scales 1 : 20,0C and 1 : 1,000,000 had been completed and, with foreig

[1] Issued as E/CONF.25/SR.4.

assistance, a 1 : 250,000 map of the whole country was in preparation and was expected to be completed in 1962 or 1963.

In the field of geodesy, the first-order work had started in co-operation with Turkey's neighbours in the north-west, especially Greece. It was intended to connect the country's geodetic net with that of Iraq and possibly that of Iran. A gravimetric network had been completed this year.

Colonel KAZEM (United Arab Republic) said that, unfortunately, cartographic work did not cover all parts of his country but only the cultivated and inhabited areas. Photogrammetry had been introduced between 1954 and 1955 and there was now a complete photogrammetric organization in the northern and southern parts of the country, but it would have to be extended in both areas in order to cope with the industrial and agricultural development projects of the Government. There was a serious shortage of personnel, but a continuous and intensive training programme had been undertaken.

Aerial photography had been done on scales from 1 : 20,000 to 1 : 40,000, covering an area of about 400,000 square kilometres. With regard to topographical maps, the country was already covered by sheets on the scales 1 : 200,000 or 1 : 100000 and, for cultivated or inhabited areas only, maps on the scale 1 : 20,000 had been prepared. Existing maps needed to be revised, particularly for gravity and magnetism.

Lieutenant-Colonel JOHNS (United Kingdom) listed in detail the various maps which, since the 1955 Conference, had been completed or were being prepared for Hong Kong, Singapore, the Federation of Malaya, Sarawak, Brunei and North Borneo, the Solomon Islands, San Cristobal, West Guadalcanal, the Florida Group, the Fiji Islands and other territories.

He then reported on the progress of the British air survey photography in the Asian region, and stated that experience had shown that photographic mapping costs were considerably reduced by using high-altitude air photography. A higher mapping output was achieved, without a reduction in standards of accuracy, while economies were effected in the provision of ground control as well as in flying hours. The survey photography specifications were: flying height, in the region of 50,000 feet; time of flying: from 8 a.m. to 10 a.m. in equatorial regions; cameras: survey type of 9-by-9 inch format with a simultaneous operating fan of three 20-inch cameras or, occasionally, seven 36-inch cameras.

As regards geodesy, the first-order and second-order triangulation networks of Hong Kong, North Borneo, Brunei, Sarawak, Singapore and the Federation of Malaya had been established for many years, but some refinements needed to be made. A very dense network of cadastral control points existed in the urban and agricultural areas of these countries.

Rear Admiral KARO (United States of America) congratulated all the countries of the region on the excellent progress they had achieved and looked forward to interesting discussions during the meeting. Since the United States did not belong to the Far East and since a recent publication on United States cartographic activities had already been distributed to delegations, he would make no oral report at this juncture.

Reverend GROOTAERS (Vatican City) said that the Vatican, while having a very small territory, was following with the utmost interest all activities which aimed at improving general knowledge to the benefit of human welfare. That was the reason why it was represented at the present Conference, which it considered as of no little importance for the future of the world.

U MAUNG (Burma) stated that the Survey Department of Burma was being extended with the assistance of the United Nations and the Governments of Canada, India, the United Kingdom and the United States of America. He briefly mentioned the work carried out in his country in the field of topography and cadastral survey, and said that the Survey Department was mostly occupied with the preparation of large-scale maps for use in various governmental projects, such as irrigation, mining, transport and industries. These maps were all prepared with modern photogrammetric methods and photogrammetry was being developed with foreign assistance. It was hoped that the topographic mapping of the whole of Burma, as well as the work on photo-interpretation dealing with geology and forestry, would be completed in the relatively near future.

A geodetic division had been created in September 1958 and the services of an expert from the Finnish Geodetic Institute, as well as a geodetic gravimeter and a DGA geodimeter, had been obtained under the United Nations technical assistance programme. The measurement of an international levelling junction line on the East Pakistan-Burma border had been successfully completed. Gravity differences between seventeen stations had been observed and observation of the four remaining stations would be completed in October 1958. They would form the main framework for an additional network of gravity stations which would cover the whole of Burma. Preliminary measurements had also been completed for the laying down of a national standard base line. A drawing office and a map printing office had been established and technicians were being trained through the assistance of the Governments of India and the United Kingdom.

Mr. LACLAVÈRE (France) suggested that observers from countries and various organizations represented at the Conference be invited to give their experience.

It was so agreed.

Rear Admiral CARLOS DE MATTOS (Brazil) regretted that his country had not been able to send a specialist to attend this important meeting. He himself was a layman and was unable to give an accurate report on the cartographic work which had been done in his country for many years and which was still being developed. However, the fact that Brazil had sent an observer was proof of the interest with which his country was following the proceedings of the Conference.

Mr. CRUZ (Philippines) explained that the main problem facing his country was that there were 7,013 islands to survey and only about 700 practising surveyors. The topographic maps of the Philippines were mostly reproduced in Tokyo by the United States Army Map Service, Far East, with the data gathered by Filipino technicians and the Army Map Service. There were also Laplace observations done by Filipinos. The present activities of the Government were concentrated on public land surveys through surveying contractors. It was hoped that the three services dealing with cartography, namely, the Land Bureau, the Coast and Geodetic

Survey Bureau and the Engineers of the Armed Forces, would be merged into one single administration. Aerial photogrammetry for coastal surveys had just been initiated in his country; actual work would start in December 1958.

Mr. LACLAVÈRE (International Geographical Union) said that the International Geographical Union was following with great interest all topographical studies throughout the world, in particular the work concerning the International Map of the World on the Millionth Scale, which was considered to be a suitable basis for most specialized and topical maps.

Dr. RANDALL (Pan American Institute of Geography and History) said that the organization he represented had long experience in co-operative efforts on a regional basis since it had begun its meetings and commissions on cartography in 1942, and was now holding on the average one meeting every two years for the American continents.

He reminded the delegates of the two recommendations prepared by the Committee of Experts on Cartography convened by the United Nations in 1949. One was that the United Nations should establish a cartographic office as part of its staff; that had been done. The second was that the United Nations should encourage and assist the organization of regional meetings such as the present one on the basis of the experience of the Pan American Institute of Geography and History.

The American Republics now had an institution which enabled them effectively to standardize the specifications for various kinds of surveys and maps, so that map information in one country could be really understood and used by neighbouring nations. They were also encouraged by the establishment of international co-operation agencies, such as the Inter-American Geodetic Survey, which had set up from the Bering Strait down to Mexico the longest chain of first-order triangulation in the world.

Finally, he noted that the Pan American Institute operated a training centre for photo-interpretation in Brazil, the courses at which were attended by two experts from each of the Republics.

Mr. LACLAVÈRE (International Union of Geodesy and Geophysics (IUGG)) noted that the IUGG had established a very close co-operation with the Cartographic Office of the United Nations and had appointed a liaison officer to that Office. The Union also maintained close contacts with other non-governmental agencies such as the World Meteorological Organization.

The Union had a number of large-scale projects which required international co-operation. Probably the most important one was the Bathymetric Chart of the Oceans. This Chart was originally published by the International Hydrographic Bureau (IHB) on the scale 1 : 10,000,000. The Bureau had neither the funds nor a staff adequate to perform the task of revision. Therefore, an amount of $10,000 had been allocated by the International Council of Scientific Unions (ICSU) to help the Bureau speed up the revision of the Chart. However, this was a complicated work. Sounding data had to be collected by some central organization which had to process it and issue the maps, and also sell them in order to get revenue. The credit earmarked by the ICSU would enable the work to be accelerated as from November 1958.

Another project which was being undertaken was a M of the Antarctic. This area was of great interest for a numb of countries, twelve of which were working there. A spec committee had been established, with Mr. Laclavère chairman, to determine the kind of co-operation that could established in order to prepare such a map. The Unit Nations Educational, Scientific and Cultural Organizati was also co-operating with this committee.

The third project of interest to the Conference was magnetic map at ground level and at different latitudes, call the World Magnetic Survey. It was proposed to start wo on it within two or three years and, when produced, the m would enable scientists to have a clear picture of magnetis in the world. It was relatively easy to collect the relevant da on the ground, but the work was very difficult in the ocea There was only one survey ship equipped for magnetic surve the Soviet ship Zaria, which was now working in the Indi Ocean, before going to the Pacific. The United Kingdom h started building such a ship but, owing to lack of funds, h had to dismantle it. It was obvious that international c operation would be required in this field.

Finally, a fourth international project which also depend on the International Union of Geodesy and Geophysics w the production of a Geoid Map. This task had been entrust to the International Gravimetric Bureau which was collecti all the relevant data throughout the world. Co-operation this field was easy in Europe, but much more difficult el where. Often only fragmentary data were given, and in suc form that the information was useless. The Gravimet Bureau had already compiled a Geoid Map for Europe a had started working on one for Africa.

Dr. TCHANG (Executive Secretary) said that the prima objective of United Nations work in the field of cartograp was to assist Governments in developing the cartograp work required for their economic and social projects. One the achievements to this end was the convening of regio cartographic conferences such as this one. Last year, a Unit Nations Seminar on Topographical Mapping as a Means Economic Development was held in Tehran with a view promoting economic development in the area, including Ir and its neighbours. Concerning other aspects of Unit Nations activities in the field of cartography, he mentioned t work of United Nations Technical Assistance Administrati cartographic experts sent to various countries and the awa of fellowships to a number of technicians from countries Asia.

Specific projects involving only the countries in this regi were the responsibility of the Economic Commission for A and the Far East (ECAFE). The most successful project w the completion of the Geological Map for Asia and the F East. The printed copy of this map would be available ve soon. ECAFE had established for many years a Worki Group of Senior Geologists for the preparation of this m and was now getting ready to produce mineral and relat maps.

Establishment of technical committees

[Item 5 of the agenda]

The PRESIDENT reported that, at the meeting of ch delegates, it was decided to request the Executive Secret

to draw up a tentative programme for the work of the technical committees including the allocation of technical items to be considered by them. He asked the Executive Secretary to express his views.

Dr. TCHANG (Executive Secretary) stated that if the Conference desired to follow the pattern of the first United Nations Regional Cartographic Conference for Asia and the Far East, which had had an agenda very similar to that of the present Conference, four technical committees would have to be set up. Taking into account the views expressed by various representatives, he submitted the following draft programme.

Committee I: Geodesy and hydrography; items 8 and 14;

Committee II: Topography, photogrammetry and photo-interpretation; items 9 and 10;

Committee III: Topical maps; item 11;

Committee IV: International Map of the World on the Millionth Scale and the ICAO World Aeronautical Chart; items 12, 13 and 15. (Item 15 was included merely to simplify the procedure.)

It was so agreed.

The meeting rose at 4.15 p.m.

SUMMARY RECORD OF FIFTH PLENARY MEETING[1]

Held at Sankei Kaikan, Tokyo, Japan, on Tuesday, 28 October 1958, at 9.30 a.m.

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President: **Dr. Chūji TSUBOI (Japan)**

Report on credentials

[Item 4 of the agenda]

The PRESIDENT said that the two Vice-Presidents and himself had examined the credentials submitted to the Executive Secretary by the delegates attending the Conference and had found them in order. He added that these credentials concerned only those delegates and observers representing countries attending the Conference.

Colonel ATES (Turkey) moved the acceptance of the report on credentials.

Mr. EBRAHIMI (Iran) and Rear Admiral KARO (United States of America) seconded this proposal.

The report on credentials was unanimously adopted.

Establishment of a regional inter-governmental cartographic commission or organization for Asia and the Far East

[Item 7 of the agenda]

Mr. OHKAWARA (Japan) introduced the draft resolution sponsored jointly by the delegations of Burma and Japan.

The general outline of the views of his delegation were given in the background paper E/CONF.25/L.78.[2] He felt it redundant to dwell upon the importance of cartography as an indispensable tool in economic development, and the pressing need to establish inter-governmental machinery for regional co-operation. He wished merely to draw the attention of the meeting to the fact that the general consensus of the last Conference had been in favour of the establishment of a regional inter-governmental organization and that the Economic and Social Council had recommended that the regional economic commissions establish cartographic committees. More than two years had passed since the Council had adopted its resolution 600 (XXI) leaving this matter to the discretion of the regional economic commissions. The subject had not, however, yet been taken up at an ECAFE meeting.

He stressed that, in this region, no international organiz tion existed in the field of cartography. Therefore it was the more important to have some kind of internation machinery which would usefully serve the pressing need Asian countries.

His delegation firmly believed that this subject could not effectively discussed without considering the financial implic tions of the problem. In other words, the proposal should realistic enough to be within the means of the participants the scheme. The proposal now before the Conference seem to be one of the most practicable ways to proceed. It was n the final solution and should rather be taken as a first measu to be completed by additional improvements.

His delegation therefore considered it advisable that t Conference should express its hope that this matter would taken up at the next session of ECAFE and that ways a means would be explored of taking concrete steps to organi regional inter-governmental channels of co-operation in t field of cartography, including the establishment of an appr priate regional machinery.

Mr. TSAO (China) supported the proposal that this matt be taken up by ECAFE at its next session.

U MAUNG (Burma) said that after due consideration all conditions existing in the region, his delegation was of t opinion that the proposal now before the meeting was the on immediate solution for strengthening cartographic activiti in Asia. He appealed to all countries with the desire to bett their cartographic standards to support the proposal.

Rear Admiral KARO (United States of America) stress that the United States was most willing to continue its acti participation in cartographic activities in the region. He f that all activity in this field should be done through the Cart graphic Office of the United Nations.

Mr. EBRAHIMI (Iran) pointed out that his delegation h not been empowered to commit its Government on t matter.

Lieutenant-Colonel JOHNS (United Kingdom) support the proposal in principle. His Government, however, wou like to know what kind of participation it would be expect to undertake. He also gave the following address in the Unit Kingdom for all mail concerning cartography: " Secretar Joint Advisory Survey Board, Ordnance Survey, Leatherhe Road, Chessington, Surrey ".

Professor SCHERMERHORN (Netherlands) also adv cated the establishment of regional inter-governmen machinery in the field of cartography. He shared the vi of the United States delegate that all work in this fi should be related to the Cartographic Office of the Unit Nations.

[1] Issued as E/CONF.25/SR.5.

[2] This paper is reproduced in part II, under agenda item 7.

He believed that the general set-up was a good one, with the understanding that it should be adapted to the local conditions in ECAFE countries, taking into account the means available. He also believed that a regional organization would have better possibilities of promoting cartography, through both seminars and formal conferences.

Mr. LACLAVÈRE (France) thought that geological as well as cartographic problems were essentially of a regional character. He therefore fully supported the proposed setting up of a regional inter-governmental organization on cartography.

Mr. OHKAWARA (Japan), in answer to a question by Mr. LAMBERT (Australia) and with reference to the statement of the representative of Iran, stressed that it was only a suggestion that the Conference should express its hope that the matter would be included on the agenda of the forthcoming session of ECAFE. The Conference thus did not commit Member Governments in any way, and, in addition, it gave them another opportunity to further discuss the question.

Mr. ELSTER (Israel) did not agree with the delegate of France: since the same problems were to be solved everywhere in the world and the same methods were applied, cartography did not have a regional character. Nevertheless, he supported the proposal to set up a regional machinery. The idea, however, should be worked out in detail and a detailed project should be submitted to this Conference before any decision was taken.

Colonel KALHA (India) supported the draft resolution, so long as the new organization was built up within the framework of the United Nations.

Mr. RASARETNAM (Ceylon) agreed that the establishment of the proposed machinery would be in the best interests of all the Governments concerned, especially since the physical resources and geographical aspects of this region differed largely from those of Europe and America. This should not, however, lead to any degree of isolation of Asian nations. The machinery should be set up in such a manner as to enable advanced countries such as the United States of America, the United Kingdom, France, the Netherlands and Australia to continue sharing their experience with them.

The Conference should not commit participant Governments in any way, particularly from the financial point of view.

Mr. OHKAWARA (Japan), in answer to a question by Mr. MILLER (Canada), said that there would be nothing to prevent other cartographic conferences like the present one from being held even after the establishment of the proposed machinery under ECAFE.

He also agreed with the representative of the Netherlands that a very close contact should be maintained by this regional organization and the United Nations Cartographic Office. Meanwhile, the draft resolution left these structural matters to be decided by the countries concerned at the next ECAFE session.

Mr. LI (ECAFE), in reply to Mr. LAMBERT (Australia), explained that the ECAFE region included all the countries of Asia and the Far East, extending from Iran in the west to Japan, the Philippines and Indonesia in the east, with the exception of Siberia and Outer Mongolia. ECAFE membership also included several countries from outside the region, namely Australia, France, the Netherlands, New Zealand, the Union of Soviet Socialist Republics, the United Kingdom and the United States of America.

Since ECAFE was part of the United Nations, there could be no doubt whatsoever about its close and most direct working relationship with United Nations Headquarters.

Mr. LAMBERT (Australia) proposed that the voting on the draft resolution be deferred until the next plenary meeting.

Professor SCHERMERHORN (Netherlands) supported this suggestion.

He also pointed out that it would be advisable for ECAFE to receive from professional circles some guidance on what was meant by the proposed machinery. He therefore suggested, with a view to speeding up its establishment, that the experts attending the Conference prepare some kind of paper for ECAFE countries, explaining what the aim of such an organization was, what results could be expected of it and how best to realize them.

As regards the draft resolution, it appeared sufficiently vague to be generally acceptable even to delegations which could not commit their Governments to anything more than participation in the discussion on the matter at the next ECAFE session, if such a discussion should take place.

Mr. OHKAWARA (Japan) associated himself with the constructive proposal of the representative of the Netherlands.

Colonel KAZEM (United Arab Republic) suggested that a detailed proposal be prepared and sent to the Governments concerned for their consideration. Any decision would be taken at another meeting of the Conference, at which time delegates would be fully empowered by their Governments to discuss the problem.

Mr. OHKAWARA (Japan) said that, in the light of the discussion, his delegation would not insist on an immediate vote.

The proposal of the representative of Australia to postpone the voting was accepted.

Re-allocation of agenda items

Professor SCHERMERHORN (Netherlands) said that the agenda items on photo-interpretation should be considered by Committee III in conjunction with the item on topical maps. He believed that it would be worth while to strengthen cartography in the eyes of many people by making it clear that this kind of inventory of natural resources belonged to the same field of activity. It would be wise for regional cartographic conferences and for the Cartographic Office of the United Nations to lay more stress on this aspect and express their definite opinion that topographical maps, including photo-interpretation, was one of the important fields of activity of the United Nations.

Dr. GERKE (Federal Republic of Germany) supported this proposal.

The Conference unanimously agreed to transfer items 9 (b) *and 9* (c) *to item 10* (c), *to be discussed by Committee III.*

As a consequence of this decision, the EXECUTIVE SECRETARY suggested amending the names of Committees II and III. Committee II would be called "Committee on Topography and Photogrammetry", while Committee III would be called "Committee on Topical Maps and Photo-interpretation".

It was so agreed.

The meeting rose at 10.50 a.m.

SUMMARY RECORD OF SIXTH PLENARY MEETING [1]

Held at Sankei Kaikan, Tokyo, Japan, on Thursday, 30 October 1958, at 9.30 a.m.

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President: **Dr. Chūji TSUBOI (Japan)**

Greetings of the Conference to Turkey

Rear Admiral KARO (United States of America) noted that 29 October had been the National Day of Turkey. On behalf of all delegations he wished the Republic of Turkey many happy returns.

Establishment of a regional inter-governmental cartographic commission or organization for Asia and the Far East

[Item 7 of the agenda]

The PRESIDENT recalled that at its previous meeting the Conference had postponed the voting on the draft resolution submitted jointly by Burma and Japan, and invited it to resume its consideration of the draft resolution.

Mr. OHKAWARA (Japan), summarizing the previous meeting's discussion, pointed out that participant countries were not being asked to commit themselves on anything new. The proposal was simply that the Conference express its hope that the next ECAFE session would take up the matter and study the possibility of taking steps to ensure international co-operation in this field. Member Governments of ECAFE were expected to issue proper instructions to their delegations attending the ECAFE session so that all of them would be well prepared to discuss the matter in concrete terms.

He also drew the attention of the Conference to resolution XVII [2] of the first Regional Cartographic Conference for Asia and the Far East, which recommended " the setting up of . . . regional inter-governmental cartographic organizations where these do not exist at present ".

In proposing the draft resolution, his delegation was not contemplating anything ambitious, such as the establishment of a new international agency comparable to FAO, WHO or ICAO. As a matter of fact, his delegation intended to sugg to ECAFE at its next session that it create within the secretar a cartographic section which would serve as a co-ordinati office on cartographic matters in the region. The cartograp section would also organize working parties on cartograp which would meet from time to time under the sponsorship ECAFE. Such working parties would surely play an import role in furthering an exchange of information and a discussi of technical problems common to the countries in the regi on a working level.

Concerning the possible participation in the proposed int governmental agency, he referred to the explanation previou given by Mr. C. Y. Li of the ECAFE membership [3] a quoted article 9 of ECAFE's terms of reference as follo " The Commission shall invite any Member of the Uni Nations not a member of the Commission to participate i consultative capacity in its consideration of any matter particular concern to that non-member ".

With regard to the regional cartographic conference, delegation firmly believed that, in the light of the experie gained during this meeting as well as at the Mussoorie C ference, the third regional cartographic conference for A and the Far East would be better held some time in 1 or 1962, regardless of any decision that might be taken at next ECAFE session. His delegation was willing to supp a motion to hold a third regional cartographic conference Asia and the Far East. If the working parties mentio above should follow the various suggestions and recommen tions on technical problems, and if the third regional ca graphic conference should review the reports of the work parties and render a guidance for the future course to adopted, a third conference would certainly prove not only great benefit to the region, but also a necessity for the caus improvement of cartography.

He again appealed to all delegations to consider the ma from a practical point of view and to support the draft res tion.

The PRESIDENT put to a vote the draft resolution s mitted jointly by Burma and Japan.

By 14 votes to none with 7 abstentions, the draft resolu was adopted.[4]

Mr. OHKAWARA (Japan) thanked the Conference for support it had given to the joint proposal of Burma Japan. He hoped that something concrete would emerg

[1] Issued as E/CONF.25/SR.6.

[2] See *United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 1, *Report of the Conference* (Sales No.: 55.I.29), page 16, paragraph 64.

[3] See summary record of the fifth plenary meeting.

[4] For the resolution, as adopted, see *Second United Nat Regional Cartographic Conference for Asia and the Far East*, vo *Report of the Conference*, page 7, resolution 1.

the forthcoming ECAFE session, in answer to the expectations of this Conference.

The PRESIDENT stated that, since the Conference, in accepting the resolution, had already referred the whole matter of establishing an inter-governmental body to ECAFE, it did not seem necessary to consider the proposal submitted by the Chinese delegation.[5]

Mr. TSAO (China) agreed.

It was so decided.

Final arrangement of the agenda

The EXECUTIVE SECRETARY introduced the final form of the agenda [6] prepared in the light of the discussion of the various Committees and of the action taken at plenary meetings, and in accordance with the procedure agreed at the second plenary meeting

Should the Conference agree with this final form, the latter would be followed in preparing the draft report of the Conference.

The final form of the agenda was adopted.

The meeting rose at 10.5 a.m.

[5] E/CONF.25/L.79, reproduced in part II, under agenda item 7.

[6] E/CONF.25/2.

SUMMARY RECORD OF SEVENTH PLENARY MEETING [1]

Held at Sankei Kaikan, Tokyo, Japan, on Saturday, 1 November 1958, at 9.30 a.m.

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President: **Dr. Chūji TSUBOI (Japan)**

Consideration of draft resolutions proposed by the technical committees and by the Rapporteur

The PRESIDENT invited the Conference to discuss and adopt the draft resolutions proposed by the technical committees and by the Rapporteur. He reported that a meeting, attended by the officers of the Conference, the chairmen of the technical committees and the Executive Secretary, had acted as a drafting committee to harmonize the texts of these draft resolutions. The amendments proposed by the drafting committee were given in E/CONF.25/L.86.

Rear Admiral KARO (United States of America) suggested that minor editorial changes should be left to the secretariat.

It was so decided.

DRAFT RESOLUTIONS SUBMITTED BY COMMITTEE I

Geodesy and hydrography (E/CONF.25/L.82)

The amended texts of the draft resolutions submitted by Committee I were unanimously adopted without discussion.

DRAFT RESOLUTIONS PROPOSED BY COMMITTEE II

Topography and photogrammetry (E/CONF.25/L.83)

The PRESIDENT pointed out that the draft resolution originally proposed for items 10 *(b)* and 10 *(c)*, on page 4 of this document, had been replaced by a general resolution given in page 4 of document E/CONF.25/L.86.

The resolutions submitted by Committee II, as amended by the drafting committee, were adopted unanimously.

DRAFT RESOLUTIONS PROPOSED BY COMMITTEE III

The PRESIDENT proposed to discuss the *draft resolutions submitted by Committee III: Topical Maps and Photo-interpretation (E/CONF.25/L.84)*.

The EXECUTIVE SECRETARY, in answer to a request for clarification made by Mr. LACLAVÈRE (France) regarding technical papers presented to the Conference, explained that the various proposed resolutions containing lists of background papers had been consolidated into one single general draft resolution, the text of which appeared at the bottom of page 4 of E/CONF.25/L.86; this resolution also covered items 11 and 12 on page 3 of E/CONF.25/L.84.

The resolutions submitted by Committee III, as amended by the drafting committee, were unanimously adopted.

DRAFT RESOLUTIONS PROPOSED BY COMMITTEE IV

International Map of the World on the Millionth Scale (IMW) and Aeronautical Charts (E/CONF.25/L.8

The RAPPORTEUR introduced the draft resolution prepared in connexion with the consideration of item 6.

Colonel KAZEM (United Arab Republic) stated that he fully agreed with the conclusion stressing the usefulness of the Conference. He therefore suggested adding one operative paragraph to this draft resolution as follows: "*Recommends* the Economic and Social Council to convene the next United Nations regional cartographic conference for Asia and the Far East not later than in 1961".

The resolution, as amended, was adopted unanimously.

Adoption of the report of the Conference

[Item 16 of the agenda]

The EXECUTIVE SECRETARY introduced the draft report of the Conference [2] prepared by the secretariat on the basis of the material and information so far available. He explained that this provisional text would be completed taking into account the current proceedings and that the final edition would be made in accordance with the procedure and practice followed by the United Nations for official publications.

With this understanding, the report was adopted unanimously.

The meeting recessed at 10.15 a.m. and resumed at 11.10 a.m.

Address by His Excellency Mr. Tatsui Chuma, Vice-Minister of Transportation of Japan, and closing of the Conference

The PRESIDENT introduced His Excellency Mr. Tatsui Chuma, the Vice-Minister of Transportation of the Government of Japan.

His Excellency Mr. TATSUI CHUMA said that the Minister of Transportation, Mr. Mamoru Nagano, deeply regretted having been prevented from attending this meeting himself. He read a message from the Minister, and told the Conference that it had been heartening that a free exchange of knowledge and technical know-how had taken

[1] Issued as E/CONF.25/SR.7.

[2] E/CONF.25/L.88.

place at this session, attended by some ninety representatives from twenty-eight countries.

He wished to express his most sincere appreciation for the active co-operation of all delegations in the discussion of various important problems, such as standardization in cartography and other questions which had been pending for many years. It was his strong belief that the remarkable results achieved by the Conference would greatly contribute not only to the development of cartographic techniques, but also to the economic progress of all countries concerned.

He was certain that the understanding and friendship that had been brought about through this Conference would strengthen the bonds among the participating countries and help to create a motive power which would produce a higher degree of improvement in cartographic techniques. He hoped that all countries represented at this Conference would be able to accomplish map adjustments of a higher standard before the next session, and that international co-operation among them would thus be further enhanced.

Rear Admiral KARO (United States of America) felt sure he expressed the feelings of all delegations when he said that this Second Regional Cartographic Conference for Asia and the Far East had proved an unqualified success. The free exchange of technical information which had taken place at the Conference would help all experts to improve their work when they were back home. Indeed, experience showed that the more you give, the more you receive in return.

He expressed the delegations' gratitude to the President, Mr. Tsuboi, for his outstanding leadership, and thanked the Executive Secretary and his staff from New York and Bangkok.

He moved a vote of thanks to the host country, Japan, for the excellent facilities provided for the Conference.

Mr. LAMBERT (Australia) endorsed the statement of the United States representative.

He also noted that the previous day had been the anniversary of the birthday of Generalissimo Chiang Kai-shek, President of the Republic of China, and wished to express to the Chinese delegation, on behalf of all delegations, his congratulations on that occasion.

Mr. SUN (China) thanked the Conference for its congratulations on Generalissimo Chiang's birthday. He also joined the previous speakers in commending the President, the Executive Secretary and their staff, and expressing his gratitude to the Government and the people of Japan for their hospitality.

Mr. LACLAVÈRE, speaking as a representative of the member organizations of the International Council of Scientific Unions (ICSU), noted the outstanding success of the Conference and pledged continuing co-operation of the ICSU with the Cartographic Office of the United Nations.

Messrs. ATES (Turkey), JOHNS (United Kingdom), SCHERMERHORN (Netherlands), CHIN (Republic of Korea), SARAY (Cambodia), MAUNG (Burma), KALHA (India), GERKE (Federal Republic of Germany), RASARETNAM (Ceylon), MILLER (Canada), KAZEM (United Arab Republic), PACHIMKUL (Thailand), SURJOSUMARNO (Indonesia), ELSTER (Israel), EBRAHIMI (Iran), LACLAVÈRE (France), SCHOLL (Switzerland) and CRUZ (Philippines) associated themselves with the expressions of gratitude to the President, to the Government and people of the host country, and to the Executive Secretary and his staff.

The vote of thanks to the Government of Japan was carried unanimously.

The EXECUTIVE SECRETARY, speaking on behalf of the Secretary-General of the United Nations and on his own behalf, thanked the Government of Japan for the excellent arrangement of the Conference. He also thanked the President and other officers of the Conference, including the chairmen of the committees, for their kind co-operation. He wished particularly to express his appreciation to the staff provided by the Japanese Government for their untiring efforts.

The Second United Nations Regional Cartographic Conference for Asia and the Far East was closed on 1 November 1958, at 12.5 p.m.

Part II

TECHNICAL DOCUMENTS PRESENTED TO THE CONFERENCE

AGENDA ITEM 6

Brief reports by Governments on the cartographic activities of the respective countries, outlining work achieved, technical developments and difficulties encountered in technical work since the Mussoorie Conference

PROGRESS OF CARTOGRAPHIC WORK IN CHINA, 1955-1957 [1]

Report by Dr. Tsao-Mo

Cartographic work in China from 1900 to 1954 was reported to the first United Nations Regional Cartographic Conference for Asia and the Far East, held at Mussoorie, India, from 15 to 25 February 1955. This report covers the period from 1955 to 1957.

Geodetic and Astronomic Work

Readjustment of ground control. More than 17,000 kilometres in axis length of different order triangulation systems in several provinces of China were readjusted into single datum to meet the requirements for revising the topographic maps during the period from 1954 to 1956.

Astronomical observation. One first-order station as Laplace point and three second-order stations were observed during the period from 1955 to 1956.

Lunar occultation. Five stations were observed with the 12-inch Cassegrainian apparatus in order to connect the geodetic co-ordinates of remote stations.

Geodetic research. A preliminary investigation on the figure of the Earth from measurement in the south-western part of China was undertaken. The work was based on the astro-geodetic measurement which was carried out during 1938 to 1939, with reasonable accuracy, covering an area about five degrees of latitude by ten degrees of longitude.

The parameters of the figure of the Earth recently computed from these measurements by the deflection method are as follows:

Semi-major axis	6,378,554 ± 54
Reciprocal of flattening	298.6 ± 1.5

It is of interest to note that the values of this preliminary determination of the dimensions of the figure of the Earth in that part of China, obtained from measurement of small territory, are rather reasonable. For instance, taking the mean value of the parameters derived from the measurements both in the east-central part of China [2] and in the south-western part, we get $a = 6{,}378{,}204$, $1/f = 298.0$, the former being close to Hough Ellipsoid, the latter close to that obtained from the Vanguard by the United States Army Map Service.

Except in Taiwan, the deviation of the vertical in magnitude and direction at stations in China has been found so far not to exceed ten seconds, both in meridian and prime vertical. It is evident that the Hayford Spheroid adopted for the computation of geodetic measurements of China is still a suitable one.

The undulation of the geoid in the south-western mountain area is lower than that in the east-central plain area. This is comparable to the values computed by Dr. L. Tani from the gravity observation.

Gravity Survey

Before 1948, there were more than 7,300 gravity stations observed in Taiwan and hundreds of stations scattered over a great part of China. Additional pendulum observations are required to connect with well-known international stations.

Topographic Work

More than 700 topographic map sheets of topographic series at scales from 1: 50,000 to 1: 250,000 have been revised and reproduced in multi-colour editions for several purposes since 1954.

Aerial Photogrammetry

Aerial photogrammetric techniques have been applied to different mapping projects, such as cadastral survey, water conservation, railroad survey and the like; the results obtained have been satisfactory. The status of aerial photogrammetry in China is studied in a separate paper by W. S. Hwang.[3]

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[1] The original text of this paper, submitted by China, appeared as document E/CONF.25/L.24.

[2] *See* " The Figure of the Earth from Measurements in China ", by Dr. Tsao-Mo, *United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 2, *Proceedings of the Conference and Technical Papers* (Sales No.: 56.I.23), page 120.

[3] *See* E/CONF.25/L.28 under agenda item 10.

THE USE OF PUNCHED-CARD MACHINES FOR GEODETIC DOCUMENTATION [1]

Report by the Institut géographique national, France

The number of geodetic points in France is currently estimated at 50,000, to which must be added an equal number of supplementary triangulation points. The documentation on these geodetic points is voluminous and of necessity subject to change. In order to make use of this information and keep it up to date a series of time-consuming and expensive operations are necessary (research, copying, collating and correction). The documentation, however, can be handled quickly and inexpensively by means of mechanographic punched-card equipment. Such equipment operates at high speed and is capable of undertaking a wide range of search and classification functions. The listings can be adapted to all requirements and the equipment is highly flexible and requires a very small operating staff.

Geodetic card catalogue

The geodetic card catalogue is a mechanographic card catalogue arranged by geodetic points. Each point is represented by two punched cards containing all the relevant information: name, type, co-ordinates, height, system of projection, date of calculation, 1: 50,000 sheet number, number of the point on the sheet, and code of the survey on which the point was determined. The basic classification of this card catalogue is the sheet of the 1: 50,000 map of France, the working unit of the National Geographical Institute (Institut géographique national). Within each sheet points are arranged in order of increasing value of the X-co-ordinate.

For each 1 : 50,000 sheet a card is also prepared for each geodetic survey which determined points shown on the sheet; this card bears a code number for the survey, the name and year of the survey, and the system and year of calculation. All these cards are prepared from the directories of geodetic points as soon as these are published.

The equipment can be used to solve the problems of geodetic documentation, that is:

(1) To arrange the cards in the logical order corresponding to the question to be answered (sorter);

(2) To print a list showing the features requested (and only those features) in logical order.

Almost all such problems can be solved by the combined use of the three machines: the sorter, the tabulator and the punching-reproducing-duplicating machine.

Potential uses

The card catalogue now covers 500 sheets of the 1 : 50,000 map of France, or approximately 50,000 points. It is sufficiently extensive for the performance of large-scale operations, some of which could not be carried out in any other way. These operations consist in listing on the tabulator and reproducing cards in the punching-reproducing-duplica machine, a special plug-board being required for each op tion.

List of co-ordinates

Lists of co-ordinates show the name and designation of point, its co-ordinates and its height. They can be prepa for any area covered by the card catalogue. Fifteen min is required to produce a list of 100 points, which would t approximately two hours to type. It is thus possible to n any request for co-ordinates relating to a particular a very quickly.

Miscellaneous lists

Lists showing only information relevant to the questio be answered, arranged in the desired order, can be prepa on request. All that is needed is to change the plug-board

Examples :

List of first-order points;

List of permanent structures whose co-ordinates have b determined (water-towers, steeples, etc);

List of points where damage has occurred;

Possibility of obtaining—by selecting suitable codes tal into account the heights of markers, number of points on ground, number of sights taken and so on—a summary of difficulties likely to be encountered in carrying out a secon triangulation in an area already covered geodetically.

Transformation of co-ordinates

A transfer can be effected directly from the rectangular ordinates, as shown in the geodetic card catalogue, to geo phical co-ordinates or to any other appropriate systen projection. For this purpose calculating-cards are prepa by duplicating the card catalogue in the punching-reprodu machine; these cards provide the data for the electr computer, which produces another set of cards on which new co-ordinates are punched. It only remains to make a in the tabulator. This method takes little time and ma possible very extensive operations which would be out of question without mechanographic equipment. All ha copying is thus eliminated.

Geodetic dictionary

An alphabetical dictionary of all geodetic points, with t co-ordinates and height, designation of bench-marks, 1 : 50 sheet number, and so on has now been prepared for th departments in which the geodetic survey has been comple This dictionary is supplemented by a historical record c taining a list of the surveys which determined points in department, with particulars of the observations and calc tions made. When the new triangulation of France is c pleted, a general dictionary of this type will be publis annually. This document will be up-to-date, because punched cards will be corrected as soon as a change i geodetic point is reported.

[1] The original text of this paper, submitted by France, under the title " Utilisation du matériel à cartes perforées pour la documentation géodésique ", appeared in French as document E/CONF.25/L.51. *See* also agenda item 8, " Geodesy ".

Card catalogue of water-towers

A card catalogue, started in 1955, permits a census to be taken of all water-towers in France. It consists of one card for each water-tower, showing the name of the commune, approximate position in co-ordinates, height above the ground, and 1 : 50,000 sheet number. It is kept up to date and published annually.

Conclusion

Because of its flexibility and output, electromagnetic punched-card equipment provides a means of handling geodetic documentation swiftly and simply. It furnishes logical and accurate answers to the questions put to it. Through the process of sorting and reproducing the cards, any type of information which the card catalogue has to offer can be obtained in list form by passing the relevant cards through the tabulator. Moreover, it is easy to keep the documentation up to date: all that is needed is to replace the out-of-date punched card with a new one bearing the desired correction. Thus, the use of this equipment saves much time by eliminating the entire process of searching, arranging and copying. The rate of output is increased, the risk of error is greatly reduced, and a very small staff is required.

" MECHANOGRAPHIC " WORKSHOP OF THE INSTITUT GÉOGRAPHIQUE NATIONAL [1]

Report by the Institut géographique national, France

Introduction

The National Geographical Institute (Institut géographique national) acquired its computing equipment in 1954 from the Compagnie des machines Bull. These machines, while not having the capacity of the large computer installations available at various other organizations, are adequate for the solution of many problems.

Before embarking on a detailed description of what the Institute has done in mechanical computation, it should be pointed out that the question of providing the Institute with a large-capacity installation has never been envisaged. The problems faced by geodesists are in fact very rarely extensive enough to make the use of equipment costing several hundred million francs economic. The cost of the Institute's entire installation has been barely forty million francs. This installation has not led to a cut in staff—rather the contrary—but it has increased the capabilities of the computing section. Certain problems that could not be tackled five years ago have now become commonplace. This is particularly true of the transformations of large sets of co-ordinates.

The decision whether a problem is more amenable to mechanical or to manual procedures is a difficult one and can sometimes be resolved only in the light of experience. To cite an example, the use of the machines was contemplated for the solution of linear systems, but it was soon realized that this procedure would be uneconomic for systems involving more than forty equations with forty unknowns. According to an estimate based on a ten-year period for the depreciation of the equipment and including wages and maintenance but excluding rent, social security contributions and the like, the machine operation costs were found to be about 40,000 francs per working day. The mechanical equipment should therefore be used only for those problems where its advantages outweigh those of the manual machines.

Apart from the direct money savings, which can be determined by comparing the cost of the same operation performed by the electronic computer and the manual computer, there is also the time factor. An operation performed by the electronic computer may be regarded as economic if considerable time is saved. For example, the solution of a system of twenty equations with twenty unknowns takes about two hours when performed by the electronic computer and thus represents a cost of 10,000 francs. The same operation on a manually operated computer would take two days and is thus somewhat less expensive. At the Institute, however, these systems are handled by the electronic computer, which can easily cope with all problems of this type which arise in the course of a working year.

The main reason why certain problems, such as the solution of large systems of equations, cannot be efficiently handled by the Institute's electronic computer is that the number of storage units is too small. The computer has only fifteen storage units, that is, its maximum storage capacity is fifteen twelve-figure numbers. This small capacity requires the steady feeding of raw data into the computer while it is processing the data supplied. The raw data are fed into the computer through subsidiary machines that operate with punched cards. With a large computer possessing, as is customary, 20,000 storage units, all the raw data can be fed into the machine at the outset; these data are then processed within a very short period, and the complete results are made available without further delay. With a small computer, on the other hand, the problem must be broken down and fed into the machine piecemeal; thus considerable time is lost as a result of the additional operations involved. The Institute's computer is therefore incapable of coping efficiently with problems of analytic photogrammetry in which a large body of data must be handled. It may therefore be asked what purpose a computer of this type serves. The answer is that it provides a means for solving various problems for which it is suited, for example, the transformation of co-ordinates, computations relating to astronomical positions, to functions and the like.

The Institute's present equipment also serves to familiarize the staff with the specialized techniques of electronic computer operation and will thus facilitate a smooth transition to the larger computers to be acquired later.

[1] The original text of this paper, submitted by France, under the title " L'atelier mécanographique de l'Institut géographique national ", appeared in French as document E/CONF.25/L.55.

Description of the Equipment

The Institute's equipment comprises an electronic computer and various subsidiary machines.

The subsidiary machines. These are all electromagnetic machines which operate by means of punched cards containing numerical or alphabetic data. As the punched cards take time to pass through a machine, the speed of a computing operation is determined by the subsidiary machines.

(a) PELEROD and VINOD. These two small machines, each of which has a typewriter keyboard, are the means by which written and printed data are transferred to cards. The PELEROD (punch) punches the cards, and the VINOD (verifier) verifies the cards thus punched. As the verifying operation means doing the same work twice, it is far from ideal and should always be kept to a minimum.

(b) The sorter. This distributes the cards into thirteen pockets according to that one of thirteen positions which is punched in a given column. The purpose of this machine is to arrange or rearrange the cards in a particular order.

(c) The PRD (punch, reproducer, duplicator). The feature of this machine is that it has two tracks for the passage of the cards: a reading track with three reading brushes; a punching track with two reading brushes and one set of punches. This machine can be connected with the computer; it handles 120 cards a minute on each track.

(d) The tabulator. This is a more complex machine; it contains counters that are capable of addition and subtraction. It is particularly useful because it can print a statement from the data punched in the cards. It can be connected with the computer, and in that case its counters can be used for the storage of data. The counters thus serve as supplementary storage units, but they are not easily accessible. The tabulator has a single track with two reading brushes. It operates at the rate of 150 cards a minute.

The operations of the PRD and the tabulator are controlled by means of a removable plugboard. They can accordingly be converted from one type of operation to another by changing the plugboard.

The electronic computer (Gamma 3M). This is identified by the formula MIEL.

M — number of storage units. There are fifteen storage units, each with twelve positions. A feature of these positions is that they are independent of one another; in other words, a single storage unit can accommodate one twelve-figure number, two six-figure numbers, three four-figure numbers, and so on.

I — number of inputs. There are six inputs, each of which makes it possible for twelve figures to be introduced into the computer from each of the cards passing through the machine connected with the computer.

E — number of outputs. The output is the opposite of the input; there are four outputs.

L — number of programme lines. A work programme is set up on the removable plugboard. It comprises a specified number of lines, each of which corresponds to an elementary operation such as transfer from storage unit to storage unit, comparison, addition, multiplication and so on. There are sixty-four lines.

The computer ordinarily operates in conjunction with PRD, which transmits the data to the computer and punc the results on to cards. In running through the machine, cards are separated by an interval equal to about half a c The speed of the computer is such that it usually carries the computation within this interval. Hence, two-thirds the time is taken up with the reading of the cards, and one-third with the computation.

The computer is provided with a very practical device kn as card programming, by means of which the fixed progran of the computer can be replaced by a flexible progran embodied in the cards. Whereas the plugboard compr only sixty-four lines, each card can carry forty-eight lines, the number of cards which can be used for this purpos unlimited. Though there is thus no limit on the numbe lines, there is the serious disadvantage that the numbe computations to be carried out must be matched by an e number of sets of programming cards. With the aid of device, very complex computations can be performed.

Problems of this kind are not met with in the newer c puters, which have a sufficient number of storage unit handle both the numerical data and the programme.

Description of the Computing Operations

The computer has up to now been employed exclusively geodetic computations; its use in connexion with the Institu other activities would be difficult in view of the very s number of storage units. In photogrammetry, for exam the data are too voluminous to be handled economically computer with fifteen storage units. With the aid, howe of the card-programming device, the computer is well ada to the transformation of co-ordinates and to astrono calculations.

Geodetic operations

First-order computations

The computation of adjustments of large nets by means small computer necessitates the division of the whole w into several parts. The manual method of computatio employed.

Basic data: observed directions, approximate co-ordina

Calculation, by means of card programming, of reducti to the chord, of bearings and of observation equations;

Normalization;

Resolution (this was carried out on the electronic comp in the case of the adjustment of the north-east France netw —with Belgium—but this has now been abandoned, and computations are performed by manual computer).

The sequence of operations, and especially the difficu encountered, will now be described.

The observation equation of the line AB is sought.

$$-dV_O + a\,dx_A + b\,dy_A + a'dx_B + b'dy_B + K = v,$$

in which

dV_o is an unknown representing the orientation e around the horizon in A;

a, b, a', b' are the functions of the provisional co-ordin and are not difficult to compute.

On the other hand, K (computed bearing—observed bearing) is not easy to compute because of the observed bearing. The computation of this coefficient necessitates a number of small operations which cannot be economically performed by the electronic computer.

For normalization, the matrix of the coefficients of the observation equations is multiplied manually column by column throughout. The same procedure could be followed with the electronic computer, but this would be very cumbersome. On a column-by-column basis, there must be as many machine runs as there are non-zero coefficients in the normal table. Preference was given to carrying out all the products in each observation equation, two by two, thus making thirty-five machine runs. The products of each set are then regrouped by sorting, and each of the groups thus formed is cumulated. This method makes it possible to deal with as many observation equations as are desired.

Resolution is a particularly difficult operation on the electronic computer. The iteration methods which are well suited to this type of equipment are not possible. Iteration methods would certainly be very slow in converging in a first-order system in which a modification is very widely propagated.

The method adopted was the conventional elimination of the symmetrical linear systems (Gauss-Doolittle method). The solution is made possible solely by its strong diagonalization, as the result of which the columns of unknowns can be introduced only when they become relevant to the computation. This also has the advantage of making it possible within a very short time to carry out a further solution of the system with another constant-term column. This method was used with the Institute's electronic computer but was given up as uneconomic. Resolution is again being carried out with the aid of manual calculations.

Some small improvements have made it possible to render this entire series of operations less cumbersome. In the first place, the method of adjustment by horizons has been replaced by the angles method, in which, since the unknowns are always a dx and dy of each station, the observation equation is relative to an angle rather than to a direction.

$$A \begin{matrix} \nearrow C \\ \searrow B \end{matrix}$$

$$a\,dx_A + b\,dy_A + a'\,dx_B + b'\,dy_B + a''\,dx_C + b''\,dy_C + K = v,$$

in which $a = a'' - a'$

$b = b'' - b'$

$K =$ computed angle $-$ observed angle.

While the observation equation would here appear to have been made more cumbersome by being given seven rather than six coefficients, the method does have the following advantages:

The elements observed are in fact angles, and the result of the computations will correspond much more closely to the observations actually carried out;

There are more unknowns in relation to the bearing;

The observation equation is symmetrical. As the unknowns always occur two by two (dx and dy), the normalization is carried out point by point. This means that instead of one machine run to compute aa, then another machine run to compute ab, and so on, there is a single machine run for computing $\begin{vmatrix} aa & ab \\ ba & bb \end{vmatrix}$.

The normalization is thus carried out in twelve machine runs instead of thirty-five. As each result card contains four products, the number of cards is divided by four, all subsequent operations carried out on the cards being reduced to the same extent.

With a view to eliminating the need for computing reductions to the chord and effecting the transfer to the plane, a computation based on variations of co-ordinates on the ellipsoid is being contemplated. The unknowns would be the variations in longitude and latitude (dM, dL). While the coefficients would be functions of greater complexity, they could be computed without any difficulty if card programming was used.

Second-order computations

Here the point of view changes completely because the computations are less uniform within the sets of data taken from the field. It has been agreed that normalization and resolution would be the only operations which the electronic computer would be called upon to handle. It has already been noted that in the case of large first-order blocks the methods of resolution by electronic computer were uneconomical. The handling of second-order triangulation has therefore had to be limited to small blocks not exceeding ten to fifteen points. This manner of dividing up the operations is, however, quite well suited to the manner in which the work in the field is divided up.

The initial data accordingly consist of the observation equations (observations around the horizon); the unknowns in the case of the azimuthal twist are eliminated through the equations in the first-order computations. The procedure has been strictly adapted to the problem to be solved, the characteristics of which are as follows:

The unknowns of the problem are in all cases coupled together, the abscissae and ordinates always going in pairs;

The result sought requires only a small degree of accuracy (about three decimal places).

The order of magnitude of the key terms in the solution is subject to very slight variation (from about one to 100), especially as the triangulations are carried out in accordance with modern techniques, for example, homogeneity of sight lines and balanced support on the first-order points. The systems to be resolved are symmetrical. The principal novelty in the procedure finally adopted is that the unknowns are grouped two by two and the calculations relate directly to the points.

For the normalization, the method of multiplication column by column was again resorted to, but at the same time the two columns (a_p, b_p) of point P were multiplied by the two columns (a_q, b_q) of point Q, the result being a card PQ containing the four cumulated products.

$$\begin{vmatrix} \Sigma\, a_p\, a_q & \Sigma\, a_p\, b_q \\ \Sigma\, b_p\, a_q & \Sigma\, b_p\, b_q \end{vmatrix}$$

The procedure is complete because only the cards containing non-zero terms of the observation equations are used and because each card contains one double term ($x\ y$) and one only. The procedure is fully effective, since x and y are always present or absent simultaneously.

For resolution purposes, the method of complete elimination is used. The system matrix is continued downward by a

unit matrix, and the process of elimination gives at the end the value of all the unknowns. This accordingly eliminates the need to proceed upwards within the system for the computation of all the unknowns from the quantities already known, as must be done in the case of a step-by-step elimination. In particular, the unknowns are dealt with two by two throughout the elimination, that is to say, instead of being eliminated one by one, they are eliminated two by two through a method of elimination dealing not with scalars but with matrices, two by two. The number of resolution operations is thus reduced by half; n points are eliminated instead of $2n$ unknowns.

The computation of the remainders is also carried out on a two-by-two basis with the same boards.

The iteration procedure has not been rejected out of hand but as yet has not to any great extent been tried out systematically. If the convergence was rather rapid—as might be expected in view of the fact that the first-order network provides a more or less solid basis for the second-order network—iteration method might be preferable to elimination method.

The computation of the third-order and lower-order adjustments is reduced to the preceding method by dividing the normal table at will by 3, 10 or 30 so that the key terms are of the same order of magnitude. In the case of the small blocks (ten to fifteen points) that are the rule in this regard, the results have been very satisfactory, and the electronic computer has been able to cope readily with all the computations which are met with at the Institute. This has made it possible to insist that systematic verifications be carried out with care after the adjustments so that the results may be regarded as completely reliable.

Computations of the Technical Section of the Division of Geodesy

In view of the paramount importance of card programming in all these computations, this type of programming and its application will now be examined in greater detail.

Card programming

As already pointed out, card programming is a procedure by which the plugboard of the computer can be replaced by cards running through one of the subsidiary machines (PRD or tabulator). The plugboard continues, however, to be used to give additional instructions to the computer. At the Institute, the plugboard contains the iterative parts of the development in series of the main functions of a variable. For example, in the computation:

$$\text{Arc } tg\ x = x - x^3/_3\, x^5/_5 - x^7/_7 + x^9/_9 \cdots$$

the quantity x is placed in one storage unit, and x^2 in another storage unit; the quantity x^3 is computed and is then substituted for x; the quantity $x^3/_3$ is computed; x is withdrawn, and $x^3/_3 - x$ is placed in a storage unit. The process is repeated, that is, x^5 is computed and then substituted for x^3; $x^5/_5$ is computed; $x^3/_3 - x$ is withdrawn and replaced by $x^5/_5 - x^3/_3 + x$, and so on up to $x^{31}/_{31}$. This computation would be long and arduous if all the instructions to the computer had to be given singly, but if the instructions are repeated, the computer will continue to perform the same operation until the denominator becomes greater than thirty.

Three fundamental iterative computations were set up the sixty-four-line plugboard annexed to the card p gramming:

$$\sqrt{x} = \text{limit of the series } y_n + 1 = y_n + {}^1/_2\,(x/y_n - y_n)$$

$$\sin x = x - x^3/_3! - x^5/_5! - x^7/_7! + \cdots$$

$$\cos x = 1 - x^2/_2! + x^4/_4! - x^6/_6! \cdots$$

$$\text{Arc } tg\ x = x - x^3/_3 + x^6/_5 - x^7/_7 \cdots$$

If, furthermore, in the trigonometric developments subtractions are changed to additions, the result is:

$$\text{Arg } Th\ x = {}^1/_2 \log \frac{Sh\ x}{(1+x)} \cdot \frac{Ch\ x}{(1-x)^{-1}}$$

If, in addition, the developments in series of $Sh\ x$ and C are cumulated in a single storage unit, the result is:

$$e^x = 1 + x + x^2/_2! + x^3/_3! + \cdots$$

It is thus apparent that an increase in speed and efficie is obtained in the Institute's card programming by sett up on the computer plugboard all the computations of basic functions $\sqrt{x}$, $\sin x$, $\cos x$, $Sh\ x$, $Ch\ x$, Arc $tg\ x$, Arg T $\log x$ and e^x. These computations are carried to ten decir places.

Computation of projections

The two projections most used at the Institute are Lambert projection and the UTM projection. The electro computer carries out the following computations:

Lambert $\rightleftharpoons$ geographic

UTM $\rightleftharpoons$ geographic

The Lambert projection does not present any diffic because in it the X and Y co-ordinates are functions o and M, and these comprise only the main functions refer to above.

The first step in the UTM projection is to carry ou conformal transformation from the ellipsoid to the sph circumscribed along the parallel of latitude L (latitude o point for which the UTM co-ordinates are sought). A tra verse Mercator projection of this sphere is then made readjustment by means of a complex transformation is carr out in order to preserve the scale along the central meridi and the meridian length is computed from the equator order to preserve the length of this meridian. This series operations makes use of trigonometric or hyperbolic functio which are easy to compute.

The transformation of geographic co-ordinates into Lamb co-ordinates is effected at the rate of twelve points a minu and into UTM co-ordinates at the rate of about seven point minute. Verification is by inverse transformation except the computation of a table, in which case verification continuity is used. In 1957, the transformation of more th 10,000 points was effected by means of the electronic comput

Calculation of geodesics

For short geodesics, for example, a first-order side of arc, an expansion limited to the first order of the elem is used.

A programme proceeding by rapidly converging iterati makes it possible to compute a large geodesic on the terrest ellipsoid, the geodesic being defined by the geographic ordinates of its end points. The computation is accurate

5 millimetres irrespective of the length of the geodesic. The computation consists primarily of:

Transition from latitude L to parametric latitude φ

$$(\text{tg } \varphi = b/a \text{ tg } L);$$

Resolution of the spherical triangle;

Computation of corrective terms Sphère → Ellipsoïde with the aid of elliptic integrals, which in practice are computed through expansions which are a function of the square of the eccentricity, and with the aid of Wallis integrals.

$$I_2 = \int_0^x \sin^2 x \, dx$$

$$I_4 = \int_0^n \sin^4 x \, dx$$

$$I_6 = \int_0^x \sin^6 x \, dx$$

which are computed by recurrence.

Each iteration takes about twenty seconds, and convergence is effected in not more than four iterations. The same computation by manual methods takes about one and a half hours.

Complex polynomial

Complex polynomials are used for all transitions from a conformal projection to another projection:

$$Z = Z_o + az + bz^2 + cz^3 + \cdots$$

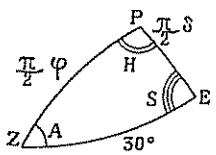
Because of the frequency with which they are used, a special board has been prepared for these transformations. For polynomials of degree 3 or lower, it has been possible to give all the instructions in sixty-four lines and to enter all the constants in the fifteen storage units. The computer thus operates at full capacity at the rate of sixty points a minute. For polynomials higher than degree 3, the complex coefficients Z_o, a, b, c, ... must be introduced one after another, with a consequent reduction in efficiency. In general, however, a polynomial of degree 3 is adequate. More than 15,000 points were transformed at the Institute in 1958.

Astronomical Computations

Computations relating to positional astronomy can be handled very well on a small computer equipped with card programming, for while the computations are long, the data are not numerous (co-ordinates of a star, parameters fixing the position of the earth at a given moment).

Computation of catalogues of observation

The equal altitude method with a zenith distance of 30° (actually 30° 00′ 30″) is used for the astronomical measurements on the ground, which provide the network. This method requires a catalogue that gives the local sidereal time with a fair degree of accuracy. The problem comes down to a resolution of the positional spherical triangle of which the three sides are known:



P: pole
Z: place of observation of latitude φ
E: star of declination δ and right ascension α

These computations are carried out for the two passages of the star. The Borda formulae are used for this purpose at the present time although it is probable that they may eventually be abandoned. They furnish:

The elements in the passage of the star: azimuth A, angle to the celestial body S, hour angle H;

The differential coefficients dz/dH, $dH/d\varphi$, $dH/d\delta$ by means of which the catalogue can be computed for an adjacent latitude (infrequently done) or the observation evenings can be computed within a short time (simply by means of cumulated products). Thus:

$\Delta H = \Delta\alpha + dH/d\delta \Delta\delta + dH/d\varphi \Delta\varphi$ and $\Delta z = dz/dH \ \Delta H$

$\Delta\alpha = \alpha - \alpha_o$ α, δ and φ instantaneous elements of the star and of the station

$\Delta\delta = \delta - \delta_o$

$\Delta\varphi = \varphi - \varphi_o$ α_o, δ_o and α_o elements taken for the computation of the catalogue.

The computation relating to a particular latitude and comprising 350 stars, that is, 700 passages distributed over twenty-four sidereal hours, is effected in one and one-quarter hours of computer time, and the results for each star are punched on to cards. The catalogue itself is obtained by sorting these cards by sidereal hour and listing the results. If the differential coefficients are to be used in such a way as to preserve the complete accuracy of the observations, there must not be a departure of more than 2′ or 3′ from the latitude of the catalogue. This means that catalogues must be computed for each 5′, and this has been done from latitude −4° to latitude +30° (a total of more than 400 catalogues).

Computation of ephemerides

This has been done on behalf of the Tananarive Observatory in connexion with the International Geophysical Year. The problem is to supply for each day, to the nearest thousandth of a second, the exact sidereal time of passage of various stars at a zenith distance of 30° in relation to a particular observatory. This computation is very similar to the previous one, but the equatorial co-ordinates of the stars must be computed beforehand for each particular day. It quite soon became apparent that the application of the formulae of the nautical almanac to the computation of the co-ordinates involved considerable work. An effort was made to replace the limited expansions by finite formulae which are relatively simple and quick to compute electronically and are based on the fact that the variations in the co-ordinates of the stars are due almost entirely to the movements of the trihedron linked to the earth.

Two programmes have been set up by sighting the stars in relation to the ecliptic instead of the equator and in Cartesian co-ordinates rather than in spherical co-ordinates.

Computation of the mean ecliptic co-ordinates

If a basic file of the ecliptic co-ordinates of the year 1900 is available, nothing more is required than a simple rotation of the axes in Cartesian co-ordinates. If a basic file of equatorial co-ordinates is available for any year, the following computations are made:

$$\begin{cases} x = p \cos\delta \cos\alpha \\ y = p \cos\delta \sin\alpha \\ z = p \sin\delta \end{cases}$$ Cartesian equatorial co-ordinates ($p=1$)

x y z	X_o Y_o Z_o	ecliptic co-ordinates of the base year (change of axis)
$X\ddot{o}$ $Y\ddot{o}$ $Z\ddot{o}$	X' Y' Z'	ecliptic co-ordinates of the year 1900 (change of axis)
X' Y' Z'	X Y Z	ecliptic co-ordinates of the selected year (change of axis)

Computation of the co-ordinates at instant t

The mean ecliptic co-ordinates of the year constitute starting point. The annual aberration is a small ve situated in the place of the ecliptic. The parallax is a ve in the same plane perpendicular to the preceding vector.

The computation of these co-ordinates is very sim nothing more being required than to add the correspon vector (dx, dy, o). The vector ρ, which was unitary at beginning, is no longer so.

Thus: $tg\,\alpha = y/x$ $\qquad tg\,\delta = z\,(x^2 + y^2) - \frac{1}{2}$

The results are in complete conformity with those of nautical almanac. The so-called Fabricius corrections di pear, the formulae being valid even for the polar star.

ACTIVITIES OF THE INSTITUT GÉOGRAPHIQUE NATIONAL IN THE TERRITORIES OF ASIA AND OCEANIA [1]

Report by the Institut géographique national, France

CAMBODIA, LAOS, VIET-NAM

Between 1952 and 1954, an aerial survey of the greater part of the territories of Cambodia, Laos and Viet-Nam was under-

[1] The original text of this paper, submitted by France, under the title " Activités de l'Institut géographique national dans les territoires de l'Asie et de l'Océanie ", appeared in French as document E/CONF.25/L.56.

taken by the National Geographical Institute (Institut graphique national) at the scale of 1: 40,000. The plate was 13 by 18, and approximately 63,000 photographs taken. The area covered by the survey is shown on the in figure 1.

In April 1955, the Governments of Cambodia, Laos Viet-Nam took over responsibility for the cartographic v relating to their respective territories. The Institute ha

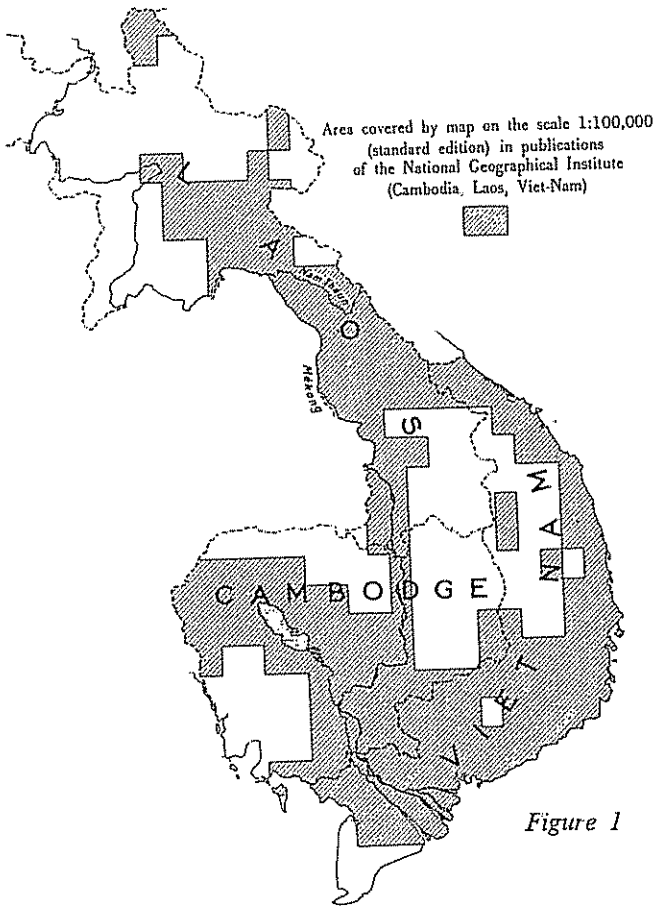
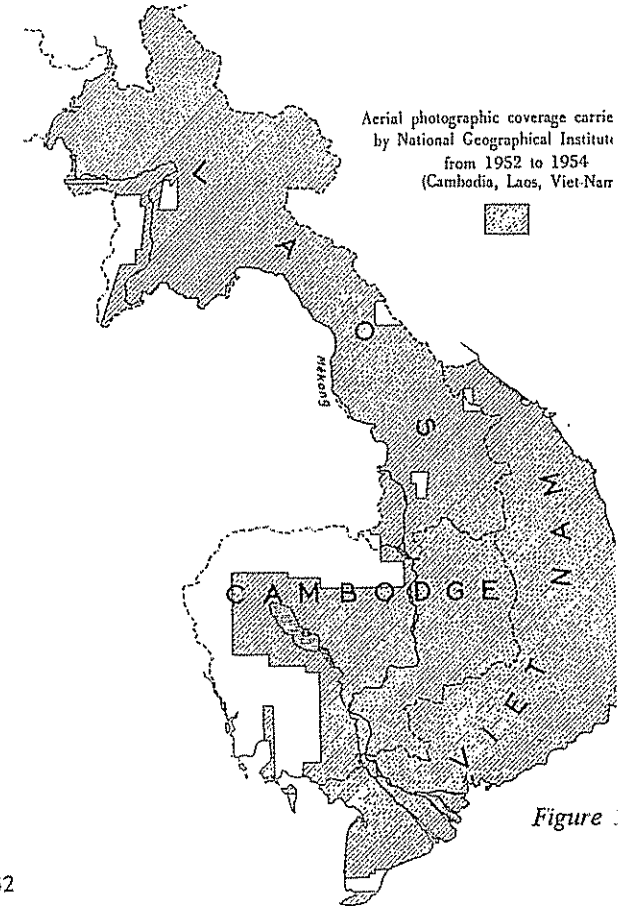
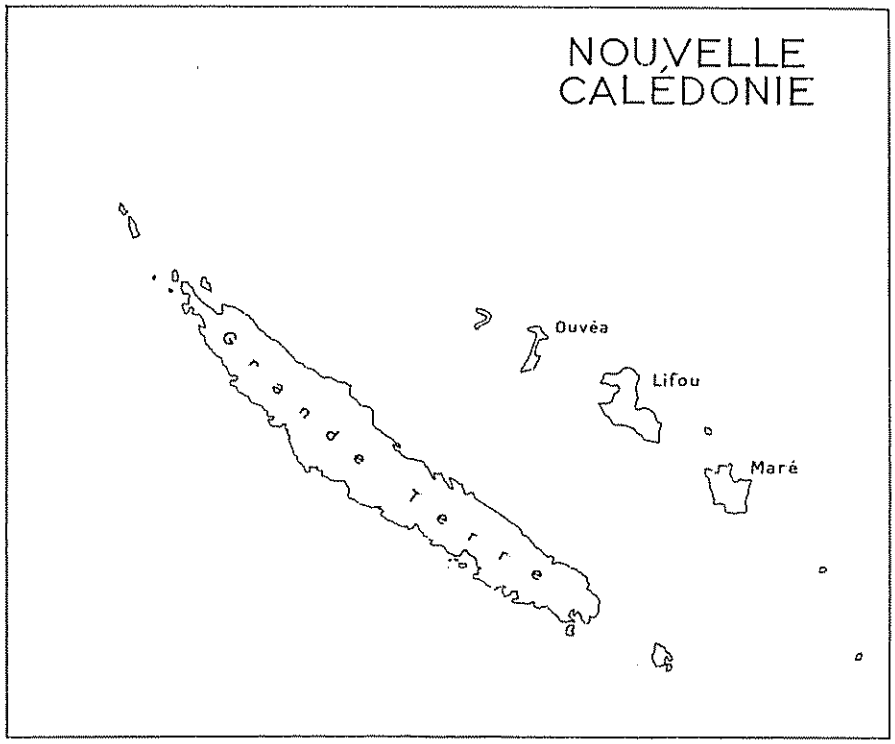


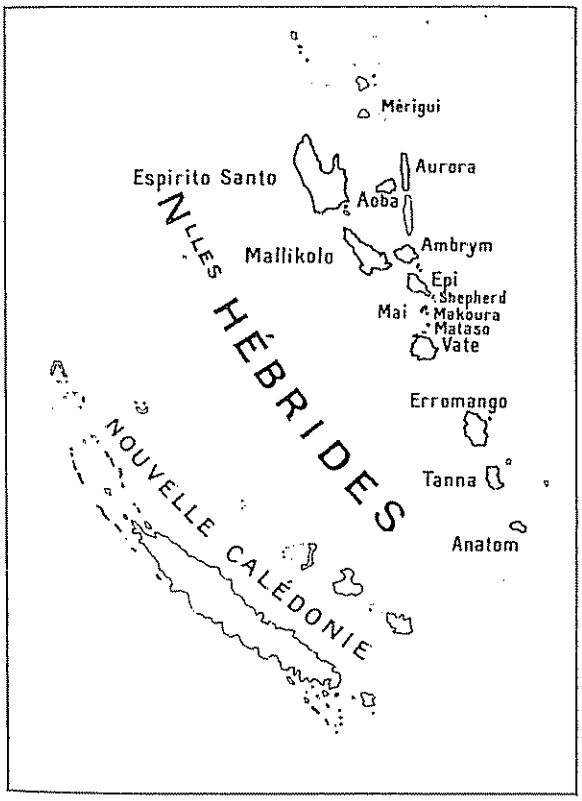
Figure 1



Figure



Aerial photographic coverage carried out by National Geographical Institute in 1954 and 1955
(New Caledonia, New Hebrides, Oceania)



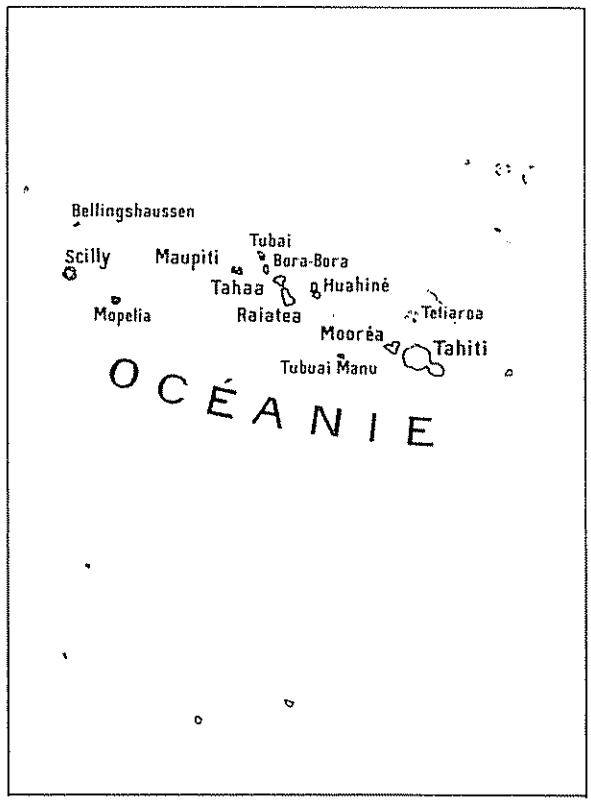


Figure 3

that date provided those territories with maps on scales ranging from 1: 25,000 to 1: 2,000,000. Most of the area of the three territories had been mapped at the scale 1: 100,000. Figure 2 shows the progress that has been made in the publication of the 1: 100,000 map.

At the request of the United Nations, the Institute has, in addition, recently completed a map at the scale 1: 20,000 of the Nam-Theun basin in Laos. On the basis of the field surveying carried out in 1956, the controls for plotting were determined by aerotriangulation. The eight sheets of the map were published in May 1958.

New Caledonia

An aerial survey of Grande Terre and of Maré, Lifou and Ouvéa islands was carried out in 1954 and 1955 at the scale 1: 40,000 (see figure 3). A total of 3,686 photographs on 13 by 18 plates were taken by the Institute's aerial survey squadron.

The field surveying work (geodetic and ground control) has made it possible to establish the controls for plotting by aerotriangulation. The plotting is now under way and will be completed in 1959.

New Hebrides

In 1954 and 1955, an aerial survey at the scale 1: 40,000 was carried out by the Institute's aerial survey squadron. This survey covered the entire area of the islands of Mérigui, Aurora, Ambrym, the Epi group, the Shepherd Islands, M Makoura, Mataso, Vate, Erromango, Tanna and Anat (see figure 3). The area of Espirito Santo, Aoba and Ma kolo islands was covered only in part. The entire sur comprised a total of 1,233 photographs on 13 by 18 plat

A survey mission carried out field surveying in 1957 a 1958. It set up the geodetic and astronomical operation the various islands and made the necessary preparations aerotriangulation, which is still being carried out.

Oceania

An aerial photographic coverage on 13 by 18 plates a at the scale 1 : 40,000 was carried out by the ae survey group in 1955 for the entire area of the isla of Tahiti, Mopélia, Maupiti, Bora-Bora, Bellingshauss Seilly, Tetiaroa, Tubuai, Manu, Raiatea-Tahaa, Tu Mooréa and Huahiné (see figure 3). This survey necessita a total of 520 photographs.

The plotting, at the scale 1: 40,000, for the islands of Tal Bora-Bora, Raiatea-Tahaa, Mooréa and Huahiné has b completed; a provisional edition of the maps of the isla of Mooréa, Huahiné, Tahaa and Bora-Bora has just b issued; and a provisional edition of the maps of Raiatea a Tahiti islands (the latter in five sheets) will be publis shortly.

The town of Papeete and the surrounding area have b plotted at the scale 1: 20,000.

REPORT ON CARTOGRAPHIC ACTIVITIES IN INDIA [1]

General

Cartographic activities in India consist of the work carried out by the Survey of India Department so far as land surveys are concerned and by the Naval Hydrographic Branch for hydrographic surveys. Private enterprise is very limited, there being only one company in India, the Air Survey Company of India (Private), Limited, which undertakes some aerial photography and surveys.

With the rapid development of India, the demand for maps on various scales varying from 1: 25,000 to 1: 1,000 for hydroelectric and multi-purpose projects, town development and the like, greatly increased and it was found that the Department was unable to cope with these demands in addition to its primary role of keeping up to date the basic map coverage of India on the one inch to one mile scale. Shortly before the first Regional Cartographic Conference for Asia and the Far East was held in February 1955 in Mussoorie, the Government of India had decided that the Survey of India Department must be expanded to cope with the increasing demands for surveys. This expansion is being satisfactorily implemented.

With effect from 1 October 1958, surveys and mapping be on the metric system in accordance with the Governn of India's decision to introduce the metric system of wei and measures. In a vast country like India, to bring all m on to the metric system is a task of no small magnitude the process must necessarily be a slow one.

With the adoption of the metric system, the scales contour intervals of our standard series maps will be:

(*a*) 1: 25,000 with a contour interval of 10 metres;

(*b*) 1: 50,000 with a contour interval of 20 metres, to rep the existing scale of one inch to one mile with a con interval of 50 feet;

(*c*) 1: 100,000 with a contour interval of 50 metres to rep the existing scale of one inch to two miles with a con interval of 100 feet;

(*d*) 1: 250,000 with a contour interval of 100 metre replace the existing scale of one inch to four miles wi contour interval of 250 feet.

Geodetic Surveys

The Geodetic and Research Branch of the Survey of I is organized into a headquarters section and three field pa and usually carries out the following tasks.

[1] The original text of this paper, submitted by India, appeared as document E/CONF.25/L.58.

Normal tasks

(i) *Geodetic triangulation.* In the course of recent years the primary series was extended over a length of 239 miles covering an area of about 3,967 square miles along the south-west coast of India. Laplace stations for control of azimuth were established at the starting base and at two other stations about seventy miles north along the series.

(ii) *Height of Mount Everest and other important Himalayan peaks.* The height of Mount Everest was re-determined as 29,028 feet above mean sea level as against the old value of 29,002 feet. In this revised determination, better value for the coefficient of refraction as determined by observations and the geoidal rise up to the peak obtained by plumb line deflections were used.

(iii) *High-precision levelling.* A second network of high-precision levelling is being carried out in the country. About 520 linear miles of it have been completed and the balance of about 800 linear miles remains to be done.

International Geophysical Year programme

(i) Precise latitude and longitude observations with the help of Wild T-4, Transit and Zenith telescopes have been carried out at Dehra Dun from 1 July 1957 onward, and are to be continued up to the end of December 1958.

(ii) Magnetic observations for horizontal force, vertical force and declination have been carried out at about sixty repeat stations spread over the whole of India, with the help of the quartz horizontal magnetometer (QHM), unifilar (Kew pattern) magnetometer and the dip circle. It is proposed to carry out similar observations at these repeat stations during the current field season as well, in order to reduce the value to epoch 1959.0.

(iii) Observations for earth tides by means of two precision gravimeters were carried out at four stations suitably located in the country. These observations consisted of half-hourly readings for thirty-one consecutive days at each station. It is proposed to carry out similar observations at four more stations in India during the coming winter. The data obtained so far are under analysis.

(iv) Annual tide predictions for thirty-eight ports between Suez and Singapore were carried out as usual. Tidal observations at sixteen ports by means of automatic tide gauges were also analysed for the tidal components. Also, observations for tidal streams were taken up for the first time by the Department, commencing with the Gulf of Cambay where about thirty sites were occupied and readings taken for twenty-five consecutive hours during both springs and neaps. It is proposed to complete such stream observations in the Gulf of Cambay and carry out similar observations in the Gulf of Cutch during the coming season. Apart from the immediate object of providing data for navigation, the stream observations will be utilized ultimately for preparing a tidal atlas for the coast of India.

Topographical Surveys

Owing to the heavy demand for surveys on varying scales for development purposes since the end of the Second World War, the primary task of the Survey of India Department of keeping up to date the basic map coverage for India has necessarily suffered a setback.

Photogrammetry

Shortly before the first United Nations Cartographic Conference for Asia and the Far East, when the decision to expand the Survey of India Department was taken, it was also decided to introduce the use of photo-plotting machines which would help to speed up the production of maps, particularly those on large scales required in connexion with the various development projects in India.

Under the United Nations Technical Assistance Programme, the Survey of India received one Wild autograph A-7 and one Wild RC5a camera, as well as being provided with the services of a foreign expert for eighteen months to start photogrammetry in India.

We were also very fortunate in receiving substantial assistance under the Indo-United States Technical Co-operation Programme in the form of first-order and second-order Wild plotting machines, third-order Zeiss plotting machines and other accessory equipment. With this equipment we propose to set up four photogrammetric units, each having two A-7s, four A-8s and seven stereotopes, besides accessory equipment.

An intensive training programme in photogrammetry was put in hand immediately and is now almost completed. Two of our officers were awarded fellowships by the United Nations Technical Assistance Board for a post-graduate course, which they successfully completed, at the International Training Centre for Aerial Survey at Delft, Netherlands.

As training of personnel was being completed, some productive work was also undertaken. This productive work has already proved that the introduction of these plotting machines was a step in the right direction. The out-turn on various scales has increased by 100 per cent in most cases, particularly on larger scales, when compared with the out-turns previously achieved by other methods. Cost has also been reduced and greater accuracy has been achieved. Aerial photography for these photogrammetric units and the Department in general, with a coverage of about 190,000 square miles, was carried out by the Indian Air Force and by the Air Survey Company of India (Private), Limited, the latter operating under a contract with the Government of India.

Mapping and Printing

India has been concentrating on the preparation of both the IMW series sheets and the 1/M-WAC-ICAO charts falling under its production responsibility on two different specifications. The interim specifications are based in general on the resolutions of 1913 and 1928 of the Central Bureau of the International Map of the World on the Millionth Scale with certain modifications. Our own requirements for standardization, as put forward before the Mussoorie Conference,[2] are being followed for the former, while the International Specifications framed by the International Civil Aviation Organization and published as " International Standards and

[2] *Official Records of the Economic and Social Council, Twenty-first Session, Annexes*, agenda item 6, document E/2823, page 11.

Recommended Practices—Aeronautical Charts—annex 4 to the Convention on International Civil Aviation" are being followed in respect of the latter.

As regards the IMW series, we would still recommend for international use the standardization and adoption of the Interim Specifications presented by India at the Mussoorie Conference. They should, of course, allow sufficient flexibility so that no change in the existing sheets would be required and countries would not be prevented from producing maps when certain factors of their local requirements do not meet the specifications.[3]

As regards 1/M-WAC-ICAO charts, appreciable progress has been achieved towards their production. Out of a total allotment of twenty-three charts, five have been printed and a sixth is being printed, while the drafting of the remaining seventeen has been practically completed ; we hope to bring out another half-dozen within the next twelve to eighteen months.

India successfully produced at the end of 1957 a National Atlas in Hindi, comprising twenty-six maps of topical interest printed in multi-colours. The work for the preparation and printing of an English edition of the National Atlas is now in hand.

Hydrographic Surveys

(*a*) *Ships.* The surveying group of the Indian Navy consists of I.N.S. Jumna, Investigator and Sutlej. The three ships are frigates especially converted for surveying duties. A new surveying ship of 2,000 tons is under construction at the Hindusthan Shipyard, Vizagapatam, and is expected to be launched by January 1959. It is being provided with a helicopter and other modern auxiliaries especially useful for its role.

(*b*) *Personnel*

(i) *Surveying personnel.* The position regarding the cadre of surveying officers has not been very satisfactory. Certain steps are being taken to improve this situation.

(ii) *Cartographic personnel.* The position regarding trained cartographic personnel has been most acute during the period under review. There has been only one trained cartographer throughout the period and other trained personnel have not been available.

[3] *Ibid.*, paragraph 34.

Regarding the training of cartographic personnel, Hydrographic Department of the British Admiralty has b most helpful in the past. They have also offered to take t or three more of the cartographic personnel for training the near future.

(*c*) *Material.* The following media have been used for basic plates of navigational charts:

(i) Copper engraving;

(ii) Enamel-coated zinc;

(iii) Zinc-mounted drawing paper.

All navigational charts are now being drawn on zi mounted drawing paper.

Experiments are being carried out on a plastic mate called Cobex, but this is difficult to obtain due to tight imp regulations. If the material is found suitable for use in Inc indigenous production will be attempted.

(*d*) *Work carried out and projected*

(i) The first navigational chart to be produced in Indi already in the press. It is expected to be published in a mont time. Two more charts are now under compilation.

(ii) With effect from 15 January 1958, Indian Notices Mariners are being published by the Naval Hydrograp Office, in printed form. These are being issued gratis to authorities concerned and to international shipping through the world.

(iii) An Indian list of lights is now under compilation an expected to be published in about six months' time.

(*e*) *General*

The hydrographic expert from the Netherlands, wh services were made available by the United Nations under Technical Assistance Programme, left India in 1955 a having trained a group of surveyors for the Marine Divis of the Public Works Department of the State of Bombay.

India became a member of the International Hydrograp Bureau in 1956. The country is represented by the Chief Hyd grapher, Indian Navy, who attended the Seventh Internatio Hydrographic Conference at Monaco in May 1957. The Ind Hydrographic Office has been fortunate in acquiring the ass ance so willingly offered by the United Nations, the Bri Royal Navy and the Netherlands Government.

CARTOGRAPHY IN INDONESIA[1]

Report submitted by Indonesia

Foreword

With the Proclamation of Independence on 17 August 1945 a new era began for Indonesia and a period of centuries of occupation by foreigners ended. Its newly achieved independence and the sympathy shown by other countries stimulated the energy of this young nation and gave it the confide that all difficulties and obstacles could be overcome. process of building up the country began with great spirit plans were made to develop its existing resources. Indon has many natural resources, both known ones and other yet undiscovered, and in addition has a population which increase production capacity to an extent greater than has been achieved. The declining economic situation is due

[1] The original text of this paper appeared as document E/CONF. 25/L.69.

the fact that Indonesia became an independent country only a few years ago and since then the restoration of the country's security has been its primary task. It was different with India and Pakistan, which, being members of the British Commonwealth, had experienced people to call upon. Indonesia has to solve all its problems alone, mostly with inexperienced people; during the colonial period few opportunities were given the Indonesian people to gain the knowledge and experience necessary for the administration of the country. However, Indonesia's favourable natural conditions and geographical situation are very conducive to raising its standard of living within a reasonable time.

In general, the Government's aim is to increase the productivity of the existing resources—material as well as manpower—to attain a constant land revenue and a higher standard of living, including better education and health and other conditions for the welfare of the population. For all of this an economic development programme and co-ordination between the existing authorities are required But the success of all of these depends on the quality and reliability of the existing information about population, soil, water utilization and raw materials.

It is by no means an exaggeration to say that maps are important tools which cannot be ignored, not only for planning purposes but also for the successful execution of the development programme of the country.

Triangulation (Geodesy)

The purpose of geodetic and astronomic measurements is to form a network of points on the earth's surface—at heights determined above mean sea level—to serve as a basis for the construction of maps. In the nineteenth century it was acknowledged in Europe that the construction of maps had to be based on a good triangulation system; such a system was started in Indonesia about 1875.

It is true that by a government decree of 25 December 1853 it was decided to use triangulation points as a basis for the topographic mapping of the Tjirebon area, but evidence shows that the experts in topographic mapping in those days did not understand their proper application. This was due to the fact that triangulation surveys were done by the Geografische Dienst van het Department van Marine (Geographical Service, Naval Department), while the topographic survey was in the hands of the Topografisch Bureau en der Militaire Verkenningen (Topographic Board and Military Reconnaissance), as an independent part of the Corps of Engineers.

On 1 May 1882 the Geografische Dienst ceased to exist and not long after, by government decree, a Triangulation Section was set up, forming a part of the Topografische Dienst. Thus, there were no more misunderstandings about the need for a triangulation framework for topographic mapping, or about triangulation surveys being completed before the detailed surveys could take place. But the triangulation survey must be done four or five years in advance of the detailed surveys, because of the time needed for the preliminary work, such as reconnaissance, erection of pillars (bench-marks) and taking base, astronomic and angular measurements.

Because of the urgency and great demand for maps of several areas, the mapping programmes are subject to change, which places those responsible for the triangulation surveys in a difficult position, since these surveys are so closely followed by the detailed surveys. It is, of course, not a good arrangement.

In the field of astronomy and geodesy (see figure 4), Indonesia is on a level with its neighbours, and opportunities are now open to begin geodetic works of a scientific character, such as geographic position measurements, and to extend them to the Tanimbar Islands, which form a network, connected at the equator, from Atjeh through Sumatra, Java and Sumbawa.

Mapping Situation

Looking back to that period when maps were made on an unsound basis with poorly-designed instruments, and comparing the materials then available to what we now have, it will seem surprising that, in the face of such shortcomings, maps could then have been made at all.

Maps made before the beginning of the nineteenth century showed only the geographical character of the area, since their purpose was purely of a commercial nature. Later on, when, due to the political situation, it was found necessary to protect Indonesia from foreign influences, the need for maps for defence purposes was realized. It is true that after this topographic maps were made, but, as mentioned above, these were made on the basis of the triangulation points established about 1875. As previously explained, adequate topographic maps are made on the basis of an accurate triangulation system; reliable maps could not be constructed, therefore, for areas where such triangulation points did not exist.

In addition to this type of mapping activity, the Topografische Dienst also made what are known as " topographic sketch-maps ", that is, maps made from sketches without control points. There were also maps made by officers, missionaries, civil servants, military patrols and so on, generally called " sketch-maps ", all of which differ from one another. There still exist in Indonesia " blank areas " for which no maps have yet been made. Figures 5 and 6 contain information on the general mapping situation in Indonesia and on the dates of the existing maps. Maps with scales of 1 : 25,000, 1 : 50,000 and 1 : 100,000 belong to the class of togographic maps which show the planimetric and hypsometric representation of the topography. Topographic sketch-maps have scales different from these.

Manuscript maps on a scale smaller than 1 : 100,000 are not mentioned here since a good manuscript map is compiled from adequate and large-scale topographic maps; those compiled from other kinds of maps may be classified as sketch-maps.

Needless to say, map production in Indonesia lags far behind the country's need for maps for economic development and defence purposes.

Present Status of Photogrammetry in Indonesia

The science of photogrammetry has developed to such an extent that its use has been accepted in the western countries for most survey purposes. In Indonesia aud many other

far eastern countries, too, this has, in recent years, resulted in a fundamental change in the approach to land surveying.

Photogrammetry will be applied in Indonesia in all cases of mapping where this modern method would seem to offer advantages of greater speed, economy and accuracy than the older terrestrial method.

Developments in photogrammetric activities in Indonesia during the past five years may be summarized as follows.

(*a*) Aerial photography has been carried out since 1950 by the Indonesian Air Force, not only for military operation purposes and reconnaissance mapping, but also for normal map production.

(*b*) Modern aerial cameras and stereoplotting instruments have been furnished and are now in use.

(*c*) Aerial photo-interpretation is more widely used in the preparation of forestry, land use, agriculture and soil survey maps.

(*d*) Studies have been made on the application of aerial photogrammetry to surveying of high accuracy, that is, cadastral surveying. For certain reasons the Cadastral Service has not, up to now, decided to accept photogrammetry as a standard method of surveying for cadastral maps.

(*e*) Almost all map-producing organizations are applying photogrammetric techniques.

(*f*) Photogrammetric science now appears on the programmes of the technical faculties of many universities.

Aerial photography

Since 1950 aerial photography has been carried out by the Indonesian Air Force, except for eastern Sumatra, which was photographed for the Caltex Oil Company by Fairchild in 1952. It is realized that this situation has several disadvantages, for example:

(*a*) It gives no guarantee of the permanent availability of a well-trained and experienced crew, because a military organization suffers more than a civilian one from changes in personnel;

(*b*) A regular supply of aerial photographs cannot be depended upon because aerial photography for normal map production can hardly lay claim to a first priority.

These drawbacks will certainly prevent the speeding up of the survey in Indonesia. Therefore, the Survey Directorate of Indonesia expects that, in the near future, the Civil Aviation Service (G.I.A.) will be able to fulfil Indonesia's needs, or that it will be allowed to establish its own flight organization.

Aeroplanes

Dakotas are the aeroplanes now used for photogrammetric purposes. Owing to their old design and thus limited ceilings, the choice of the photo-scale for certain objects is also limited.

These survey planes are not usually completely equipped with all necessary auxiliary instruments, such as statoscopes, gyroscopic control, radar altimeters and the like. Normally, ground check points are used for controlling the parallel strips with the aid of special sights. Difficulties arise from this simple method, particularly in forest areas with a monotonous pattern, so that gaps often result.

Aerial cameras

Modern types of cameras now in use for photogrammetric map production are:

Wild RC5, 18 by 18 centimetres, with Aviotar, f = 21 centimetres;

Wild RC5, 18 by 18 centimetres, with Aviogon, f = 11.5 centimetres;

Fairchild T11 camera, 9 by 9 inches, with Aviogon, f = 6 inches.

These are all film cameras, calibrated by the factory. They ha distortion-free lenses, provide for a high degree of resoluti and afford evenness of image and perfect perspective represe tation over the whole field.

Old-fashioned cameras are no longer used for mappi purposes. The scale of photography for topographic mappi in Indonesia is normally 1 : 20,000. One of the reasons the choice of this photo-scale is that it is acceptable for aer photo-interpretation in nearly all the technical fields wh aerial photographs are used.

Photographic films and papers

Films used are Eastman Kodak Super XX Aerographic a Gevaert Hyper Rapid. Normal photographic papers are us such as:

(*a*) Bromide paper by Kodak and Gevaert;

(*b*) Chloride paper by Gevaert (Ridax);

(*c*) Resisto paper by Kodak.

Owing to the fact, however, that Indonesia already has pho grammetric plotting instruments using common cont prints, photographic papers with aluminium foil inserts soon be used to increase the accuracy of the map.

Furthermore, Gevaert glass plate diapositives are norm used.

Areas photographed

Several parts of Djawa, Sumatra and Kalimantan h been photographed for photogrammetric purposes in c nexion with the production, not only of regular topograp maps, but also of certain technical maps required for spe purposes relating to the economic development of Indone These purposes are:

(*a*) *Agriculture*. Construction of detailed soil maps. general, these maps play an important part in land use plann and are also very useful for town and country planning highway engineering.

(*b*) *Water utilization*. Large-scale maps for drain irrigation and hydroelectric power projects (Djatiluhur Asahan project).

(*c*) *Forestry inventories*. Compilation of medium-s forestry maps by photogrammetric methods. Interpreta of aerial photographs.

(*d*) *Miscellaneous*. (i) Distribution of population/transmi tion (Sukadana and Djajaloka); (ii) road building (A

Palembang); (iii) agricultural centres; (iv) mineral resources and industries (iron and steel (Semangus), resin).

Photogrammetric maps are therefore used as a basis for the intensification and organization of the over-all development scheme. The total area photographed during the past five years was about 25,000 square kilometres.

The photo-scale varies from 1 : 5,000 to 1 : 20,000, but most areas are photographed at 1 : 20,000. The size of the negative is 18 by 18 centimetres or 23 by 23 centimetres.

Difficulties of aerial photography for mapping purposes

The greatest difficulty has been that, until now, no special agency or office has existed to provide regular information on real weather conditions. This may be obtained from several offices for civil aviation, but it is not usual to depend on such information for mapping purposes (aerial survey).

Other technical difficulties

In experiments on cadastral surveying, applying photogrammetric methods, it is sometimes difficult to identify the signal marks placed on roads which are not encircled on the aerial photographs.

Plotting instruments

The photogrammetric instruments which contribute for the most part to mapping productivity in Indonesia are the following.

At Djakarta: one Wild Autograph type A7; one Wild stereoplotting instrument type A8; two Wild stereoplotting instruments type A6; four Zeiss stereotope plotting instruments; three complete sets multiplex Bausch and Lomb with nine projectors; one radial secator; several simple photogrammetric instruments, such as mirror stereoscopes and parallax-bars (Zeiss and Wild).

At Bandung: one Wild Autograph type A5; three Wild stereoplotting instruments type A6; one rectifier SEG V; two Zeiss stereotope plotting instruments; several Wild and Zeiss mirror stereoscopes.

Third-order Zeiss stereotope plotting instruments are also used in Indonesia for the compilation of soil survey and forestry maps.

Mapping methods

Aerial triangulation

Aerial triangulation is not required for the whole country, since many parts are already covered by third-order triangulation and even by fourth-order triangulation for the cultivated areas (Djawa).

There also exist triangulation points observed by other governmental services or private concerns, which are of sufficient reliability since they are normally connected to the national geodetic triangulation net.

Up to now, aerial triangulation has been applied to the establishment of the passpoints necessary for detail plotting. The decision to apply aerial triangulation to mapping depends normally upon the accuracy required and whether or not it will be economical for a given type of terrain. The method of operation and adjustment is the usual one, and the results in most cases have been quite tolerable.

Radial triangulation

In flat areas, mechanical radial triangulation will be used to obtain the minor control points needed for rectification of the photographs and for detail plotting. Only in those areas which have a dense network of second-order and third-order triangulation will the ground control points for the rectifier be determined directly, to increase the accuracy of the map as a compensation for the higher cost involved. For topographic maps at a small scale and especially for flat areas, this method is accurate enough.

Restitution of air photographs

Stereopairs. The restitution of air photographs is mainly carried out at the Photogrammetric Institute of the Military Topograhic Service at Djakarta, and at the Central Photogrammetric Service at Bandung, which, as the civil mapping organization, has the task of large-scale and medium-scale map production. These organizations are under the direct supervision of photogrammetric engineers. At the Military Topographic Service, the base map is normally produced on drawing paper with aluminium foil inserts (correctostat) at a scale of 1 : 10,000. From this map all topographic maps are derived—namely, those at 1 : 25,000, 1 : 50,000 and 1 : 100,000. At the Central Photogrammetric Service at Bandung, photogrammetric mapping is done directly on plastic material (astralon).

Single pairs of photographs. Due to the fact that Indonesia now has at its disposal the new Zeiss rectifier SEG V, it is planned in future to map the low-lying and coastal plains by using the well-known method of rectifying single pairs of photographs.

Capacity of the plotting instruments in relation to one year's map production

Supposing that the aerial photography is carried out partly with a camera 18 by 18 centimetres and partly with a camera 23 by 23 centimetres on a photo-scale 1 : 20,000, and further that one stereopair is finished within two days, a maximum yearly map production of ± 13,600 square kilometres can be reached by the Military Topographic Service. The reasons why the maximum capacity has not yet been obtained are mainly that funds are not always available at the time they are needed for aerial survey (aerial photography and mapping), and that no regular supply of aerial photographs is forthcoming from the Indonesian Air Force.

Production as from 1955

Topographic maps

In the period from 1955 to date the following mapping activities were carried out with the use of photogrammetric methods:

(*a*) New topographic maps of Bali at a scale 1 : 25,000;

(*b*) New topographic maps of southern Sumatra at a scale 1 : 50,000;

(*c*) New topographic maps of eastern Sumatra at a scale: 1 : 100,000;

(*d*) Revision of the existing topographic maps of Djawa at a scale 1 : 50,000; for certain reasons, part of the revision was done by the classical terrestrial method.

Production. Seventeen sheets of scale 1 : 25,000, each covering an area of 85 square kilometres, twenty sheets of scale 1 : 50,000, each covering an area of 340 square kilometres, and seven sheets of scale 1 : 100,000, each covering an area of 1,350 square kilometres have been completed by the Photogrammetric Institute of the Military Topographic Service.

Technical maps

Technical maps as a basis for civil engineering. As already mentioned, aerial photogrammetry is applied to various fields of civil engineering. It has been extended to many branches of that field, including city planning (Bandung; Palembang), hydroelectric planning (Asahan; Djatiluhur), road-building, road improvements and extensions (Atjeh; Palembang), irrigation (Krawang; Sukadana/Tegineneng), harbour improvement (Bitung) and location of water pipelines (Tjikalong). A great many technical maps for these purposes have been produced during the past four years, the scales varying between 1 : 2,000 and 1 : 10,000.

Methods to increase map production

If there are no financial problems, the yearly map production—especially of topographic maps—can be increased mainly by the following methods: (1) a more regular supply of aerial photographs, and (2) a smaller photo-scale—for example, photo-scale 1 : 30,000 for the topographic map 1 : 25,000 and photo-scale 1 : 40,000 or 1 : 50,000 for the topographic maps 1 : 50,000 and 1 : 100,000.

Accuracy and economy

Accuracy

The actual accuracy of the maps, both as to position and height, has not yet been determined.

The maps are tested in the field only by the normal terrestrial check measurements. For the time being, the maps are qualified as good when they fulfil the same requirements as already determined for the terrestrial topographic map. It is realized that much work still remains to be done in the field of mapping, with regard not only to the existing map situation, but also to the economic development of Indonesia. Therefore, the best mapping policy to follow would seem to be to produce as many new maps as possible within the shortest possible time, with accuracy sufficient for their special purposes. The determination of the actual accuracy of these maps may come later.

Economy

To give some information concerning the economy of the application of aerial photogrammetry to topographic mapping, it is noted that up to now this useful method has cost, on the average, about 50 per cent less than the classical terrestrial survey, and is also about three times quicker.

Educational standards

For the task of operator of the (precise) stereoplotting and other photogrammetric instruments, it has proved sufficient to have a person with a secondary education who has successfully followed a special course in practical photogrammetry. In Indonesia, such personnel must have completed the basic two-year course in terrestrial surveying and, in addition, a special course in photogrammetry, also of a two-year duratic It has proved necessary for leading personnel to have h besides the above-mentioned terrestrial and photogrammet courses in the home country, two years of higher educatior especially in mathematics—and to have successfully complet a more specialized photogrammetric course at institutes abro staffed by a sufficient number of experts in this field; for ample, the International Training Centre for Aerial Surv at Delft.

CADASTRAL SURVEY

Report of the survey experiments and computations execu with large-scale aerial photography of Bandung, West Ja with the Wild Autograph A5 for the determination of accuracy of the terrestrial co-ordinates of points which can obtained photogrammetrically (Experiments in the applicat of aerial photogrammetry to cadastral surveying)

Data

(1) The aerial photographs were taken in May 1956 w the Wild RC5 film camera (No. 106), which has a focal tance of 210.73 millimetres.

(2) The flying height H above the terrain during the pho graphy was about 1,260 metres.

(3) The photo-scale $\frac{f}{H}$ was therefore about 1 : 6,000.

(4) The overlap in the flying direction of two success photographs was about 60 per cent of the size of the phc graphs (18 by 18 square centimetres).

(5) The terrain area in one stereopair which can be measu stereoscopically was then about 450 by 900 square met

(6) The terrestrial foundation consisted of polygon poi of which Polyeder co-ordinates and heights were measu and computed by the Cadastral Service.

Remarks

All of the ground control points are visible on the phc graphs because they are encircled by concrete curbs wit mean radius of about 10 centimetres.

The proper polygon points generally do not coincide v the centre of gravity of the white concrete curbs; these cen were measured in the Autograph, and the radius of the cir varies in many cases from ±8 centimetres to ±15 centimet

Measurements

(1) The photopair 15-16 from run V was *provision relative oriented* in the Wild Autograph A5 (No. 242) accorc to the method of Von Gruber for independent photopa by which a scale of about 1 : 3,000 was chosen for the mc scale, which means an enlargement of the photo-scale by ab two times.

(2) After that the photopair was *provisionally abso oriented* with the aid of three of the nineteen polygon poi already identified.

(3) Next the photopair was *numerically relative orie* twice in succession according to the stringent method adjustment worked out by Ir. J. Henkel, that is, with the

of nine observations of the vertical parallaxes and with the use of the Dove-prisms.

(4) In this definitively relative oriented and provisionally absolute oriented photopair, the model co-ordinates x, y and h of all the nineteen already identified points were then measured twice in the model.

Computations

(1) By using a stringent adjustment method, the *definitive corrections* to the tip, $\Delta\psi$ and to the tilt $\Delta\omega$ were numerically computed from the measurements and the given terrestrial co-ordinates of the nineteen polygon points.

(2) With the aid of the above-mentioned correction $\Delta\psi$ and $\Delta\omega$ the *differences* were determined between the terrestrially measured heights and the photogrammetrically measured heights of the nineteen polygon points.

(3) The *model co-ordinates* x and y of the nineteen polygon points were *provisionally* transformed to the system of the terrestrial co-ordinates by means of a conformity connexion to two of those points.

(4) For each polygon point, the *differences* between the given terrestrial co-ordinates X_T and Y_T and the co-ordinates X and Y computed from the measurements were represented in direction and in magnitude by vector, the linear scale of which was exaggerated (1 : 10), compared with the scale of the map (1 : 10,000).

(5) Seven polygon points were chosen from the diagram, the mean differences of which can be taken as representative of the whole. These seven points were used for the computation of a more reliable conformity connexion.

(6) With the aid of the conformity transformation formulae obtained, the *model co-ordinates* X and Y of all nineteen points were transformed to the given terrestrial co-ordinate system X_T and Y_T, and next the *co-ordinate-differences* were determined between the given and the computed co-ordinates.

(7) The *mean square errors* in various quantities were determined by computations based on theoretical derivations considered generally acceptable.

Mean square errors (m.s.e.)

Taking the flying direction as the x axis and the perpendicular to it as the y axis, and using the following denominations:

U_p = m.s.e. in the single parallax measurements (by using Dove-prisms),

U_l = m.s.e. in the single measurements in direction X or Y by constant height,

$M_{X_T}, M_{Y_T}, M_{H_T}$ = m.s.e. in the given terrestrial co-ordinates at scale of the terrain,

$U_{X_T}, U_{Y_T}, U_{H_T}$ = the same, but at scale of the photographs,

M_{X_F}, M_Y, M_H = m.s.e. in the co-ordinates of a photogrammetrically measured point, caused by purely photogrammetrical sources of errors, at scale of the terrain,

$U_{X_F}, U_{Y_F}, U_{H_F}$ = the same, but at scale of the photographs,

M_X, M_Y, M_H = total m.s.e. in the photogrammetrically measured and computed points, so caused by photogrammetrical and terrestrial errors, at scale of the terrain,

U_X, U_Y, U_H = the same, but at scale of the photographs,

$1 : S_f$ = photo-scale,

n = number of photogrammetrical measurements of one point,

f = focal distance of the camera,

b = photo-base,

c = a constant factor, depending on camera and plotting equipment,

the following are obtained:

$$M_X^2 = M_{X_F}^2 + M_{X_T}^2 = S_f^2 \, (U_{X_F}^2 + U_{X_T}^2)$$
$$M_Y^2 = M_{Y_F}^2 + M_{Y_T}^2 = S_f^2 \, (U_{Y_F}^2 + U_{Y_T}^2)$$
$$M_H^2 = M_{H_F}^2 + M_{H_T}^2 = S_f^2 \, (U_{H_F}^2 + U_{H_T}^2)$$

Further, with a rough approximation:

$$U_{X_F}^2 = \frac{l\,c^2}{12} U_p^2 + \frac{l}{n} U_l^2.$$
$$U_{Y_F}^2 = \frac{l}{3} (l + c^2) U_p^2 + \frac{l}{n} U_l^2.$$
$$U_{H_F} = \frac{f^2}{b^2} (l + c^2) U_p^2.$$

Results of the measurements in the aerial photographs of Bandung

From the measurements it follows:

U_p = 5.6 micron.
U_l = 6.5 micron.

Estimating that:

$M_{X_T} = M_{Y_T}$ = 6.0 cm,
M_{H_T} = 2.0 cm,

Derived from computations: c = 2.3.
Furthermore it is known that: n = 2,
f = 210 mm,
b = 70 mm.

As final results were found by measurements:

U_X	= 10.8 micron,	M_X	= 6.5 cm,
U_Y	= 14.5 micron,	M_Y	= 8.7 cm,
U_h	= 41.3 micron,	M_h	= 24.8 cm,

and by application of the above-mentioned formulae:

U_{X_F}	= 5.8 micron,	M_{X_F}	= 3.5 cm,
U_{Y_F}	= 8.4 micron,	M_{Y_F}	= 5.0 cm,
U_{H_F}	= 39.9 micron,	M_{H_F}	= 24.0 cm,

and:

U_X	= 11.8 micron,	M_X	= 7.1 cm,
U_Y	= 13.6 micron,	M_Y	= 8.2 cm,
U_h	= 40.1 micron,	M_h	= 24.1 cm.

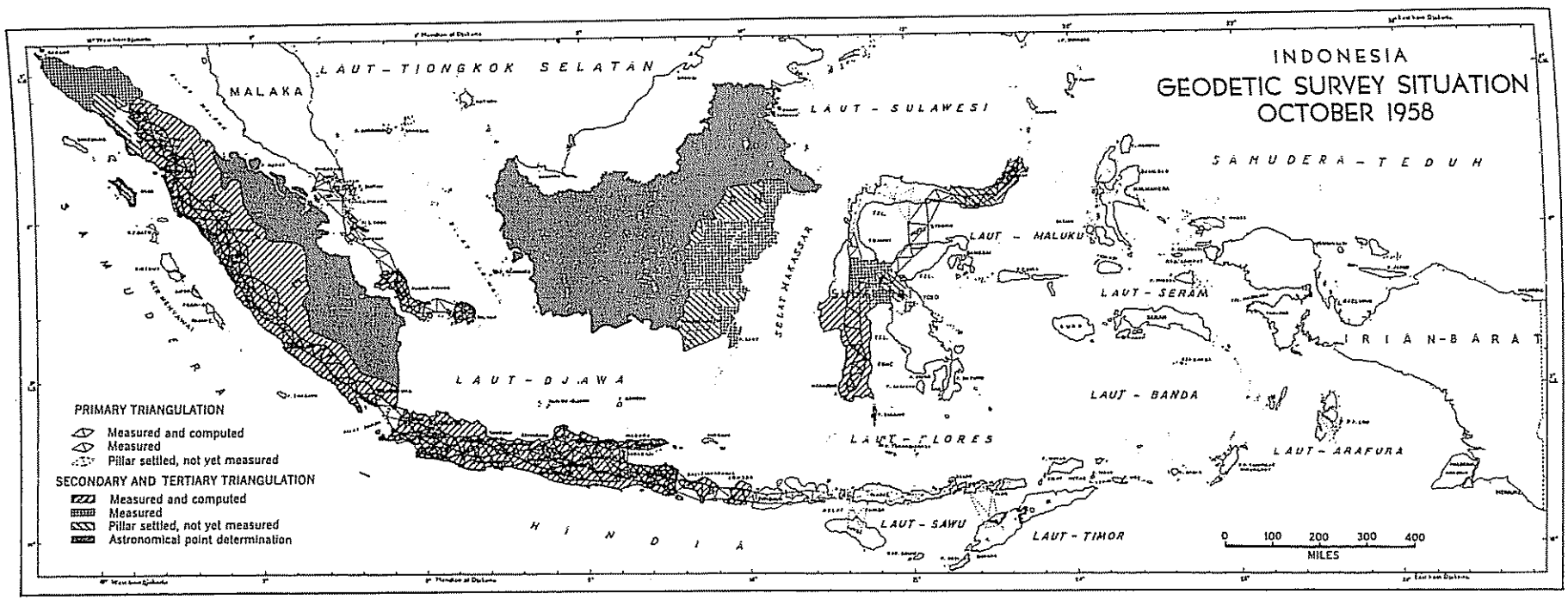

INDONESIA
GEODETIC SURVEY SITUATION
OCTOBER 1958
LAUT – TIONGKOK SELATAN
MALAKA
LAUT – SULAWESI
SAMUDERA – TEDUH
LAUT – MALUKU
LAUT – SERAM
IRIAN-BARAT
SELAT MAKASSAR
LAUT – DJAWA
LAUT – BANDA
LAUT – FLORES
LAUT – ARAFURA
LAUT – SAWU
LAUT – TIMOR
H I N D I A
PRIMARY TRIANGULATION
Measured and computed
Measured
Pillar settled, not yet measured
SECONDARY AND TERTIARY TRIANGULATION
Measured and computed
Measured
Pillar settled, not yet measured
Astronomical point determination
0 100 200 300 400
MILES

Figure 4

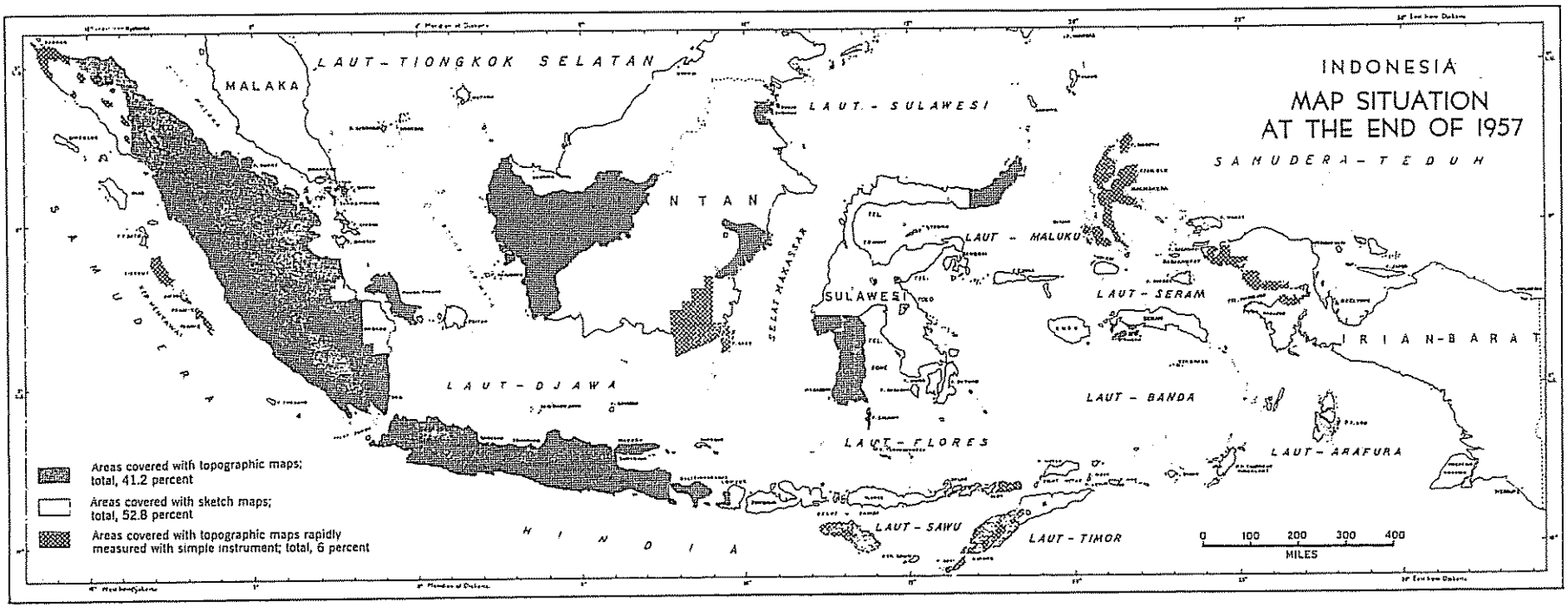

INDONESIA
MAP SITUATION
AT THE END OF 1957
MALAKA
LAUT - TIONGKOK SELATAN
LAUT - SULAWESI
SAMUDERA - TEDUH
LAUT - MALUKU
SULAWESI
LAUT - SERAM
IRIAN-BARA
SELAT MAKASSAR
LAUT - DJAWA
LAUT - BANDA
LAUT - FLORES
LAUT - ARAFURA
LAUT - SAWU
LAUT - TIMOR
H I N D I A
Areas covered with topographic maps; total, 41.2 percent
Areas covered with sketch maps; total, 52.8 percent
Areas covered with topographic maps rapidly measured with simple instrument; total, 6 percent
0 100 200 300 400
MILES

Figure 5

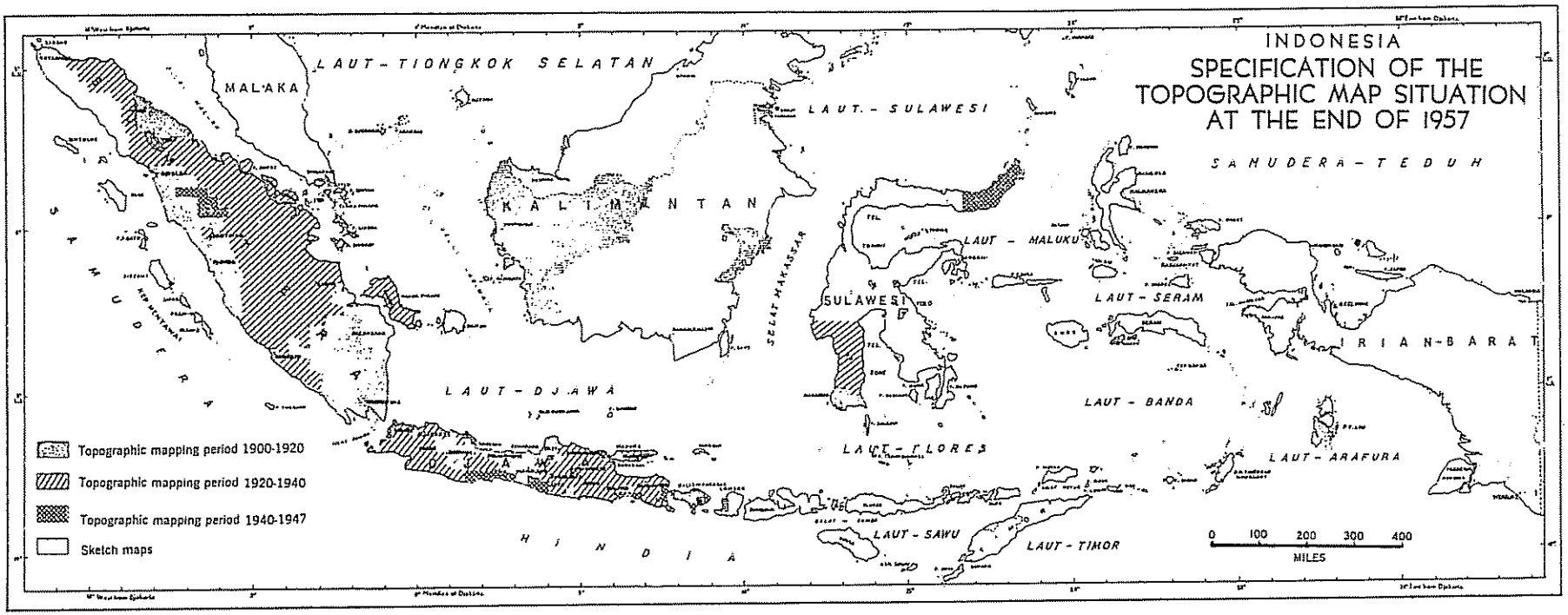

INDONESIA
SPECIFICATION OF THE
TOPOGRAPHIC MAP SITUATION
AT THE END OF 1957
LAUT - TIONGKOK SELATAN
MALAKA
LAUT - SULAWESI
SAMUDERA - TEDUH
KALIMANTAN
LAUT - MALUKU
SULAWESI
LAUT - SERAM
IRIAN-BARAT
LAUT - DJAWA
LAUT - BANDA
LAUT - FLORES
LAUT - ARAFURA
LAUT - SAWU
LAUT - TIMOR
HINDIA
Topographic mapping period 1900-1920
Topographic mapping period 1920-1940
Topographic mapping period 1940-1947
Sketch maps
0 100 200 300 400
MILES

Figure 6

REPORT ON CARTOGRAPHIC ACTIVITIES IN IRAN [1]

by the National Cartographic Centre, Iran

Recognizing the importance of cartography for the provision of accurate and reliable data for purposes of economic and social development, the United Nations Economic and Social Council, in 1948, recommended that the Member Governments should take appropriate action to stimulate the accurate mapping of their national territories and should encourage international co-operation in this field. We are pleased to note that the Council is making every effort to accomplish this purpose.

One thing that is certain—particularly as regards countries which have taken very energetic action to further their development—is that not all States possess the latest scientific and technical data needed for modern high-precision mapping

It is equally clear that certain mapping projects cannot be successfully carried out without international co-operation. No country is able by its own efforts to develop the techniques, methods or instruments used in the various phases of mapping.

Cartographic seminars were thus organized by the Economic and Social Council in order to encourage international co-operation in the field of cartography, especially between neighbouring countries; to facilitate the exchange of technical data between such countries, and to strengthen the technical assistance activities of the United Nations.

These seminars provide an opportunity for the discussion of technical and scientific problems as well as general ones, and for the analysis and solution of difficulties through the exchange of views and results of experience on the part of the various cartographic agencies and through the assistance provided by experts.

The present report outlines briefly the cartographic work of the Iranian civil services and the technical assistance received from the United Nations. A more detailed description is given of the structure and activities of the National Cartographic Centre.

History of Cartography in Iran

The first government agency in Iran to engage in mapping was the Ministry of Foreign Affairs, which, after the First World War, drew up various frontier maps. The topographic mapping section of that Ministry was established by Mr. Abdorrazagh Boghayeri, an engineer, who also provided training in topographic mapping for the young men on his staff.

The second government agency to engage in mapping was the Military Geographic Service, which is still functioning as part of the General Staff.

In addition to these two agencies, topographic mapping, the quality of which is more or less open to criticism, is carried on by the Cadastral Office, the Ministry of Industry and Mining, the Department of Irrigation, the Ministry of Roads, the Oil Company, the various municipalities and the Seven-year Plan Agency. Owing to a certain lack of co-ordination among these various agencies, there has been some duplication of effort.

In 1953, the Seven-year Plan Agency decided to centralize the civilian cartographic activities and accordingly set up the National Cartographic Centre. In accordance with the regulations under which it was established, the Centre is responsible for the preparation of a general map of the country, the centralization of cartographic activities and documentation, the regulation of cartographic activities and the provision of assistance to other government agencies.

The greatest difficulty faced by the Centre at the outset was the lack of trained staff and of the necessary instruments. A programme for the training of staff and the purchase of instruments was drawn up, and it will be made clear in succeeding paragraphs how successful this programme has been.

United Nations Technical Assistance

In 1952, that is, before the establishment of the Centre, two United Nations experts, Mr. D. Chicca and Mr. P. de With, were sent to Iran. Mr. Chicca was assigned to the Oil Company, and Mr. de With to the Department of Irrigation. Mr. de With was transferred to the Centre in 1955 and continues to serve there as an expert. In 1954, at the request of the Centre, Professor W. Schermerhorn came to Iran to study and discuss the general programme prepared by the Centre. He returned to Iran in 1955 in order to appraise the progress and accomplishments of the Centre. The assignment of an expert photogrammetrist, Mr. J. Visser, was approved by the Technical Assistance Administration in 1957, and he has continued to serve up to the present time. In addition to these experts, whose services are greatly appreciated, we have also obtained five fellowships—three in photogrammetry, one in geodetic surveying and one in cartography.

Structure and Activities of the National Cartographic Centre

Structure

Although figure 7 shows the structure of the Centre, the following additional explanation seems desirable.

At the present time the membership of the Governing Body consists of two representatives of the Seven-year Plan, the Director of the Military Geographic Service, one representative each of the Ministry of Communications, the Ministry of Agriculture and the Ministry of the Interior, and a representative of the University of Tehran.

The financial division consists of the following sections: budget, accounts, purchases, sales, equipment, audit and cashier. The administrative division consists of the following sections: administration, personnel, files, secretariat and translation. The programming section consists of the following units: statistics, co-ordination, estimates, and reports and publications. The transport section is responsible for the maintenance and repair of the existing thirty-eight machines,

[1] The original text of this paper, submitted by Iran, under the title "Rapport sur les activités cartographiques en Iran", appeared in French as document E/CONF.25/L.67.

for equipment rentals and the like. The "computation" section is in charge of all technical computations, adjustments, preparation of cards and diagrams and similar activities.

The technical divisions of the Centre are as follows: geodetic surveying—triangulation (first-order, subsidiary orders, upkeep), precise levelling, computations and adjustment; topographic mapping—original surveys (large-scale), stereopreparation, completion, control, and technical office; cartographic—equipment, drafting, copying, printing, technical office and research; and photogrammetric—operation of mapping aircraft, photography, plotting, aerial triangulation and preparation.

Activities

Geodetic activities

First-order triangulations were begun in 1956. In the southern coastal system, which is 1,012 kilometres long and 42 kilometres wide, reconnaissance and the setting up of monuments have been completed, and in a 450-kilometre segmen containing sixteen first-order corners, the preliminary observa tions and adjustments have been completed.

The trans-Iranian system (between Turkey and Pakistan was initiated with the co-operation of the Military Geographi Service in 1957 and has been continued by that service alon since 1958.

Second-order and subsidiary triangulations are mainl local in character since they relate to local projects. A tota of about 1,000 square kilometres has been covered in this way The Wild theodolite model T3 is used for first-order triangula tion, and the Wild theodolite model T2 for second-orde triangulation.

Precise levelling

Along the coast of the Persian Gulf, reconnaissance and th setting up of monuments have been completed over a distanc

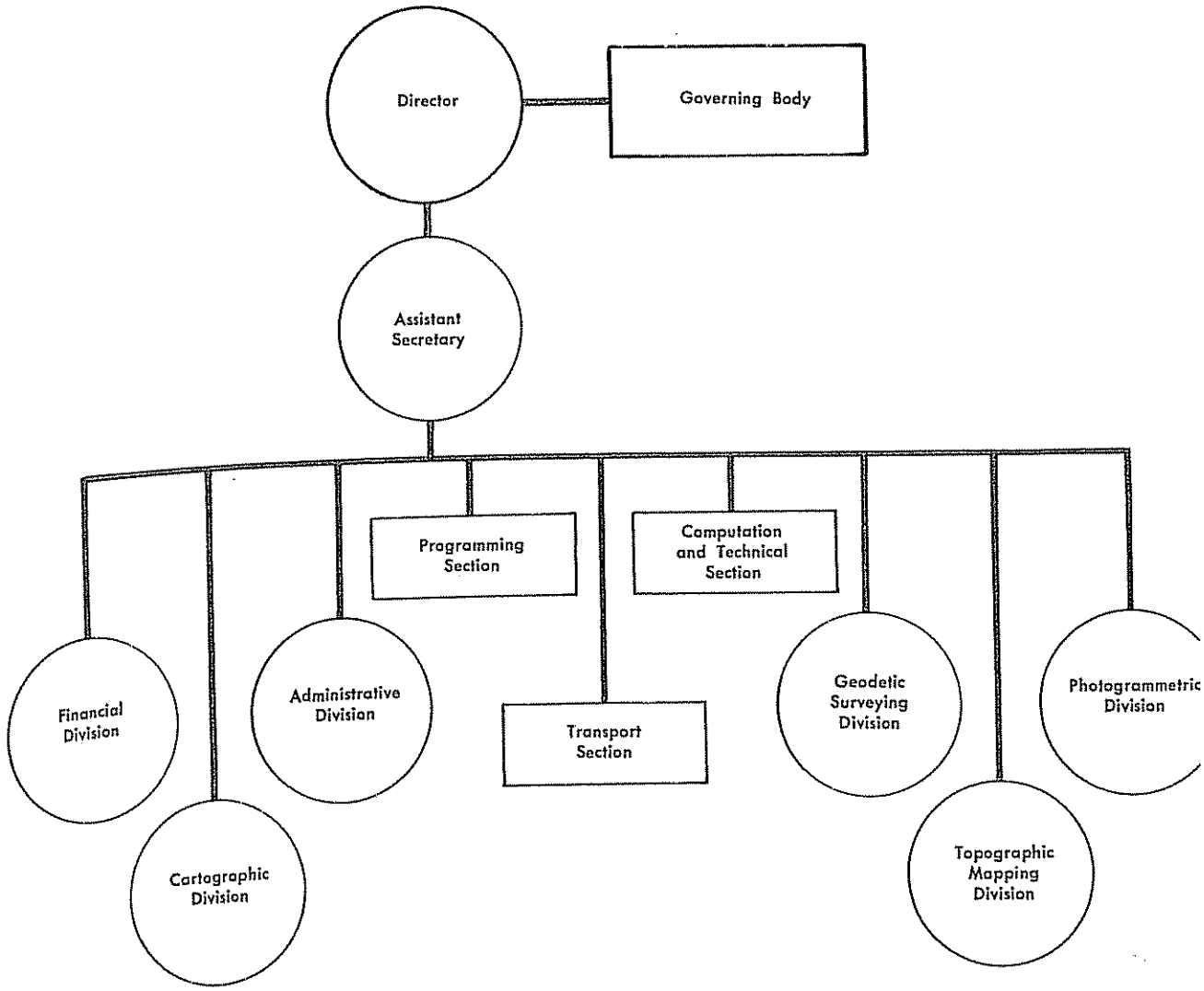


Figure 7. Diagram showing structure of National Cartographic Centre, Iran

of 650 kilometres and observations and computations over a distance of 400 kilometres. The principal network, which was begun in 1957 in co-operation with the Military Geographic Service, has, since 1958, been entrusted to that service alone. Secondary networks have been tied in to the principal network for local irrigation projects, road construction and the like. The total length of these networks is 612 kilometres.

Second-order levelling has been carried out in various parts of the country over a total distance of 1,450 kilometres.

Wild Model N III levels are used for first-order levelling, and Wild model N II or model NK II or Zeiss model Ni2 automatic levels are used for second-order levelling.

Topographic surveying

Original surveys. The National Cartographic Centre, from the outset, obtained the agreement of certain ministries that it should carry out their topographic surveys. It thus did the surveying for the Resht-Gorgan road and part of the Tehran-Meshed road over a total distance of 830 kilometres. Topographic mapping at the scales 1 : 1,000 to 1 : 5,000 has been carried out over a total area of 365 square kilometres, which includes lands of His Imperial Majesty, state lands, mining areas and private property.

Stereoscopic ground control. In addition to the stereoscopic ground control that has been set up for 150 towns, control points have been established for various areas totalling more than 1,100 square kilometres. The Centre is now able to put in the field about fifty teams equipped with good-quality instruments, communications facilities, field equipment and camping equipment. It has a total of fifty-two theodolites, mostly of Swiss manufacture, five Wild self-reducing tacheometers, and thirty-six levels, most of which are Zeiss automatic levels.

Photogrammetric surveying

Aerial surveys. For the first two years (1956-1957), the Centre concluded an operational and training contract with Fairey Air Surveys, Ltd. of London. The contract provided for the taking of aerial photographs and for the training of inexperienced staff. The total area photographed at different scales (between 1 : 6,000 and 1 : 40,000) was as follows:

	Square kilometres
For 197 towns	14,700
For twelve islands and eight ports	11,300
For ten irrigation districts	24,500
For road-construction surveys	74,000
For airport-construction surveys	1,500
TOTAL	126,000

These photographs were taken on film with a Wild model RC5A camera equipped with an Aviogon lens.

Photographic laboratory. Glass diapositives were prepared for most of the photographs, but in every case the photographs were printed either in the same size as the negatives or enlarged. More than 2,500 mosaic units, both controlled and uncontrolled, have been supplied and more than 130,000 prints have been produced in the past two years. Our laboratory, which is equipped with four contact printers, one Zeiss model SEG V automatic rectifier and one Klimsh Super-Auto Horika copy camera, is capable of meeting the country's need for non-military photographs.

Plotting. Some of the plotting is done in the country (either by the National Cartographic Centre or by private Iranian companies), and some is done abroad. In addition to the plotting of fifty towns, the preparation of the maps for the Chiraz and Yezd airports and of maps covering an area of 32 square kilometres has been finished. Completion of the maps is now in progress, and reproduction will begin soon. Our plotting equipment includes two Wild model A8 plotters and one OMI photomapper. The private companies already have one Galileo-Santoni stereosimplex model III, one OMI photomapper, one (German) exactograph and one Poivillier model D, and they will soon have one additional photomapper, two Kelsh plotters and one Wild plotter, model A8.

Aerial triangulation. Slotted templet triangulation is now being carried out over an area of about 2,000 square kilometres, and preparations have been completed for the aerial triangulation of the towns of Tehran (900 square kilometres) and Meshed (400 square kilometres). Our Wild model A7 first-order apparatus has recently been installed and is now in operation, and we therefore hope that we shall soon be able to carry out high-precision triangulation.

Cartographic activities

Drawing. The fair drawing is usually done on plastic sheets by the "Astrascribe" method; 0.010-inch sheets with an orange coating have been successfully used. The engraving is done with plastic tripods provided with a Zephyr point. The most important project in this connexion has been the fair drawing of forty sheets of the Lar Valley at the scale 1 : 10,000, the contour interval being ten metres and locally five metres. Considerable progress has been made with the compilation of maps of 250 towns at the scale 1 : 2,500 and maps of private and public lands at the scale 1 : 5,000. More than a hundred men and women are engaged in the work of map drawing.

Reproduction. Since copies of the maps are not yet required in large numbers, reproduction is being done by ozalid print, but colour reproduction is contemplated and will soon be started. In order that this may be accomplished, four employees are now in Germany for training in the various methods of reproduction.

Finally, it should be added that a building project suited to the purposes of the Centre is being constructed near the Mehrabad airport and that the photogrammetric and photographic equipment belonging to the Centre has already been stored there. As both temperature and humidity vary within a wide range at Tehran, this building is being air-conditioned. The main building, now under construction, will have a total area of 2,500 square kilometres, and there will also be subsidiary buildings, such as a garage, generator plant, kitchen, dining-rooms, club and so on.

REPORT ON GEODETIC WORKS, CARTOGRAPHY, REPRODUCTION AND CADASTRAL SURVEY CARRIED OUT BY SURVEY OF ISRAEL, DURING THE YEARS 1955 TO 1958 [1]

Surveying activities in Israel have been greatly extended in the years 1955 to 1958 and have made remarkable progress.

The Survey Department in Israel is an agency of the Ministry of Labour, to which Ministry also belong the Public Works Department and the Department of Housing.

It is the task of the Survey of Israel to carry out all the stages in the production of maps from the initial geodetic survey (triangulation, precise levelling, gravimetry, magnetometry) to cartography, reproduction and cadastral survey.

Geodetic Works

Survey of the first-order triangulation network

During the past few years the angular measurements in the southern part of the country's network were carried out. It has been a period during which the actual conditions for survey operations were mainly unfavourable. The observations were carried out with the aid of the Wild T3 theodolite, by the directional method of six rounds.

We aim to have a triangulation network in which the closing error in any triangle should be one second and, in any case, will not exceed three seconds, and the mean error of angle measurement, as computed according to Ferrero's formula, will not exceed 0.7 second. This set task will demand, in the nearest future, the re-observation of angles in certain triangles of the southern network.

Base measurement for the astro-geodetic network

The astro-geodetic network is worked in between two bases, of which the southern one, about four kilometres long, was measured in 1954. The measurement was carried out with the aid of Yaderin's apparatus. The accuracy achieved was 1 : 1,400,000.

Precise (geodetic) levelling

The geodetic levelling network of Israel should supply in the future, among other data, the difference in height between the mean sea level of the Mediterranean and the mean sea level of the Gulf of Aqaba. In connexion with this, we shall have to construct several mareographs (recording tide gauges) of the fundamental type.

During the years 1955 to 1958 about 400 kilometres of lines were levelled, which included relevelling some lines run in the past.

The levelling network is based on eight fundamental precise bench-marks, of which two have been recently constructed.

The measurement is carried out with the aid of a Wild NIII levelling instrument, employing invar staff, and observations with backsights and foresights of equal length, which varies from a minimum of 8 metres to a maximum of 40 metres.

Geodetic astronomy

For astronomical observations we employ the Wild theodolite No. 22861. A laboratory check was carried out 1958 on this instrument for the purpose of establishing constants and determining errors in the individual systen The observations were carried out at the Holon experimen station.

At present, the geographical positions of the basic (geodet points of the network are being determined.

We use the sidereal time chronometer made by Uly Nordin, which has a rate of from + 7.5 seconds to + 9 seconds, for determinations of latitude and azimuth only.

Chronograph Favag (mean accuracy 0.01 second) is used determine longitude and azimuth.

Time signal for fixing the chronometer correction is receiv from Moscow. For longitude determination, W.W.V. registered on the chronograph tape simultaneously with t closing of the self-recording micrometer circuit.

Radio receiver for determination of the correction of chror meter time is the Zellweger, type ZZE, of frequency from 8 15 megacycles. For longitude, we use the radio receiver w range of wavelengths from 30 to 5,000 metres.

Methods of observation. (*a*) Latitude—by zenithal distar of star pairs in meridian (Sterneck method). Observi sixteen pairs of stars during three nights. (*b*) Longitu —by meridian method. Registering the transits of st with the aid of a contact micrometer with the simultanec registration of time signals, received by radio, on the chror graph tape. Repeated eight times from a group of eight sta (*c*) Azimuth—by observing α Ursae Minoris at random hc angle.

Observing programme for each round: azimuth mark—s —star—mark. Triple registration on the chronograph tape star transits by the movable wire of the contact micromet in its three positions.

A series of observations consisted of six sets. Final res was obtained on the basis of three such series of observatic carried out on three separate nights.

Computation methods and accuracy obtained. The adju ment of observations was carried out by the least squa method. The mean errors of final results were as follov

(*a*) Latitude	m = ± 0".35
(*b*) Longitude	m = ± 0".02
(*c*) Azimuth	m = 0".4

Gravimetric works

Although we realize the importance of gravimetric measu ments in improving the quality of our astro-geodetic and p cise levelling networks, we shall not in the near future ha available the financial means required to initiate such wor Up to the present, gravimetric measurements have been carr out only for exploration purposes.

[1] The original text of this paper, submitted by Israel, appeared as document E/CONF.25/L.70.

Magnetic surveys

During the years 1955 to 1958, field measurements of magnetic declination were carried out.

We do not as yet possess a magnetic observatory.

Cartography

The basic topographical map of the country is in the 1 : 20,000 scale, covering the developed part of the country, and the still undeveloped part is being mapped in the 1 : 50,000 scale.

The following topographical maps have been published or are in preparation for publication.

(1) A general map in the scale of 1 : 250,000, in two sheets, covering the whole country. This map will appear shortly to replace the series of three sheets published up to the present.

(2) A new series of maps in the scale of 1 : 100,000, consisting of twenty-six sheets, is in preparation. The old edition, consisting of twenty-four sheets, will not be reprinted.

(3) The series in the scale of 1 : 50,000 will cover the southern part of the country, and will consist of thirty-five sheets. It is suggested that four to five sheets will be published yearly. These maps are being prepared from aerial photographs taken in approximately 1 : 35,000 scale, which are plotted in 1 : 20,000 scale and reduced to 1 : 50,000.

(4) The area covered by the series of 1 : 20,000 scale is steadily being resurveyed, as, owing to the rapid development of the country, the production of a more accurate series of maps has become a necessity. This new series is prepared from aerial photographs taken in a scale of 1 : 18,000 to 1 : 20,000 and plotted in the 1 : 10,000 scale.

The most developed part of the country will be covered by a series of maps in the 1 : 10,000 scale, showing, in addition to the basic map, agricultural specifications and development schemes. The total number of sheets will be about 400, of which only a few have been published up to now.

(5) Many topical maps have been published.

A series of geological maps in the 1 : 100,000 scale has been printed.

Geological maps in the 1 : 50,000 scale are now in preparation and will appear in 1958.

Soil conservation maps in the 1 : 20,000 scale have been published in eighty-two sheets.

Other topical maps published are meteorological and historical maps.

The National Atlas of Israel, which consists of 100 sheets, 50 centimetres by 70 centimetres, covering the following subjects: cartography, geomorphology, geology, climate, hydrology, botany, zoology, landscape, evolution, history, population, settlements, agriculture, industry and commerce, communications and services, has also been published.

Reproduction

In general, normal offset printing methods are used.

Co-operation with the Photogrammetric Section

(*a*) Astrafoils with grid-netting in black or blue are supplied. Astrafoils are punched and pins are used in order to register one on top of the other.

(*b*) If provisional maps are being prepared, the photogrammetric plotting is done on two different Astrafoil sheets. On one appear culture and vegetation (in black and white inks) and on the other contours and water features (in black and white).

The separation of the black and white inks is done photographically, placing black or white paper, respectively, under the transparent Astrafoil original. Lettering is added by hand drawing and the provisional map is printed using the photogrammetric plotting (partly Austrian method).

Co-operation with the Cartographic Section

(*a*) In all cases of map compilation or reduction for smaller scales, the existing maps are sprayed with a translucid (semi-opaque) nitrocellulose white enamel. The basic monochrome map is then drawn upon this surface. This method makes the expensive preparation of blue prints obsolete. As far as is known to us, it is used only in Israel.

(*b*) *Blue prints* for fair drawing are prepared on Astrolon (transparent or white) or on coated zinc plates. All routine drawings are printed in black on the blue print.

(*c*) *Lettering*. Nearly all the lettering is done photographically on stripping film. The film is coated with an adhesive wax. If opaque lettering is required, the film is first coated with a white enamel and afterwards coated with the adhesive wax. All the alphabets and the method of composing have been worked out in the Survey of Israel, including 120 signs.

Photography

All photographic work is done on polysterene-based film.

Layer suits with different screen patterns are composed from masks using the punch and pin method.

As more and more drawings are made on transparent material, contact negatives are prepared, or, if reduction is required, this is done in the camera in transparency.

Plate-making

Plates are made mainly from positives, using the gum reversal method.

Cadastral Survey

The cadastral survey started under the British Mandatory Power in 1928. The plan was to finish in twenty years the settlement of rights in regard to about 14,000 square kilometres of the total area of 27,000 square kilometres.

During the rule of the Mandatory Power until 1948, about 6,000 square kilometres were surveyed for cadastre.

In Israel the cadastral survey area is estimated at approximately 6,000 square kilometres.

Owing to the very extensive changes which have occurred in different parts of the country, considerable areas must be resettled in connexion with reparcellation and the founding of many new settlements.

The cadastral survey is carried out by chain survey based on trigonometric control and traverse points.

The area is divided into villages and the villages into registration blocks, which are plotted in 1 : 5,000, 1 : 2,500 and 1 : 625 scales.

The determination of areas is carried out by semigraphical method on the field sheet.

During the past three years an area of approximately 300 square kilometres has been covered by cadastral survey.

Some experiments have been carried out in the field of photogrammetry for cadastral purposes. An area of four and one-half square kilometres has been photographed, using a Wild RC5A camera with Aviotar lens (focal length = 209.69 millimetres) at a height of 1,900 metres. Six hundred bounda points have been marked by tin plates of orange colour, 40 40 centimetres for traverse points and 30 by 30 centimetr for boundary marks. For the purpose of identification, t photographs have been enlarged to a scale of approximate 1 : 1,250.

On the aerial photographs, 190 points have been identifi in photogrammetric instruments.

Some photographs were sent to the field for identificati and 125 additional points have been identified. The expe ment is still being continued. It is assumed that the sm number of points identified was due to a large number stones and rocks scattered in the area.

REPORT OF CARTOGRAPHIC WORKS IN JAPAN FOR THE PERIOD FROM 1955 TO 1957 [1]

by the Geographical Survey Institute, Japan

The present report is a brief description of cartographic and related works carried out in Japan during the period from the beginning of 1955 to the end of 1957. This description is, for the sake of convenience, given in separate sections under the headings of Geodesy, Geomagnetism, Photogrammetry, including mapping and application of aerial photography, and Compilation of Maps.

GEODESY

Base-line measurements

Five-metre sub-standard bars were calibrated in terms of light waves by means of an interference comparator of Fabry-Perot type standard which was devised in 1955 in our Institute. The results of calibrations show that the lengths of the five-metre sub-standard bars are determined with the mean error of ± 0.2 to $\pm 0.3\mu$.

In 1956, trial measurements of the base line and the second enlarged side of the Tenjinno base-line net were carried out by utilizing a geodimeter (NSAM-2). The results of these trial measurements are given below (in metres):

	Geodimeter	*Mean error*	*Length hitherto adopted*	*Difference*
Base line	3,515.788	0.004	3,515.7955	−0.008
Second enlarged side	18,383.307	0.006	18,383.380	−0.073

The results of the geodimeter measurements were worked out by assuming the velocity of light waves to be 299,792.5 kilometres per second, as given in the resolutions passed by the 1957 Toronto meeting of the International Association of Geodesy.

Triangulation

During the period from 1955 to 1957, areas of about 54,840 square kilometres, in which sixty-seven first-order triangulation points are included, were subjected to revision surv Of these, areas of about 2,400 square kilometres lie in Hokk do, in which four first-order triangulation points are situat These areas, together with those where the triangulation w revised in 1954, are thought to have been disturbed by t 1952 earthquake, of which the epicentre was off the coast Tokachi Province. The horizontal displacements of triangu tion points deduced by comparing the results of the rec survey with those of the previous survey are not conspicuo the displacement being about forty centimetres at most.

The other areas are in the West Chugoku and Chu districts (westernmost and central parts of Honshu, resp tively) and comprise about 52,340 square kilometres in involving fifty-seven first-order triangulation points. areas in the Chubu district include the areas which might ha been disturbed by the 1945 Mikawa earthquake and the 19 Fukui earthquake. The influences of the earthquake dist bances are not, however, manifest in the results of the revisi of the first-order triangulation. The crustal deformations these areas which might have been caused by the earthqual were found as a result of the revision of the second-order a third-order triangulations carried out in 1955 and 1956. T second-order and third-order triangulations were also revi in the areas occupied by Tottori and Niigata prefectures, b being situated on the Japan Sea, though the results have yet been published.

The first-order triangulation in the areas in the W Chugoku and Chubu districts is the extension of that execu during the period from 1949 to 1952 in the areas in the Nan and Kinki districts where the earth's crust had been disturb conspicuously by the 1946 Nankai earthquake. The resu of the triangulation in all the areas mentioned above subjected to simultaneous net adjustment and are compa with the results of previous surveys in the same areas. displacements of triangulation points are thus deduced reference to some points which are assumed as fixed dur the period from the time of the previous surveys to that of recent surveys.

[1] The original text of this paper, submitted by Japan, appeared as document E/CONF.25/L.68.

As for the degree of accuracy of the above-mentioned first-order triangulation, we may refer to the fact that the mean square error for a single angle is 0".64 to 0".65, as deduced from closures of triangles, and 0".69 to 0".75, as deduced from net adjustments.

Geodetic astronomy

During the period mentioned, forty-seven astronomical stations were occupied and measured by the usual method, of which seventeen are Laplace points, where the azimuths, as well as the longitudes and latitudes, were measured. The occultation observations were also made at ten stations. These data are applicable to the adjustment of the distortion of geodetic triangulation nets and in studying local undulations of geoidal form.

The observations of the passages of stars were made accurate by application of the Electronic Transit Detector (ETD), completed in 1955 by I. Tsubokawa. The accuracy of the ETD observations of passages of stars is given by the standard deviations of ±10 milliseconds to ±25 milliseconds for a single star and ±3 milliseconds to ±5 milliseconds for a set of ten to sixteen stars.

Levelling

During this period, the revision of precise levels was made along lines of about 3,000 kilometres in the Tohoku district (north-eastern part of Honshu) and the region along the coast of the Japan Sea, and 102 kilometres in Kyushu. The results of these revision surveys were compared with those of the previous surveys, and rising and sinking of the earth's surface were found in various localities along the lines of levels.

Of these, the rising and sinking of the earth's surface in the neighbourhood of Fukui is attributed to the disturbance due to the 1948 Fukui earthquake. Besides these crustal deformations due to destructive earthquakes, sinking of the earth's surface is notable in the vicinities of Taira and Niigata and in Northern Kyushu. This local sinking of the earth's surface is thought to have been caused by underground excavation (in the case of sinking in the environs of Taira and in Northern Kyushu), or phenomena which have occurred in or underneath the surface layer. Remarkable sinking of the earth's surface is also observed in Tokyo, Osaka, and their vicinities, where there is a thick surface layer of alluvial soil. Studies in the sinking of the earth's surface in those areas have been continued by repeating the precise levels and by utilizing the continuous recording apparatus specially provided for the measurement of sinking.

Gravity

International tie observations of gravity were made between the fundamental gravity stations of Japan and the United States in 1955 by a Geographical Survey Institute (GSI) party and also between those of Japan and Singapore and Cape Town in 1957 by the Japanese Antarctic Research Expedition party, in which GSI personnel responsible for gravity measurement participated. In these observations of gravity, the GSI pendulum apparatus was utilized and the results obtained are:

g NBS $- g$ GSI $=$ -310.4 ± 0.3 mgal
g Kyoto $- g$ GSI $=$ $+68.3$ ± 0.3 mgal
g SIN $- g$ GSI $=$ $-1{,}709.2$ ± 0.5 mgal
g C.T. $- g$ GSI $=$ -142.8 ± 0.5 mgal

The values of gravity at Singapore (SIN) and Cape Town (C.T.) relative to the g-value at Kyoto (international fundamental gravity station, g Kyoto = 979.7215 gal) are therefore obtained as follows:

g SIN = 978.0806 gal.
g C.T. = 979.6470 gal.

A series of relative gravity measurements at each benchmark and other points where the height marks are installed have been carried out by using the North American gravimeter. The gravimeter stations thus occupied during the period from 1955 to 1957 number 3,993. At seven stations, relative gravity measurements were made during the same period of time by means of the GSI pendulum. These pendulum stations are properly distributed among the nets of gravimeter stations and they are regarded as reference stations for the gravimeter survey.

It may be mentioned that the measurements of the vertical gradients of gravity were made by N. Kumagai of Kyoto University, and that a special type of pendulum apparatus for gravity measurements at sea was designed by C. Tsuboi of Tokyo University.

GEOMAGNETISM

During the period from 1955 to 1957, a second-order geomagnetic survey was extended over the area covering the western half of Japan, and fifty-five first-order geomagnetic stations were re-occupied to obtain secular variations in geomagnetic elements. The second-order geomagnetic points, where the measurements were made during the above-mentioned period, number 384, of which 235 are re-occupation points. The Hydrographic Office has recently completed the sixth magnetic survey of the whole of Japan, based on the resolution passed by the International Hydrographic Conference. In this survey, the last seventy-six stations in the western half of Japan were occupied in 1955. The magnetic stations occupied by the Hydrographic Office are, in general, different from those occupied by the Geographical Survey Institute. The data thus obtained are reduced to the values at the epoch of 1955.0, referring to the data obtained at Kakioka, where the measurements of geomagnetic elements have been made continually. From these deduced data, the distribution charts of geomagnetic elements and those of secular changes in geomagnetism are made available. The surveys by the Geographical Survey Institute were executed by use of the GSI magnetometer, and those by the Hydrographic Office by use of the HO (Hydrographic Office type) magnetometer.

The Geographical Survey Institute recently constructed a new type of proton procession magnetometer, by use of which the total geomagnetic force can be measured free from the influences of air temperature and pressure and the values obtainable can be kept as accurate as those obtained by the GSI magnetometer. An air-borne magnetometer was constructed by Y. Kato of Tohoku University and his collaborators. A trial survey flight with this air-borne magnetometer was made under the sponsorship of the Hydrographic Office with quite satisfactory results.

An observatory of the Geographical Survey Institute is being built at Kano-zan, Chiba prefecture, about fifty kilometres south-east of Tokyo, over Tokyo Bay. The Kano-zan observatory is to be furnished with rooms for geomagnetic

standards, geomagnetic variometers, a gravimeter for permanent observations, and astronomical observation facilities. This observatory will therefore be well equipped to serve as the geodetic standard station of Japan, when it is completed.

A magnetic observatory was established in 1954 by the Hydrographic Office at Shimosato, Wakayama prefecture, about 130 kilometres south of Osaka. The observatory has been so equipped that it deserves to be the basic station for the magnetic survey executed by the Hydrographic Office.

Kakioka Magnetic Observatory is constantly in operation as the reference station for magnetic surveys in Japan.

Photogrammetry

For the topographical survey, the photogrammetrical method has been widely developed in our country. Since 1952, when the ban on aerial photography was removed, private agencies have been in charge of taking aerial photographs with modern aerial cameras, and the cameras recently added are Zeiss RMK's 18/21, 15/23 and 11/18 of the Geographical Survey Institute and Wild RC8 of the Pacific Surveying Company. Of these cameras, RMK 18/21 was prepared for the Japanese Antarctic Research Expedition.

The areas where the aerial photographs were taken during the period mentioned are tabulated below, classified as to their purposes.

	Square kilometres
City planning	20,926
Harbour improvement	926
River improvement	4,036
Forestry resources	55,572
Land improvement	7,672
Highway planning	4,153
Railroad planning	1,291
Transmission line planning	6,561
Sand guard	1,865
Cadastral	219
Other	1,514
Total	104,775

The aerial photographs were taken on various scales according to their purposes; for instance, those for topographical mapping were taken, in general, on the scale of about 1 : 20,000 or smaller, while those for city planning, land improvement, cadastral survey and the like were usually taken on the scale of 1 : 10,000 or larger.

The number and type of photogrammetric plotting instruments now in operation in our country are:

Stereoplanigraph C5	1
Stereoplanigraph C8	3
Wild autograph A7	1
Stereoplotter A8	6
Kelsh plotter	9
Nistri photomapper	2
Multiplex	27
Stereotope	23
Radial secator	3
Automatic rectifier	4

Of these, one stereoplanigraph C8, two stereoplotters A8, twelve multiplexes, fifteen stereotopes, two radial secators and one rectifier (SEG V) are kept by the Geographical Survey Institute. In the Institute, the stereoplanigraph C8 is applied to aerial triangulation and to mapping on the sc of 1 : 5,000 and 1 : 10,000, together with the stereoplotter Detail mapping on the scales of 1 : 25,000 and 1 : 50,00 carried out with multiplexes or stereotopes.

Formerly, there was not much need for aerial triangula in Japan because the whole country was covered with a tl order triangulation net and fourth-order triangulation cultivated land was being carried out; but now aerial trian tion has become a usual method for establishing passp for mapping on larger scales.

The land is completely covered with 1,263 sheets of 1 : 5 topographical maps, while the coverage of 1 : 25,000 graphical maps is about one-fourth of the land. Under circumstances, our mapping programme has been c forward as follows:

Revision of 1 : 50,000 topographical maps. Since 1952, the provisional revision of 1 : 50,000 topographical ma completed, a new revision programme has been carrie that is, about sixty sheets par annum of 1 : 50,000 topog cal maps have been revised.

Revision and extension of 1 : 25,000 topographical ma revision and new surveying of 1 : 25,000 topographica have been made by utilizing multiplexes and stereoto the case of multiplex mapping, the passpoints are dete by means of bridging, while, for stereotope mappi passpoints are furnished by stereoplanigraph plott already mentioned. During the period mentioned, four sheets of 1 : 25,000 topographical maps were and 390 were newly surveyed.

Revision and extension of 1 : 10,000 topographical m surveying of 1 : 10,000 topographical maps has been using the stereoplotter A-8. In the case of revision s flat plains, the radial secator was also used in n combined with the rectifier. During the period un sideration, thirty sheets of 1 : 10,000 topographical m revised and eighteen sheets were newly surveyed.

Mapping for road planning. In 1957, the prepa 1 : 5,000 scale maps needed for planning a highway tion project was requested by the Road Bureau of the of Construction. The maps, 320 sheets in all, were c photogrammetrically; eighty-three sheets were do Geographical Survey Institute, and the rest by sever agencies under the supervision of the Institute.

The Hokkaido Development Agency entrusted th phical Survey Institute with mapping of waste uncultivated land, where the medium-scale maps a importance in planning the development progra sheets of these maps number thirty, the scale being and the mapping operation was brought to a stand end of 1957.

The Japanese Antarctic Research Expedition (J of 1956, in which a photogrammetrist of the G Survey Institute participated, took a series of ae graphs of Ongulu Island and its environs, whe camp of the expedition was established. From photographs, a map of East Ongulu Island was pl scale of 1 : 5,000.

Application of aerial photogrammetry is repo been extended over wide fields of civil and agri gineering by its use in making 1 : 5,000 to 1 : 1

graphical maps, which are of basic importance for planning public works. The Forestry Agency plans to survey the forests throughout Japan by taking aerial photographs of all forest areas at intervals of ten years. By means of these aerial photographs, research is to be made on the growth of the woods, the estimation of amounts of standing timber and the like. Forest maps are also made by using these aerial photographs.

Until now, maps prepared on the scale of 1 : 5,000 or larger have, in general, been based on surveys by means of the plane table. But, even in this field of mapping, the plane table method is being replaced by aerial photogrammetry. For example, the photogrammetric method was applied to the study of the buried ruins of the prosperous Nara Epoch, which dates back about 1,000 years. By using the maps plotted photogrammetrically on the scale of 1 : 1,000, with the help of photo-interpretations, the scope of the ancient palace of the Nara Epoch was made more or less clear.

In compiling 1 : 50,000 land utilization maps, the method of aerial photo-interpretation was applied with successful results. The compilation of these maps commenced in 1952, and since then 300 sheets have been completed by the Geographical Survey Institute. The method was also applied to the survey of land classification, sample sheets of which have already been published.

Studies have been made on the application of ordinary photographs, together with infra-red photographs, to the analysis of geological structures, indispensable to public works. Application of coloured aerial photographs to photo-interpretation has also been studied.

The method of photo-geology has been developed in surveying oilfields and coal mines in Hokkaido and Kyushu. In applying it to these fields of survey, complicated features and artificial deformations of the earth's surface may impede the attainment of fruitful results.

Some distinguished geologists have recently tried to apply this method to geological surveying in volcanic areas and have pointed out the following advantages of the application of photo-geology to surveying such areas.

(*a*) In the aerial photographs, it is comparatively easy to recognize delicate differences in the surface features of the earth which appear in response to the differences in geological features, which are not clear in 1 : 50,000 topographical maps.

(*b*) By using aerial photographs, the distribution and characteristics of lava flows, pumice flows and sediments of *nuée ardante* can be traced in detail.

(*c*) Structures of volcanoes, which are not seen on 1 : 50,000 topographical maps nor easily recognized by field surveying, are manifest on aerial photographs; for instance, small craters and small-scale lava flows, which are usually smoothed out on the 1 : 50,000 topographical maps, are found by stereoscopic viewing of pairs of aerial photographs.

(*d*) Open cuts and routes in jungles, wastelands and deep valleys can be easily recognized on aerial photographs.

It may be noted that terrestrial photogrammetry is still advantageous in mapping dam site areas on very large scales and in estimating rock mass produced by blasting. In studying motions of water waves and propagations of flood surcharges, this method of, terrestrial photogrammetry, together with aerial photogrammetry, is said to be quite useful.

Compilation of Maps

Smaller-scale maps are compiled using as data the 1 : 50,000 topographical maps and other materials, such as records of geographical names, administrative boundaries and the like. The maps thus compiled during the period under consideration comprise about forty sheets of 1 : 200,000 and eight sheets of 1 : 500,000; the latter cover the whole of Japan. The map of Japan and its environs was compiled on one sheet on the scale of 1 : 2,500,000.

Special maps compiled on the scale of 1 : 50,000 comprise fifty sheets of land utilization maps, six sheets of landform classification maps and two sheets of soil maps. As already stated, the land utilization maps which have been compiled since 1952 comprise 300 sheets in all. The landform classification maps and soil maps, together with the surface geological maps, constitute a series of land classification maps. The compilation of these maps has been done in accordance with the National Land Survey Programme.

The soil map of unproductive areas is compiled on the scale of 1 : 200,000, in connexion with the Land Improvement Programme. Several sheets of these maps have already been completed.

The Geological Survey has published a series of geological maps on the scale of 1 : 50,000. The geological maps formerly published on the scale of 1 : 75,000 are now being revised on the scale of 1 : 50,000.

Additional Notes

Besides the works reported in the sections above, fourth-order triangulation was carried on in various localities. This fourth-order triangulation was executed for the control of cadastral survey and of surveys of local character. Since, however, the cadastral survey was not greatly extended during the period under consideration, a report of activities on this subject is omitted here.

On the other hand, altogether 1,676 sheets of maps were obtained during the announced period as the result of public surveys. Of these, 807 sheets were plotted on the scale of 1 : 3,000, 475 sheets on the scale of 1 : 5,000, and 335 sheets on the scale of 1 : 10,000.

These maps were, in general, made photogrammetrically by private companies under the sponsorship of governmental and public agencies, for the purposes of city planning, land improvement, river improvement, railroad planning and the like.

BRIEF REPORT ON CARTOGRAPHIC ACTIVITIES IN KOREA [1]

In Korea, there were originally 34,192 triangulation and levelling points in the whole peninsula of 220,890.94 square kilometres. Of these, 17,733 were located in the northern part of Korea and 16,459 in the south, of which over one-half were either destroyed or buried during the conflict in 1950. In carrying out the work of rehabilitation, army engineers started in 1955 a plan to make a survey for 3,000 to 4,000 points and to restore about 1,000 of them a year. As of July 1958, measurements for 7,400 points had been completed, including the restoration of 1,200 points. It is believed that all the lost points will be restored by the end of 1960. In view of the lack of geodetic control points, the topographical survey was possible only for limited areas. Thus, when the topographical survey could not be made, the preparation of maps had to be based on old maps revised by the aerial photographic survey. In this connexion, the United Nations Forces in Korea contributed considerably, both through financial aid and technical co-operation. At present, production of topographic maps of Korea on a scale 1 : 50,000 is in progress and a large number of sheets are already available; maps on a scale of 1 : 100,000 will be produced by the end of this year. Maps on the scales of 1 : 20,000 and 1 : 500,000 are available for public distribution. In addition, maps of twenty-two cities on a scale of 1 : 12,500 are completed. Based on these topographical maps, maps for water control and city planning are being produced by the Ministry of Home Affairs, cadastral maps by the Ministry of Finance, geological maps by the National Geological Survey, traffic maps by the Ministry of Transportation and maps for educational purposes by the Ministry of Education. In April 1958 the Geographical Survey Institute was set up in the Ministry of Defence to develop cartographic activities. A geographical name standardization committee was organized under the Institute and a plan is being formulated to publish a gazette of standard names which will contain the official names adopted and the romanization thereof; for example, the name of the capital city—Seoul, or the name of the sea lying between Korea and Japan—the Eastern Sea. However, the work of standardization on an international level is also necessary in this regard as some maps printed recently in certain countries still bear the old form of romanization based on the Japanese style of spelling Korean place names.

Hydrographic surveying is conducted by the Naval Hydrographical Bureau; the survey has been completed for all the sea areas surrounding the southern part of Korea.

In conclusion, cartographic work in Korea is still in a stage of development and substantial assistance is needed both in the training of technical personnel and in technical facilities.

[1] The original text of this paper, submitted by the Republic of Korea, appeared as document E/CONF.25/L.80.

REPORT ON CARTOGRAPHIC ACTIVITIES OF THE ROYAL SURVEY DEPARTMENT [2]

Prior to 1909, land surveying in Thailand was undertaken by the Royal Survey Department under the auspices of certain governmental organizations at various times since its formation as a department by royal decree in 1885. The chief duty of the Department at that time was to survey the flat rice fields which constitute a major portion of the inhabited area of central Thailand. After the transfer of the Department to the Army in 1909, cadastral survey was carried out by a new service set up under the Ministry of Agriculture. This service is now under the Ministry of the Interior.

The Royal Survey Department has since confined its efforts to topographical mapping and is at present known as the Army Survey Department.

A summary is given below of the work accomplished in geodesy, gravimetry, terrestrial magnetism, topography and aerial mapping up to June 1958.

GEODESY

Triangulation

Primary triangulation was started in 1909, and up to the present time a considerable part of the country has been covered with a network of triangulation, as may be seen from the index map in figure 8.

In accordance with the resolution passed at the Madrid meeting, and later at the Stockholm meeting of the International Association of Geodesy and Geophysics, that Thailand and neighbouring countries should extend their systems of triangulation to their frontiers and effect connexions with the object of continuing, if possible, the chain of triangulation to the Australian continent and the Philippines, Thailand has expanded its system of triangulation to appropriate localities. Connexions between triangulations of India and Thailand have been effected at three junctions and the Malaya-Thailand connexion was made at one junction.

Base lines

Eight base lines have been measured with invar tapes and wires and six of these are used for the control of primary triangulation. Besides these base lines, a total of thirteen first order base lines was recently measured by the United States Army Map Service by means of Bergstrand geodimeters in connexion with a mapping agreement between the United States and Thai Governments. The locations and disposition of the base lines are shown on the index map in figure 8.

Precise levelling

A total of 6,908.9 kilometres of first-order levelling has been measured in Thailand. One India-Burma-Thailand precise levelling connexion has been effected as a notable achievement

[2] The original text of this paper, submitted by Thailand, appeared as E/CONF.25/L.74.

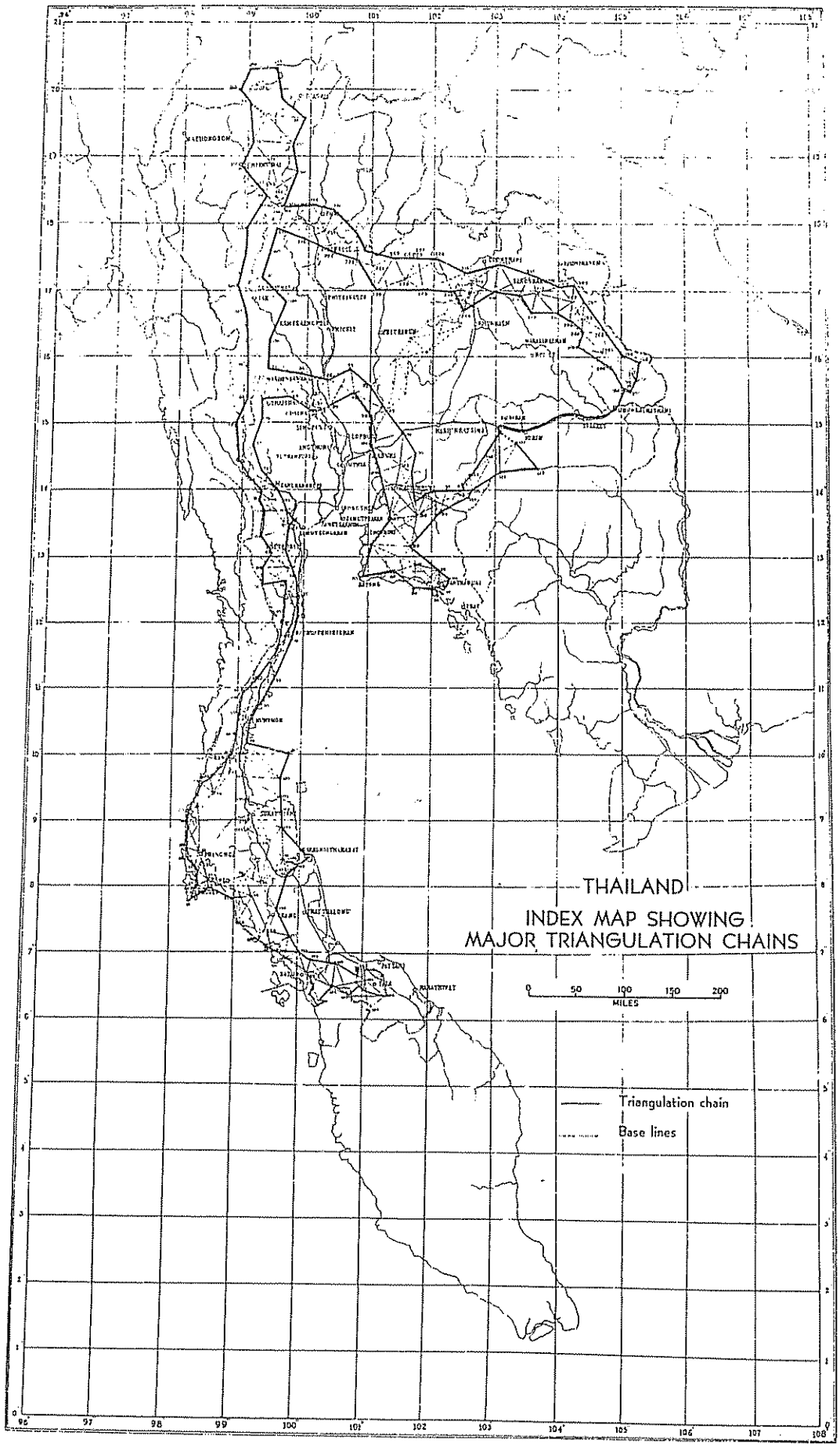

THAILAND
INDEX MAP SHOWING
MAJOR TRIANGULATION CHAINS
0 50 100 150 200
MILES
Triangulation chain
Base lines

Figure 8

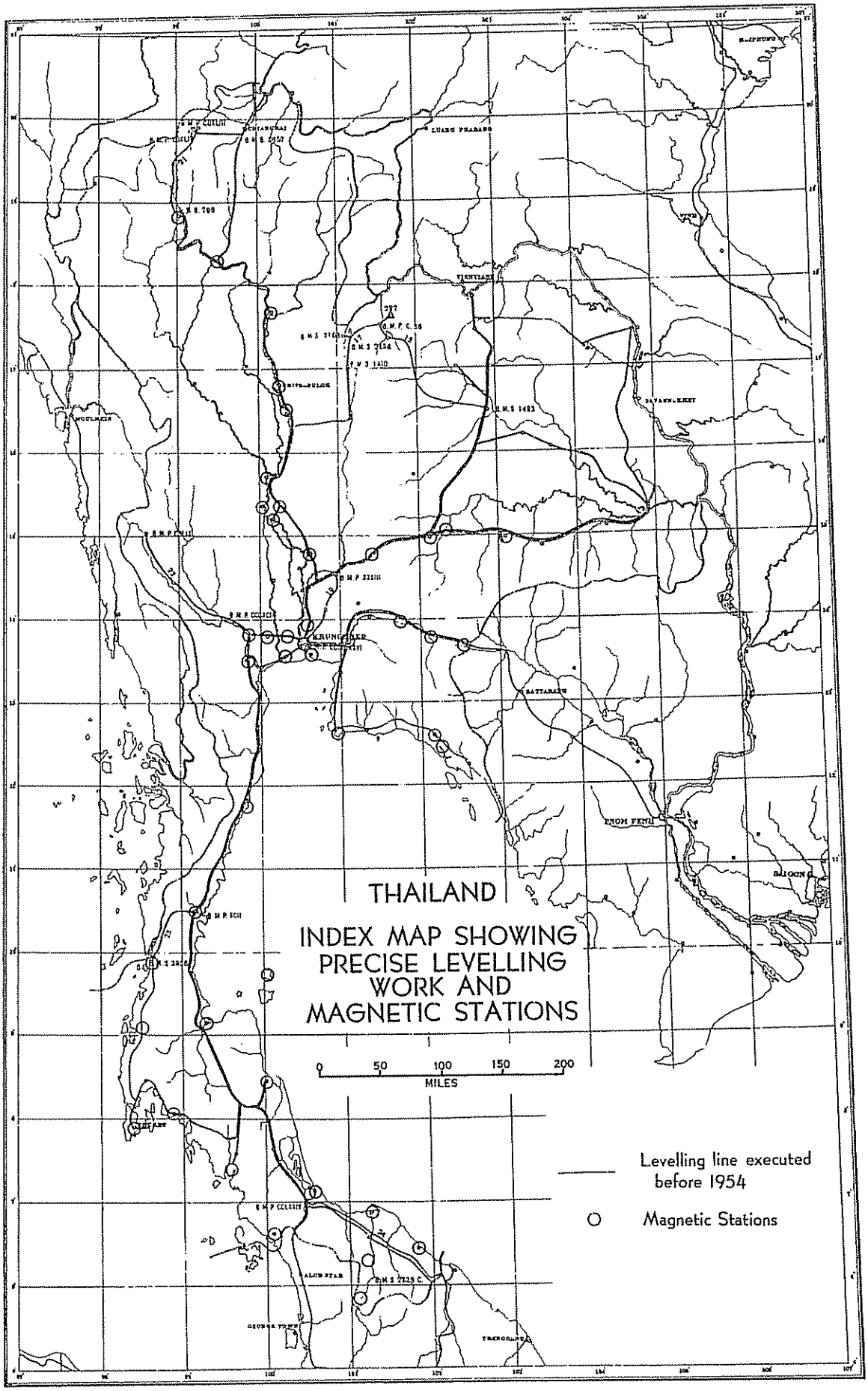

THAILAND
INDEX MAP SHOWING
PRECISE LEVELLING
WORK AND
MAGNETIC STATIONS
0 50 100 150 200
MILES
Levelling line executed before 1954
Magnetic Stations

Figure 9

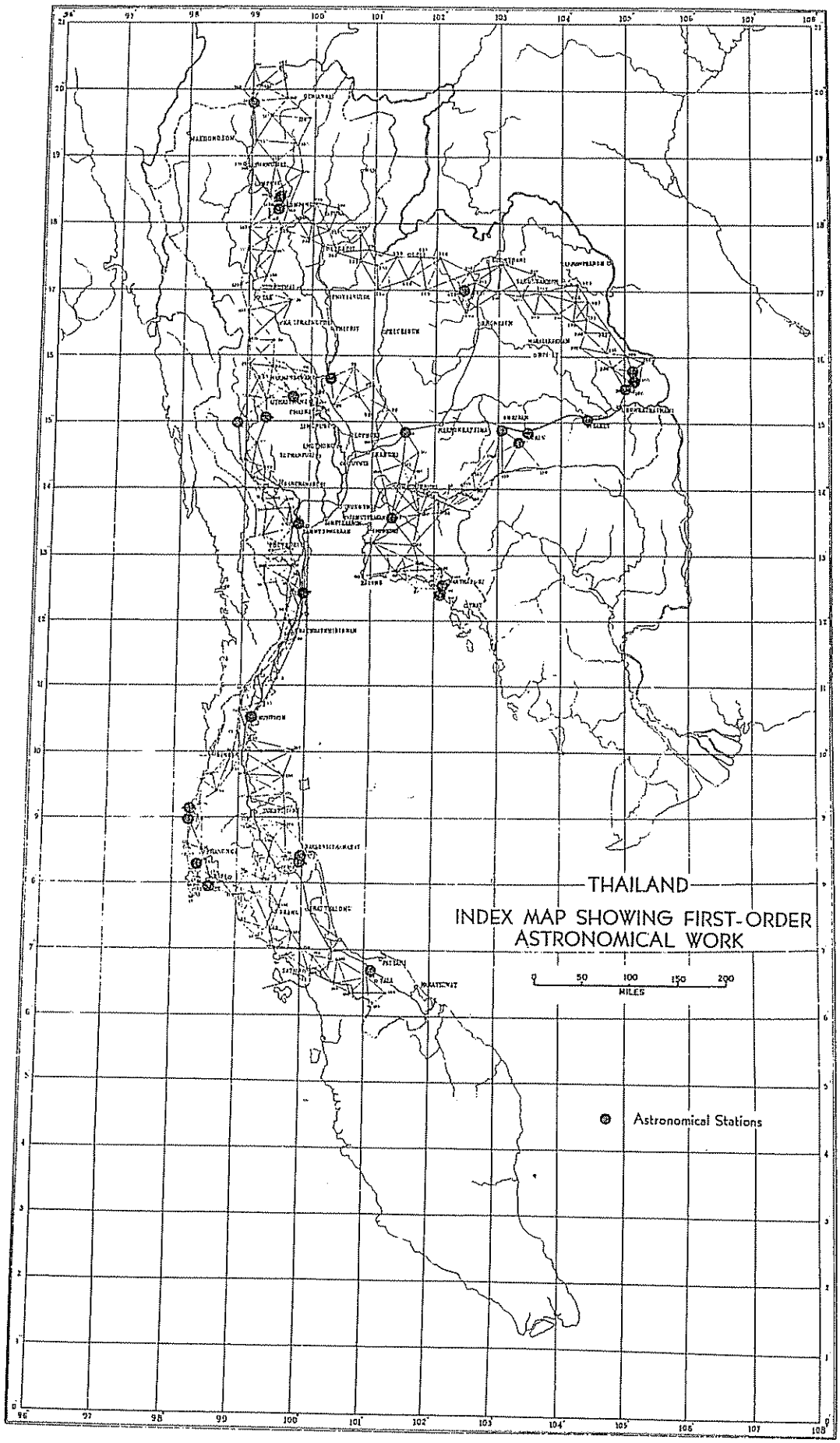

THAILAND
INDEX MAP SHOWING FIRST-ORDER
ASTRONOMICAL WORK
0 50 100 150 200
MILES
Astronomical Stations

Figure 10

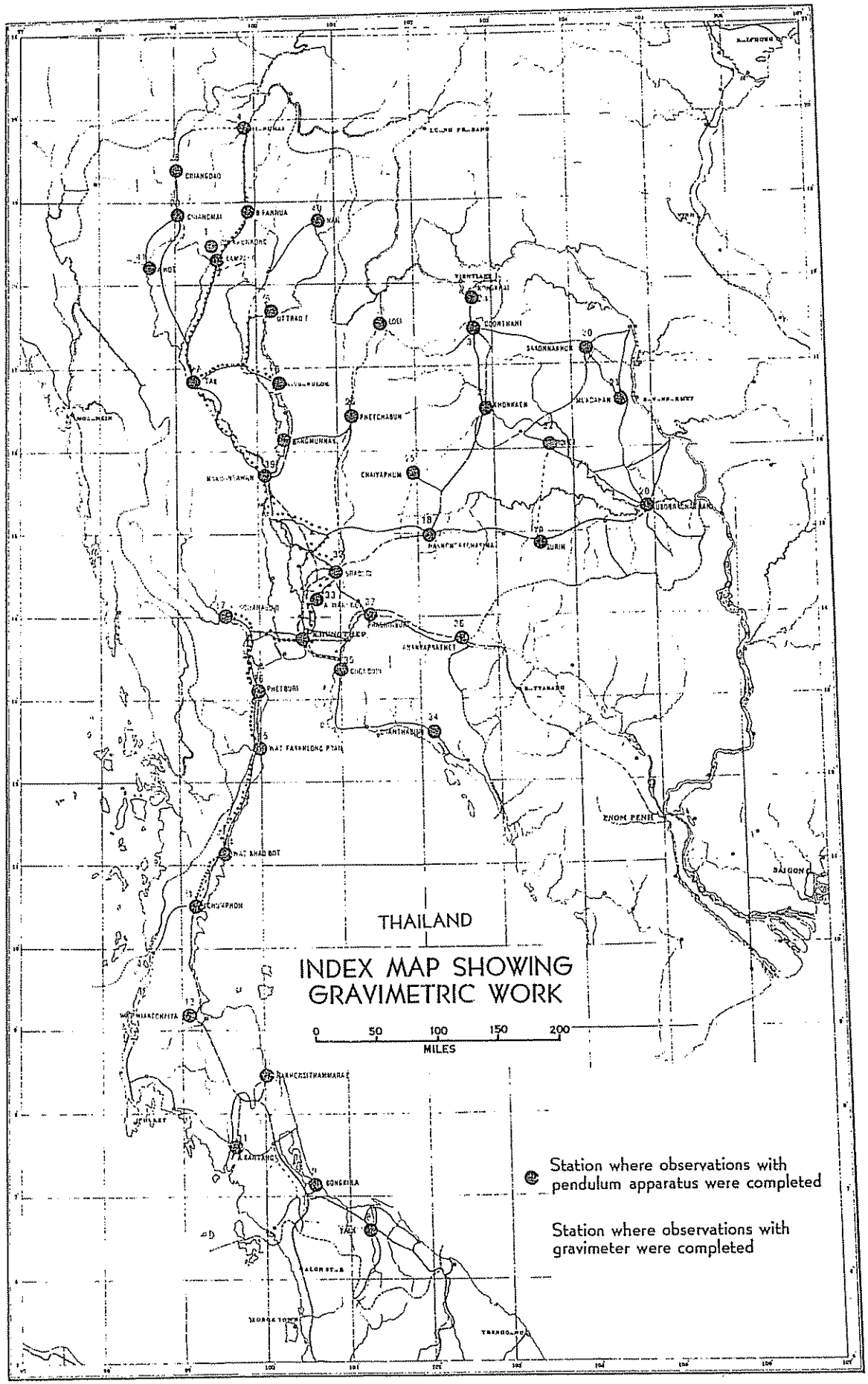

THAILAND
INDEX MAP SHOWING
GRAVIMETRIC WORK
0 50 100 150 200
MILES
Station where observations with pendulum apparatus were completed
Station where observations with gravimeter were completed
CHIANGDAO
CHIANGMAI
B FANNUA
NAN
UTTRADIT
LOEI
KHONKAEN
PHETCHABUN
CHAIYAPHUM
SURIN
PHETBURI
WAT KHAO BOT
PHOM PENH
SAIGON
YALA

Figure 11

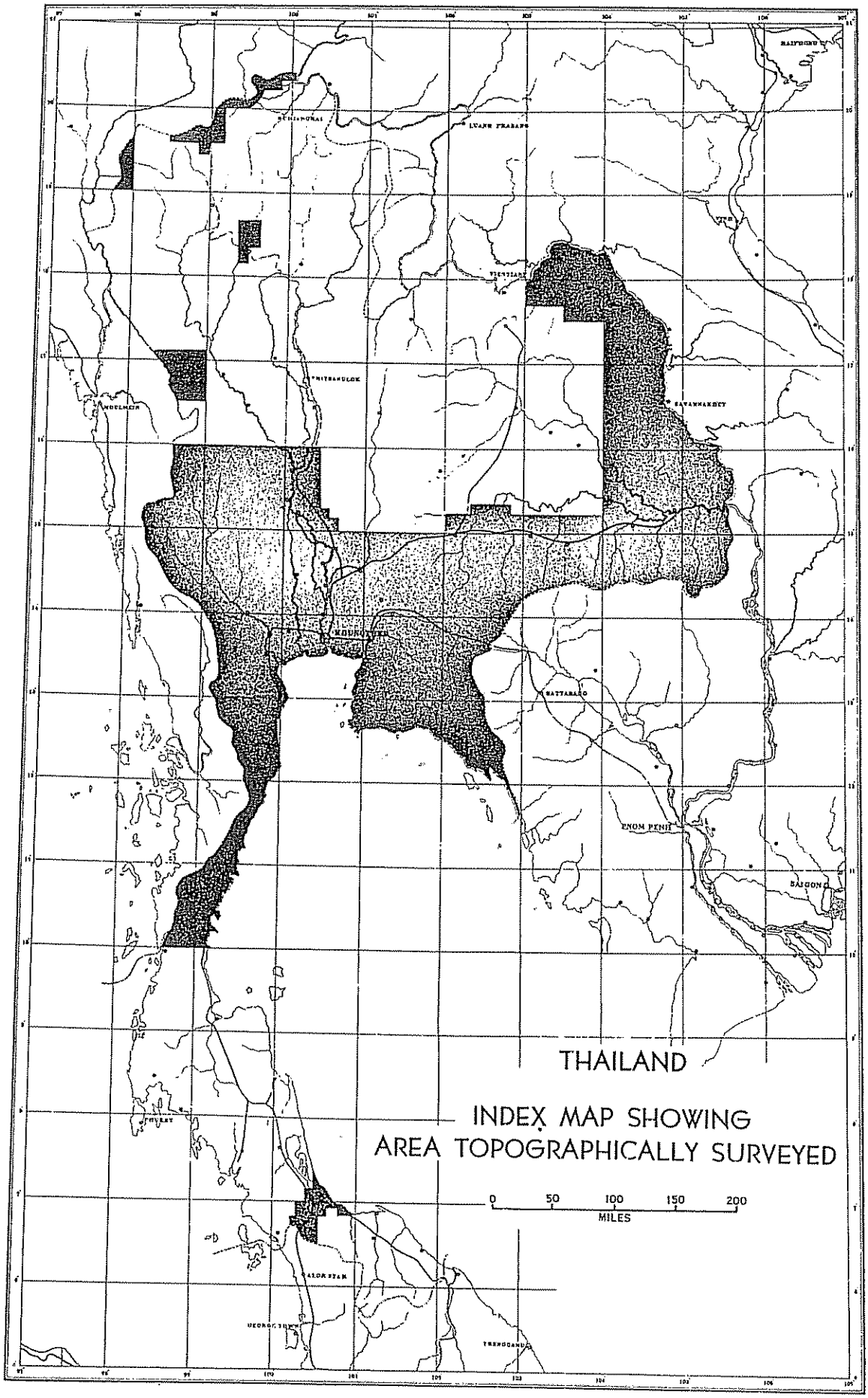

THAILAND
INDEX MAP SHOWING
AREA TOPOGRAPHICALLY SURVEYED
0 50 100 150 200
MILES
LUANG PRABANG
VIENTIANE
SAVANNAKHET
PHOM PENH
SAIGON
ALOR STAR
TRENGGANU

Figure 12

The Thailand datum for levelling is the tidal observatory at Koh-Hlak (Prachuab Kirikhan), where continuous observations were taken during the period from 1910 to 1915. The index map in figure 9 shows the distribution of the levelling lines.

Astronomical work

First-order astronomical observations have been carried out in Thailand since the commencement of the primary control work. Recently the United States Army Map Service carried out observations at ten first-order triangulation stations in accordance with a mapping agreement between the United States and Thailand. The index map in figure 10 indicates the locations of the astronomical stations.

Intensity of Gravity

Pendulum observations for gravity in Thailand were first executed in 1938 and were continued for two seasons. Activities in this work were renewed after being held in abeyance for ten years. Cambridge invar pendulum apparatus was used in all the main stations. Up to the present, forty-two stations have been observed.

A Norgaad gravimeter was recently procured and observations have already been made at eighty-eight stations.

The index map in figure 11 shows the locations at which gravimetric observations have been carried out.

Terrestrial Magnetism

The first observations of terrestrial magnetism in Thailand were made in 1906, and the activities of the Department as regards magnetic observations were confined to field observations for dip, declination and horizontal force. The sixty-nine field stations at which observations have been executed are shown on the index map in figure 9.

Topography

Topographical survey and aerial mapping

In 1909, topographical survey, using the ordinary plane-table method, was initiated in Thailand and was carried out continuously until recently when aerial photographic and photogrammetric procedures were instituted for detail survey. An area of over forty per cent of the territory of Thailand was surveyed by the plane-table method, the scales used being 1 : 25,000, 1 : 50,000, 1 : 100,000 and 1 : 200,000. The index map in figure 12 shows the coverage of the area topographically surveyed.

In 1952 a bilateral agreement was made with the United States concerning a co-operative mapping programme, as a result of which practically all of Thailand has been photographed for aerial mapping at 1 : 50,000 scale.

These photographs were flown at scales ranging from 1 : 40,000 to 1 : 50,000. Simultaneously, large-scale photography was obtained. The photography was flown during 1953 and 1954. The ground control phase of this programme has recently been finished. As a result of this work we have horizontal and vertical picture points in bands across the entire country at intervals of from ten to forty-five kilometres apart.

With the assistance of the United States Army Map Service, thirteen first-order base lines have been measured by geodimeter. This work was done during 1955. All geodetic data have been adjusted and tied into the Indian datum by the United States Coast and Geodetic Survey.

The map compilation programme is just being initiated. It is expected that all of Thailand will be mapped at 1 : 50,000 scale in about five years. There are about 1,400 map sheets in this series. These maps will be based on the Universal Transverse Mercator projection.

Although the Royal Thai Survey Department experimented with photogrammetry in connexion with map making for many years, it did not go into the field seriously until early in 1955. During the past few years, the Department has been in the process of setting up, equipping and training a modern air mapping organization. Its equipment programme calls for first-order triangulation machines and second-order plotting instruments at a ratio of about one to six. Considerable progress has been made, but it will be at least two more years before the organization is completely effective. Its greatest problem is training qualified supervisors.

The Department is developing a cartographic capacity geared to its compilation efforts. Recently it has introduced the latest plastic scribing techniques for its standard map colour separation work.

REPORT OF CARTOGRAPHIC ACTIVITIES IN TURKEY [1]

by the Geodetic Survey of Turkey

I. Triangulation and Base Measurements

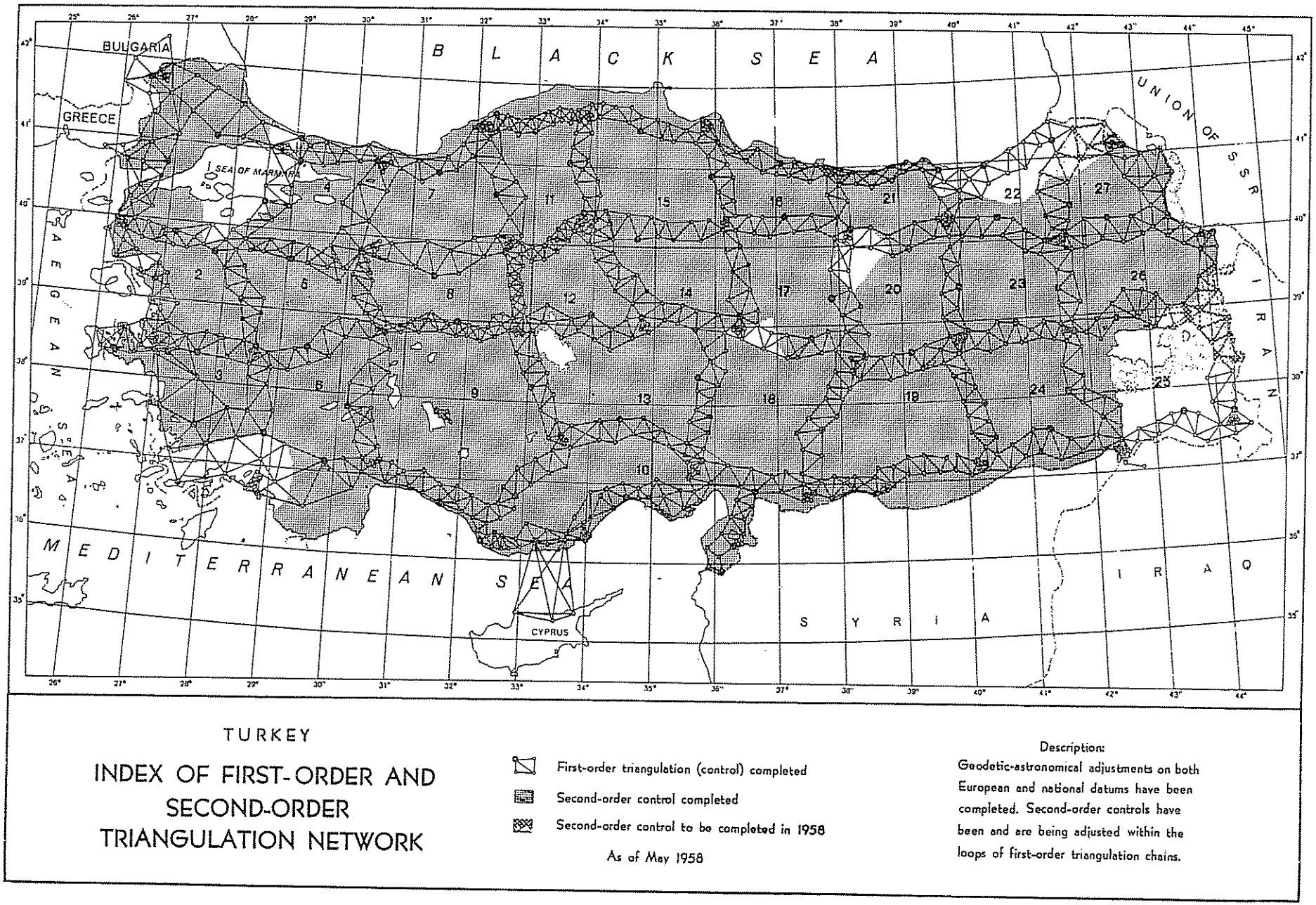
General

First-order triangulation

The first-order triangulation works shown on the index map in figure 13 were essentially started in 1940 and completed in 1953.

The first-order triangulation chains are extended from north to south and from east to west with an average length of 180 kilometres. They consist of well shaped triangles except for six chains which are made up of complete quadrilaterals. In junction figures, that is, at the beginning and at the end of each chain, a base line is measured, and additional base lines are measured where the length of the chains exceeds 200 kilometres. The base lines are measured with an accuracy of 1/2,000,000. Laplace stations are established on one station of junction figures and on one of the stations 70 to 100 kilo

[1] The original text of this paper, submitted by Turkey, appeared as document E/CONF.25/L.60.



TURKEY

INDEX OF FIRST-ORDER AND SECOND-ORDER TRIANGULATION NETWORK

First-order triangulation (control) completed

Second-order control completed

Second-order control to be completed in 1958

As of May 1958

Description:

Geodetic-astronomical adjustments on both European and national datums have been completed. Second-order controls have been and are being adjusted within the loops of first-order triangulation chains.

Figure 13

metres apart, along the chains, to control the swing of the chains and to determine the deflection of verticals. The sides of the triangles are usually between 25 and 35 kilometres, and small angles less than 40 grades are not taken. The angle observations are usually carried out using Wild T3 theodolites (14 centimetres in diameter); sometimes Max Hildebrand theodolites (27.5 centimetres in diameter) are used.

In observing the angles, Schreiber's combination method with the weight of 24 was in use until 1947, and since that date direction method has been used. At every station, twenty-four sets of observations (each consisting of the observation made in the direct and the reverse positions of the instrument) are made for each direction.

Day observations are made with heliotropes, starting two hours before sunset, and night observations are made with Zeiss ISG signal lamps. The observations on a station are carried out over three nights.

In order to secure the intervisibility of stations, and in plane land to elevate the line of sight from the ground to lessen the effect of refraction, Bilby steel towers are used. The figure and observation of base-line expansion stations will be explained in the following sections; the observations at the terminal points of base lines are made on towers 7.5 metres high.

The amounts, accuracies and data of the observed and adjusted first-order triangulation chains are shown in table 1.

Second-order, third-order and fourth-order triangulations

In general, two second-order triangulation chains are put in the area limited by first-order triangulation chains and then second-order triangulation chains (the distance between which must not be less than 40 kilometres) are set into the remaining area. After this, the areas between first-order and second-order triangulation chains are covered with the nets of points of second-order triangulation and, in turn, the points of third-order triangulation are put in the areas which are limited by the second-order triangulation stations.

Second-order triangulation chains consist of well shaped triangles; the average length of the sides is about 10 to 20 or 20 to 30 kilometres. The angles are observed with Wild T3 theodolites, and direction method of 8 to 12 sets is used. About 90 per cent of second-order control, covering the entire country, has been completed.

The angles at the station of third-order triangulation nets, which are put in the areas limited by first-order and second-order triangulation chains, are measured with Zeiss and Wild theodolites. The lengths of the sides of the triangles are between five and eight kilometres and the observations consist of from three to six sets.

The values of fourth-order triangulation points are determined by intersections only and they are not yet adjusted, but they will be adjusted by applying the Anfelderung method as they are completed within each loop.

The circles of the theodolites used in all triangulation works are divided into 400 grades.

Adjustment of triangulations

General values

The International Hayford Ellipsoid (a = 6,378,388 metres and f = 1/297.0) has been adopted as the reference ellipsoid.

Astronomic co-ordinates of the datum point Mesedağ are:

$$\varphi = 39^\circ\ 52'\ 10''.451 \pm 0''.139$$

and

$$\lambda = 32^\circ\ 34'\ 38''.430 \pm 0''.210.$$

General method of adjustment

Up to 1954, for mapping purposes and for the preparation of the general astronomic-geodetic adjustments, the chains between two base lines were adjusted independently, including the angle, side, length and azimuth equations (simple Laplace equations). Now, the first-order triangulation network of the whole of Turkey is adjusted simultaneously by the method of variation of co-ordinates, based on both European and national datums.

Second-order chains, which connect the first-order chains of the polygons and divide the area covered by the polygons into four parts, are adjusted, including the angle, side, length, and azimuth, longitude and latitude equations.

Second-order and third-order triangulation points are adjusted according to co-ordinates by the method of variation of co-ordinates.

Formulae used for computing successive geographic co-ordinates

$$-\Delta\varphi'' = S.B.\cos\alpha + S^2.C.\sin^2\alpha + D.(\delta\varphi'')^2 - h.S^2.E.\sin^2\alpha$$

$$\Delta\lambda'' = A'.S.\sin\alpha.\sec\varphi'; \quad \text{where } \varphi' = \varphi + \Delta\varphi''$$

$$-\Delta\alpha'' = \Delta\lambda''.\sin\tfrac{1}{2}(\varphi+\varphi').\sec\tfrac{1}{2}\Delta\varphi'' + (\Delta\lambda'')^3.i$$

$$\alpha' = \alpha + \Delta\alpha'' + 180^\circ \qquad h = S.B.\cos\alpha$$

$$B = \frac{1}{R_m.\ \text{arc}\ 1''} \qquad E = \frac{1 + 3\tan^2\varphi}{6\ N^2}$$

$$C = \frac{\tan\varphi}{2\ NR_m.\ \text{arc}\ 1''} \qquad F = \frac{\sin\varphi_m.\ \text{arc}^2\,1''.\cos^2\varphi_m}{12}$$

$$D = \frac{3\,e^2\sin^2\varphi.\ \text{arc}.\ l''}{2\,(1-e^2\sin^2\varphi} \qquad A' = \frac{l}{N'\ \text{arc}\ l''}$$

Use of plane (rectangular) co-ordinates

Plane co-ordinates X and Y are determined by direct transformation of geographic co-ordinates, using the Transverse Mercator (Gauss-Krüger) projection formulae.

The projection in use is the Gauss-Krüger projection.

The width of zones is 3 degrees and scale factor is 1.00 for scales larger than 1 : 25,000, and for 1 : 25,000 and smaller scales, the width of zones is 6 degrees and scale factor m 0.9996.

Use of Laplace stations

Laplace stations are taken on first-order triangulation stations situated 70 to 100 kilometres apart and on one of first-order triangulation stations of junction figures of polygons.

These Laplace points were previously used to form simple Laplace equations for independent adjustment of the chains and later for the simultaneous adjustment of the entire triangulation network of Turkey, which was finished in 1954.

Connexion with neighbouring countries

The following geodetic connexions were made between the triangulation network of Turkey and those of neighbouring countries.

In Thrace: between Turkey and Bulgaria and between Turkey and Greece;

In the west: between Turkey and Greece;

In the south: between Turkey and Cyprus;

In the south-east: between Turkey and Iraq.

These triangulation connexions are shown on the map in figure 14.

Altitude determination by trigonometric levelling

(1) Differences of elevations by reciprocal observation of zenith distances are computed by the following formula:

$$\Delta h = S \sin \tfrac{1}{2}(Z_2 - Z_1) : \cos \tfrac{1}{2}(Z_2 - Z_1 + n).$$

(2) Determination of differences of elevations by a single zenith distance observation is made by the following formula:

$$\Delta h = S \cot Z + K S^2,$$

where:

Δh is the differences of elevations,

S is the distance between the points in question,

$$n = \frac{s}{R}\sigma^{cc} = \frac{S_m}{10}; \quad m = \frac{1}{2} - \frac{(Z_1 + Z_2) - 200}{2 \cdot S \cdot \sigma^{cc}} \cdot R,$$

$$K = \frac{1 - 2m}{2R} = \frac{(Z_1 + Z_2) - 200}{2 \cdot S \cdot \sigma^{cc}}.$$

(3) Refraction coefficient is determined from the equations of m and K. For Turkey, determinations from numerous observations made in different parts of the country are:

$m = 0.08$ and $K = 6.589 \times \overline{10}^{8}$ $\quad$ Log $K = \overline{8}.819$.

Measurements of base lines

General condition of measurements

The lengths of base lines are transferred to the side of first-order triangulation chains by the expansion figures (usually in rhombs).

In general, the expansion figures consist of single rhombs and the angles opposite base lines are not taken less than 40 grades. The expansion ratios (the ratio of base line to the expanded length) are always taken greater than 1/3. Generally the lengths of base lines are between six and ten kilometres.

The directions of the lines of expansion are measured with the Max Hildebrand theodolite; the direction of the side of angles opposite to the base line is observed in forty-eight sets, and the direction of the sides of angles adjacent to the base lines is observed in twenty-four sets.

Observations at the terminal points of base lines are made from the ten-metre high Bilby steel towers.

Base lines are usually selected in areas with a grade of less than 7 per cent. Construction of base-line terminals is established according to the Ditrich method.

Instruments

The base lines are measured with Carpentier's invar tapes 24 metres in length. In general, measurements are made by using Carpentier's tripods and the Witram stretcher. Since the whole of the base line and the sections of it measured daily are always taken as 24 or its whole integer multiples, there is no need for divisional computations.

Base-line levelling is accomplished by using a Zeiss II (31 magnifying power) levelling instrument. Observations are made on levelling rods 1.5 metres long with steel tape along the centre divided into millimetres. These rods are held on markings at the terminal points of 24-metre subsections.

Method of field measurements

For base-line measurements, Carpentier's tripods and, in some cases, 80-centimetre-long stakes fixed into the ground are used.

Terminal points of the 24-metre subsections are fixed by nails driven into stakes from 30 to 40 centimetres in length, which are fixed into the ground within 3 centimetres of accuracy in the direction of the base line, using 20-metre steel tapes.

The whole base line is divided into sections of about twenty-five to thirty tape lengths and terminal points of each section are then fixed by concrete blocks. Sections of base lines are measured with six different tapes, once with each tape. The average rate of measurement is about one kilometre per hour.

All the base lines are taken as straight lines and no broken lines are used. In order to compute the grade corrections, the differences in elevations of terminal point marks of tape lengths are measured within one millimetre of accuracy. The departure of tape length terminal points from the base-line direction is measured by alignment and the correction to be made to each tape length is computed.

Standardization

The standardizations of invar wires used in base-line measurements are made by comparing them with the fixed 1,152-metre-long standard base founded near Ankara, Turkey.

The length of this standard base was determined by invar wires which were standardized in 1942 and 1943 by the Physikalische Technische Reichsanstalt, Berlin, in 1943 and 1946 by the Bureau international des poids et mesures, and in 1947 and 1949 by the Geodetic Institute of Finland.

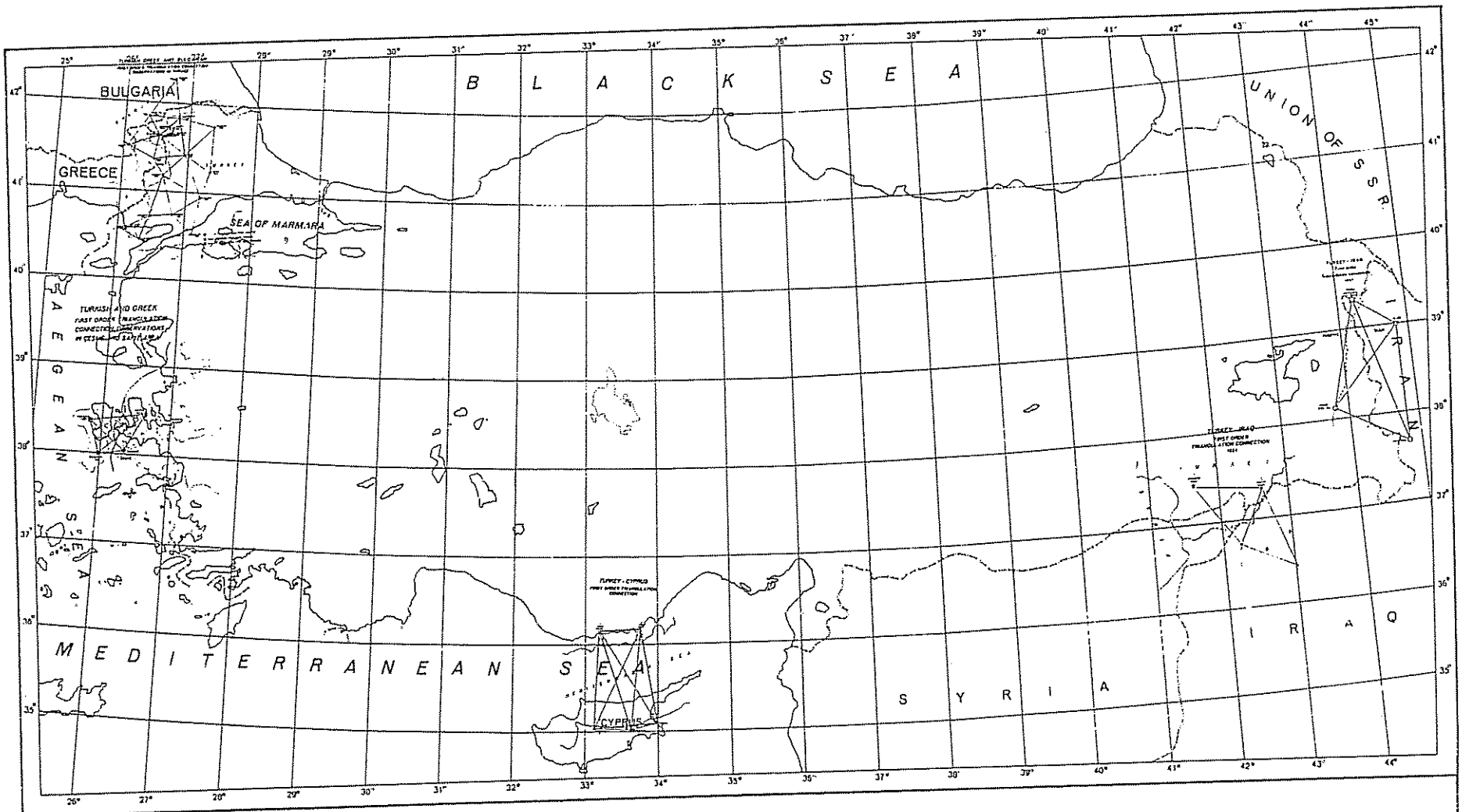
There is no other "comparator" for standardization of invar wires and no temporary standard base is taken in the field.

Five different readings are taken on the eight-centimetre-long, millimetre-divided rulers on both ends of each wire.

Four measurements are carried out with each wire in order to compare them with the standard base. The accuracy of standardization is 0.03 millimetre.

Expansion coefficients of invar wires were determined by the Bureau international des poids et mesures. Expansion coefficients of some of these wires were redetermined in 1949 at the Geodetic Institute of Finland.

Variations in length of the invar wires are determined from their comparison measurements made with the standard base before and after field measurements and from the field measurements of six invar wires used in the measurements.



TURKEY

GEODETIC CONNEXIONS BETWEEN TURKEY AND NEIGHBOURING COUNTRIES

Some temporary increases in the lengths of the invar wires are observed during field measurements, but they return to their original lengths after a period of rest.

Computation of base lines

The length of each section computed from each wire measurement is corrected for temperature and centring.

When the entire length of the base line has been measured with each wire and corrected, the following further corrections are made: grade correction; stretching correction; ruler grade correction; alignment correction; wire standardization correction.

The mean lengths of the entire base line are then corrected for difference of gravitation (tension correction) and the final corrected lengths are reduced to sea level.

Computation of errors

Mean square error of the base line is computed from the measurements of six different invar wires for the entire length.

Measurement discrepancies between the wires used do not exceed three millimetres per kilometre, and the accuracy obtained is higher than 1 : 2,000,000.

Details of the measurement of the base lines from 1942 to 1952 are given in table 2.

Table 1. Turkey: First-order triangulation chains

Name of chain	*Number of figures*	*Average closing error of a triangle (seconds)*	*Average length of sides* (kilometres)	*Length of chains* (kilometres)
Etimesgut – Çaycuma	10	0.0	36	176
Etimesgut – Eskişehir	10	0.7	38	180
Eskişehir – Adapazari	10	0.6	39	152
Eskişehir – Afyon	5	0.4	30	100
Eskişehir – Yeniceoba	6	0.8	20	132
Çaycuma – Devrekâni	7	0.7	12	160
Etimesgut – Hüseyinli	7	0.7	15	95
Bafra – Devrekâni	16	0.4	23	172
Tokat – Bafra	13	0.5	30	150
Hüseyinli – Tokat	13	0.7	27	196
Hasankale – Muş	10	0.4	27	132
Adapazari – Yeşilköy	12	0.3	28	140
Afyon – Yeniceoba	40	1.0	25	220
Devrekâni – Hüseyinli	31	1.3	18	135
Yeniceoba – Karapinar	15	0.9	30	180
Ceyhan – Karapinar	19	0.9	30	210
Tokat – Suşehri	13	1.0	26	180
Ceyhan – Gaziantep	14	0.9	30	160
Gaziantep – Malatya	17	0.9	25	220
Suşehri – Malatya	13	0.8	30	180
Suşehri – Bayburt	10	1.1	30	160
Bayburt – Hasankale	13	1.0	23	160
Muş – Cizre	16	1.3	23	210
Cizre – Derik	16	1.1	32	200
Derik – Palu	16	0.9	25	150
Derik – Urfa	11	0.5	23	130
Urfa – Gaziantep	17	0.7	28	150
Edirne – Yeşilköy	15	0.4	38	230
Edirne – Ezine	21	0.6	38	250
Ezine – İzmir	30	1.0	32	215
İzmir – Alaşehir	11	0.7	25	150
Malatya – Palu	15	1.4	25	160
İslahiye – Antakya	9	1.8	21	85

Table 1 *(continued)*

Name of chain	*Number of figures*	*Average closing error of a triangle (seconds)*	*Average length of sides* (kilometres)	*Length of chains* (kilometres)
Bayburt – Palu	13	1.3	30	180
Muş – Palu	16	0.9	24	165
Afyon – Alaşehir	14	0.7	25	200
Silifke – Ceyhan	24	1.3	24	260
Adapazari – Çaycuma	9	0.7	30	144
Balikesir – Yeşilköy	13	1.2	32	164
Balikesir – Ezine	17	1.1	24	168
Balikesir – Alaşehir	12	1.3	27	159
Balikesir – Eskişehir	19	1.1	27	220
Köyceğiz – İzmir	20	+	53	272
Köyceğiz – Alaşehir	14	+	37	192
Köyceğiz – Antalya	10	+	46	160
Gazipaşa – Antalya	20	0.9	25	196
Gazipaşa – Karapinar	17	0.8	25	176
Gazipaşa — Silifke	16	1.2	21	148
Mucur – Yeniceoba	14	0.8	29	188
Pinarbaşi – Ceyhan	20	0.6	27	248
Pinarbaşi – Mucur	10	0.6	30	136
Pinarbaşi – Tokat	11	0.6	29	168
Pinarbaşi – Malatya	13	0.7	30	184
Ordu – Bafra	15	0.9	24	184
Ordu – Suşehri	9	1.1	24	104
Ordu – Bayburt	20	1.2	26	224
Ardahan – Bayburt	29	+	28	308
Ardahan – Hasankale	19	+	29	268
Ardahan – Iğdir	20	+	28	120
Muradiye – Iğdir	9	+	27	132
Muradiye – Muş	15	+	28	188
Muradiye – Yüksekova	14	+	29	192
Cizre – Yüksekova	16	+	26	184
Antalya – Afyon	15	1.0	28	196
Iğdir – Hasankale	17	+	29	239

All of the first-order triangulation was completed and the entire net of twenty-seven loops, consisting of sixty-six chains, was simultaneously adjusted on national and European datums.

Table 2. Turkey: Measured base lines

Year and name	*Length (metres)*	*Relative mean error*
1942		
Etimesgut	9,605.2097	1 : 3,313,000
1943		
Çaycuma	5,498.1177	1 : 5,100,000
Eskişehir	7,235.6804	1 : 6,600,000
Adapazari	5,402.3803	1 : 6,500,000
1944		
Yeniceoba	8,615.6886	1 : 6,330,000
Yeşilköy	6,284.5446	1 : 9,125,000
1945		
Afyon	7,913.0784	1 : 8,000,000
1946		
Balikesir	10,167.3078	1 : 8,600,000
Devrekâni	7,394.1681	1 : 6,700,000
Hüseyinli	7,825.1234	1 : 7,800,000
1947		
Tokat	10,857.5258	1 : 9,000,000

Table 2 *(continued)*

Year and name	*Length (metres)*	*Relative mean error*
1947 (continued)		
Muş	9,054.4549	1 : 9,570,000
Bafra	5,374.8125	1 : 8,451,000
Hasankale	7,783.7599	1 : 8,018,090
1948		
Cizre	7,733.6649	1 : 3,057,000
Malatya	9,978.6710	1 : 4,000,000
Suşehri	6,762.8495	1 : 7,300,000
Bayburt	7,125.7259	1 : 10,380,000
Gaziantep	7,057.8875	1 : 4,120,000
Ceyhan	10,902.4254	1 : 3,300,000
Urfa	9,368.1099	1 : 5,615,000
Derik	8,951.9742	1 : 4,720,000
Karapinar	9,111.1998	1 : 4,220,000
1949		
Edirne	6,435.4518	1 : 14,820,000
Ezine	6,895.3882	1 : 8,016,000
İzmir	11,188.6232	1 : 7,080,000
Alaşehir	10,911.1124	1 : 2,175,000
Antakya	8,437.8091	1 : 3,897,000
Ordu	3,003.2672	1 : 5,730,000
Palu	7,448.5486	1 : 4,340,000
Pinarbaşi	6,845.4805	1 : 19,320,000
1950		
Mucur	7,650.0193	1 : 2,985,000
Silifke	8,751.1030	1 : 6,350,000
Gazipaşa	4,153.2719	1 : 2,045,000
Antalya	7,241.6115	1 : 2,840,000
1951		
Muradiye	8,882.4998	1 : 2,344,000
Yüksekova	9,413.8152	1 : 9,520,000
Iğdir	9,391.9546	1 : 1,860,000
Ardahan	8,693.2098	1 : 2,133,000
1952		
Köyceğiz	7,399.9477	1 : 2,727,000
Beyşehir	8,188.0267	1 : 1,959,000

All necessary base lines are thus completed.

II. Precision Levelling

General

The length of the lines levelled at the time of writing is 13,705 kilometres and, at the end of 1957, their total length will be 15,156 kilometres. The results of the measurements and their systematic and accidental errors are shown in table 3. The systematic errors *Ms* and accidental errors *Ma* are computed by the following formulae:

$$M_a^2 = \frac{1}{4}\left(\frac{[\Delta^2]}{[L]} - \frac{[r^2]}{[r^2]}\cdot\left[\frac{S^2}{L^2}\right]\right)$$

$$M_s = \frac{1}{4[L]}\left[\frac{s^2}{L^2}\right],$$

where Δ is the difference between forward and backward runs of the distance, r is the length between two consecutive points, L is the total length of the line levelled and S is the algebraic sum of Δs.

Bench-marks

Bench-marks are made of bronze and are fixed in concrete blocks which are established every 2 to 2.5 kilometres approximately.

Instruments and rods

Precise levelling measurements are made with a levelling instrument Zeiss III (magnifying power 36), Wild N3 (magnifying power 42) and levelling rods with invar bands along the centre divided into 0.5 and 1.0 centimetres. In second-order lines, *Ni* 2 levels (with automatic horizontal setting) are also used.

Methods

Measurements of first-order levelling are generally made between 6.00 and 10.00 a.m. and between 4.30 and 8.00 p.m., especially when the air movement is lowest. In flat terrain, the back-sight and the fore-sight distances are taken equally and at less than fifty metres. After the forward measurements of a ten-kilometre line are completed, measuring two kilometres daily, the backward measurements of the same line are carried out.

At present, only dynamic-orthometric correction is applied, using the following formula:

$$dh = -2h\,\alpha\,\mathrm{Sin}\,2\varphi\left[1 + \left(\alpha - \frac{2\beta}{\alpha}\right)\cos 2\varphi\right]d\varphi.$$

No method other than geometric levelling is used in the first-order levelling measurements.

Crustal movement

So far no work has been done in this field.

Adjustment and datum of network

As soon as the levelling work of the entire country has been finished, the adjustment of this network will be started.

Junctions

The following observed differences have been found in connexions between the Mediterranean and the Black Sea, the Aegean Sea and the Sea of Marmara (in centimetres):

Mediterranean–Aegean Sea:	
Antalya–İzmir	−16.8
Mediterranean–Sea of Marmara:	
Antalya–Bandirma	−7.0
Antalya–İzmit	−17.7
Mediterranean–Mediterranean:	
Mersin–Antalya	−9.5
Mediterranean–Black Sea:	
Antalya–Akçakoca	−17.6
Antalya–Ereğli	−18.3
Antalya–Samsun	−20.1
İskenderun–Trabzon	−30.4

Mean sea levels are determined by means of tide-gauges in Antalya, İzmir, Ereğli and İskenderun. In other places, scales are used for the determination of the mean sea level.

Levelling across the Straits of Bosporus and the Dardanelles

In order to have the levelling net in the European part of Turkey (Thrace) and that in the Asiatic part of Turkey (Anatolia) on the same datum surface (mean sea level), two levelling ties have been made across the Straits of Bosporus and the Dardanelles and thus a levelling loop has been formed around the Sea of Marmara.

Two Wild N3 levelling instruments were used to carry out the observations on both sides of the Straits. The observations were carried out for two days across both Straits with 200 readings with each instrument, one set across the Bosporus, 860 metres in width, and two sets across the Dardanelles, 1,450 metres in width. The method used in both cases was a combination of differential (geometric) and trigonometric levelling.

The first-order levelling net of Turkey is given on the index map in figure 15.

Table 3. Turkey: Precise levelling

Year and name of line	*Order* First *(kilometres)*	Second	*Mean square errors (±)* Accidental *(millimetres)*	Systematic
1944				
Dinar – Afyon	114.0	+	0.78	0.10
1945				
Afyon – Eskişehir – Sivrihisar	269.6	+	0.89	0.18
1946				
Sivrihisar – Ankara – Gerede	309.4	+	0.87	0.12
1947				
Afyon – Uşak	82.8	+	0.88	0.22
Gerede – K. D. Ereğlisi	151.6	+	0.99	0.08
1948				
İskenderun – Perveri	311.1	+	0.79	0.01
1949				
Perveri – Malatya – Tercan	463.6	+	0.88	0.17
1950				
Uşak – İzmir	289.4	+	0.73	0.02
Tercan – Aşkale – Trabzon	237.7	+	1.06	0.20
Elâziğ – Diyarbakir	158.9	+	0.78	0.15
1951				
Ankara – Çankiri – Kastamonu	256.0	+	1.11	0.09
Kastamonu – Samsun – Havza – Zigala	412.0	+	1.09	0.49
Zigala – Sivas	177.0	+	0.88	0.40
Diyarbakir – Siirt	189.0	+	0.88	0.37
Kütahya – Balikesir	246.0	+	1.03	0.18
Gölbaşi – Konya	242.0	+	0.93	0.58
Sarimsakli – Sivas	173.0	+	0.84	0.08
1952				
Ulukişla – Mersin	153.0	+	1.02	0.06
Tarsus – Toprakkale	127.0	+	0.80	0.05
Yalak – Saimbeyli – Kozan – Adana	+	228.0	1.98	0.10
Sivas – Zara	73.0	+	0.82	0.10
Zara – Erzincan – Mut	273.0	+	0.80	0.10
Pinarbaşi – Maraş	202.0	+	1.07	0.36
Diyarbakir – Mardin	100.0	+	0.85	0.18
Mardin – Savur	+	50.0	1.77	0.09
Balikesir – Bandirma	105.0	+	0.52	0.01
Afyon – Konya	236.0	+	0.92	0.05
Konya – Ulukişla	381.0	+	0.80	0.02

Table 3 *(continued)*

Year and name of line	*Order* First *(kilometres)*	Second	*Mean square errors (±)* Accidental *(millimetres)*	Systematic
1953 [a]				
Aşkale – Hasankale – Muş	295.0	+		
Muş – Bitlis – Baykan güneyi	201.0	+		
Siirt – Gercüş	+	71.0		
Diyarbakir – Urfa	188.0	+		
Savur – İdil and 15 km east	+	188.0		
Cihanbeyli – Akşehir	+	170.0		
Kayseri – Niğde – Ulukişla	181.0	+		
Tokat – Niksar – Erbaa	+	101.0		
Balikesir – İzmir	226.0	+		
Eskişehir – Bilecik	87.0	+		
Düzce – İzmit – Yenişehir	251.0	+		
Gerede – Bolu – Düzce	92.0	+		
Bolu – Mudurnu	+	52.0		
Düzce – Akçakoca	40.0	+		
Sincanköy – Çayirhan	+	101.0		
Kirikkale kuzeyi – Kalecik	+	40.0		
1954				
Sarayköy – Aydin – İzmir	266	+	0.97	0.07
Alaşehir – Sarayköy – Dinar	216	+	0.98	0.26
Yenişehir – Bursa – Bandirma	154	+	1.12	0.20
İzmit – İstanbul	129	+	1.11	0.11
Kalecik – Kirikkale – Çorum	226	+	0.82	0.09
Samsun – Giresun	221	+	1.05	0.17
Çorum – Merzifon	63	+	1.02	0.01
Şebinkarahisar – Giresun	144	+	1.20	0.14
Trabzon – Giresun	160	+	1.17	0.20
1955				
Hasankale – Doğubeyazit	304	+	1.18	0.19
Doğubeyazit – Erciş – Tatvan	260	+	1.19	0.00
Narli – Urfa – Mardin	446	+	0.95	0.06
Konya – Beyşehir	95	+	0.96	0.07
Bandirma – Çanakkale	212	+	1.15	0.10
Babaeski – Havsa – Kilitbahir	242	+	1.13	0.14
Babaeski – Kirklareli	71	+	1.47	0.33
İstanbul – Babaeski	205	+	1.22	0.03
1956				
Muradiye – Van – Beytüşebap	371	+	2.12	0.35
Siirt – Şirnak	103	+	2.21	0.01
İskenderun – Kirikhan – Topboğazi	157	+	1.10	0.19
Kirikhan – Fevzipaşa	80	+	0.91	0.22
Mersin – Silifke – Konya	353	+	1.10	0.10
Beyşehir – Manavgat – Silifke	542	+	1.29	0.03
Manavgat – Antalya	91	+	0.84	0.64
Aydin – Muğla – Antalya	508	+	+	+
1957 (planned)				
Trabzon – Artvin – Erzurum	530			
Artvin – D. Bayazit	480			
Çanakkale – İzmir	330			

[a] For 1953 levelling, computations are not yet completed.

III. Geodetic Astronomy

General

The geodetic datum to which the triangulation positions are referred is the International Hayford Spheroid of:

$a = 6{,}378{,}388$ metres, $b = 6{,}356{,}911.946$ metres and

$f = 1 : 297.0$.

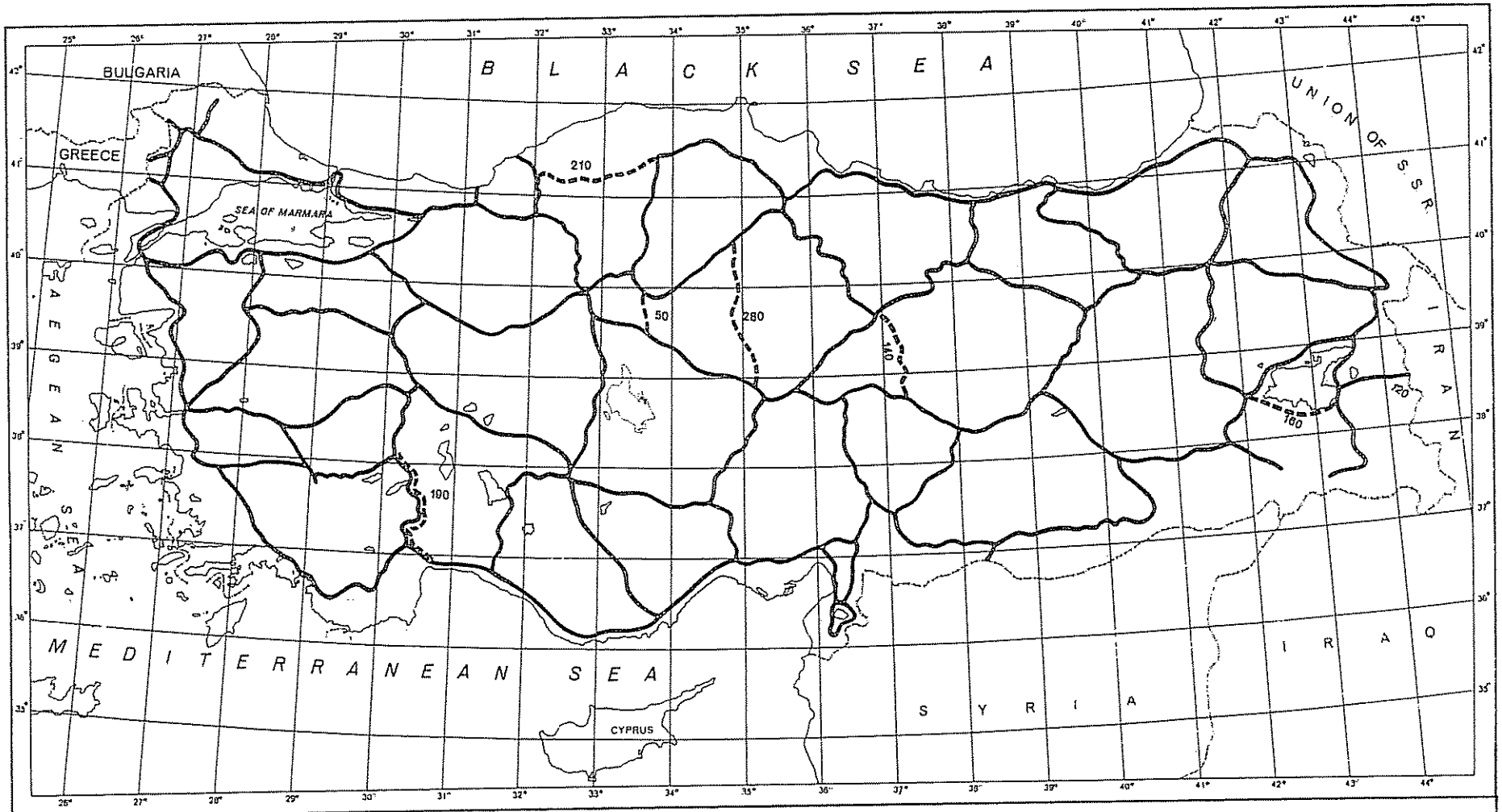

BULGARIA
GREECE
B L A C K S E A
UNION OF S S R
SEA OF MARMARA
AEGEAN SEA
M E D I T E R R A N E A N S E A
CYPRUS
S Y R I A
I R A Q
I R A N
210
50
280
100
190
180
TURKEY
INDEX OF FIRST-ORDER (PRECISE) LEVELLING NET
Measured levelling lines
Levelling lines to be measured
As of May 1958
Instruments used: Wild levelling instrument stadias, with invar tapes along the axis
Forward and backward measurements of the same sections carried out on the same day. Discrepancies between forward and backward measurements are kept under ± 4.0 √K mm.

Figure 15

Astronomic latitude and longitude of the origin (Mesedağ, national datum point) were adopted. The geodetic co-ordinates are:

$$\varphi = 44.^g\ 2995\ 219 \text{ and } \lambda = 36.^g\ 1970.462.$$

Since 1954, European datum has been adopted for all geodetic works.

The ninety-eight established astronomic (Laplace) points are listed in table 4 and shown on the index map in figure 16.

Additional observations

A number of additional Laplace stations will be established along the first-order chains, which will be used in determination of Geoidal Section.

Instruments of observation used

Before 1947, the Max Hildebrandt universal theodolite was used for azimuth observations, and the Askania passage instrument of 90-mm aperture was used for latitude and longitude observations. Since 1947, the universal theodolite Wild T4 has been used for the observations of azimuth, latitude and longitude.

Astronomical method used

The FK3 Jahrbuch, Boss Star Catalogues and Nautical Almanacs have been used in the preparation of the list of stars for astronomic observations.

Method of astronomic observations and their mean errors

Longitude of Laplace stations determined before 1947 was not connected with the astronomic central point. In 1947, a central point was selected near Ankara, Turkey, and its longitude was accurately determined. Since then, it has been customary to make longitude observations on this central point before and after field works. As yet, the longitude of the central point has not been connected to any international datum. Astronomic observations are made on first-order triangulation stations situated 70 to 110 kilometres apart and on one of the first-order triangulation points of junction figures of polygons. In order to eliminate personal and instrumental errors, the astronomic observations are made by the same observer using the same methods and instruments.

Longitude determination

For the determination of differences of longitude, differences of sidereal times are measured by observing transits of stars over meridians, using transit instruments with a transit micrometer, and registering these transits simultaneously with the beatings of an astronomic contact chronometer, which is regulated to local sidereal time, on the band of a chronograph. Time observations of central points of Laplace stations are made for four nights. Each consists of observations of fifteen time stars and three circumpolar stars. Time stars are so chosen as to make the algebraic sum of their azimuths factors nearly equal to zero, that is, half of the stars are taken north of the zenith and the other half south of the zenith. In order to determine accurately the azimuth of the axes of the transit telescope, circumpolar stars with a declination of 75 to 80 degrees are chosen, and some are observed at upper culmination and others at lower culmination.

Latitude determination

For latitude determination, two nightly observations are carried out using the Harlow Talcott method, and occasionally the Sterneck method is also used. Twelve pairs of stars are observed each night; some of the star pairs are taken for both nights' observations. In order to eliminate systematic errors of catalogues, the pair of stars is chosen from different catalogues. The mean square errors of latitude determined are shown in table 4.

Azimuth determination

For azimuth determinations, the observations are made on the polaris (at the time of elongation, whenever possible). The observations are made on first-order triangulation stations by measuring the angles between the polaris and one of the first-order triangulation lines by the direction method. Observations are carried out on three nights, and eighteen complete sets, each consisting of four measurements of angles in first and second positions of the instruments, are observed. Observations are made with universal Wild T4 theodolites of 65-mm aperture (diameter 25 centimetres, 360 degrees) and TSG Zeiss lamps (10.5 centimetres in diameter) are used.

One complete set of observations is made in fifteen minutes. In order to have the polar star and the station observed in approximately the same direction, a first-order triangulation line in northerly direction is selected.

Azimuth and longitude observations are made on the same nights whenever possible.

The mean square errors of azimuth of stations determined are shown in table 4.

Foreseen accuracy of results and manner of evaluation

The accuracies of the astronomical values are given by their mean errors in table 4. The mean errors of the azimuth and latitudes are computed by the formula:

$$m = \pm\sqrt{[vv] : (n\text{-}l)}$$
$$M = \pm m : \sqrt{n},$$

where v is the difference between the individual values and the mean of all values, and n is the total number of observations throughout.

The mean errors of longitudes are computed by the formula:

$$m = \pm\sqrt{[Pvv] / (n\text{-}l)}$$

$$M = \pm m : \sqrt{[P]};\ M' = M \sec \varphi,$$

where

$$P = \frac{c}{\mu_x^2} \quad \frac{n.\ a.\ b.}{n.\ a. \times b.},$$

$$n = \frac{\mu_x^2}{\mu_s^2},$$

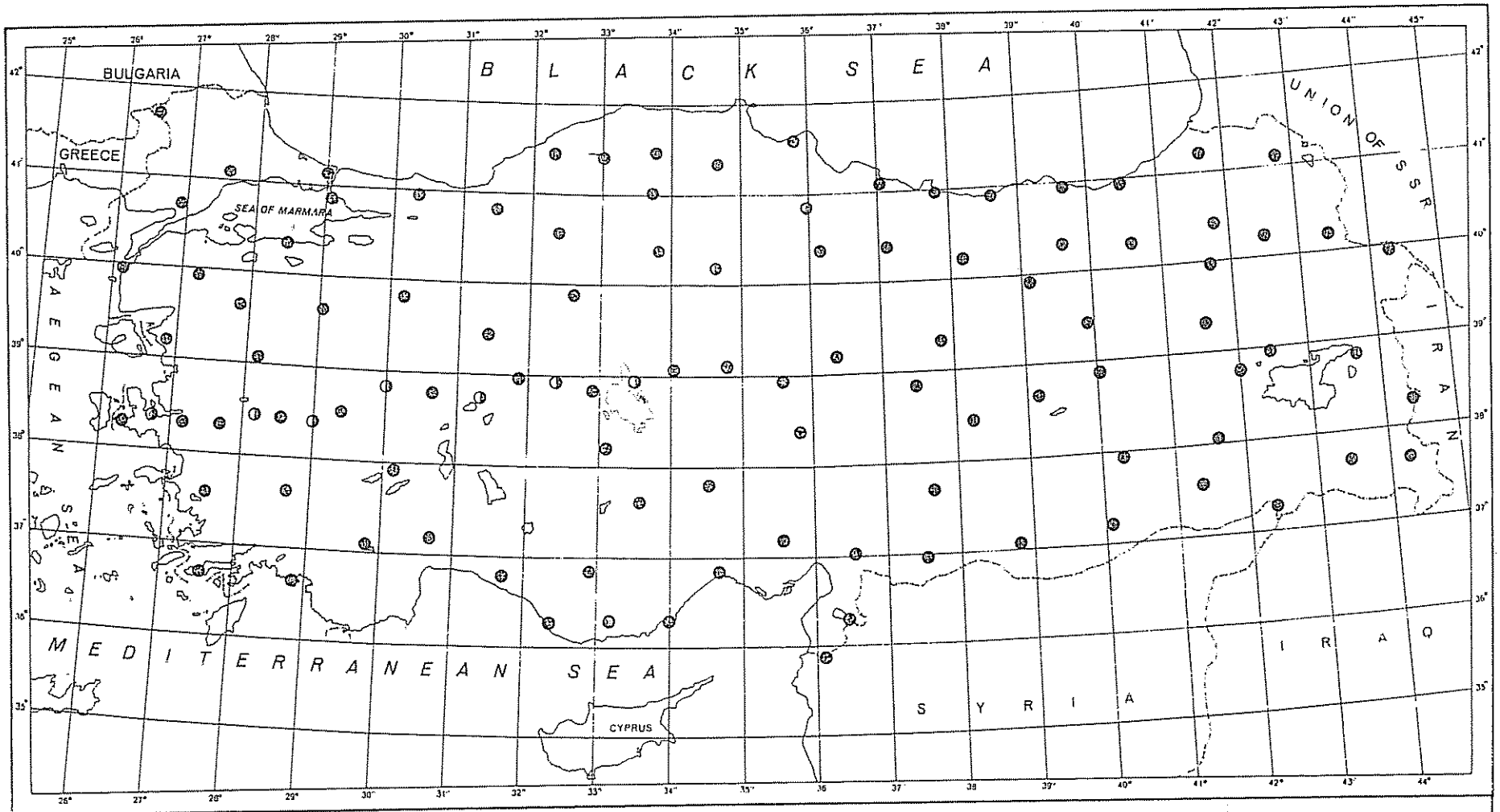
$c = 0.0002$ and

a = number of signals received, and

b = number of stars observed.

Time signals and types of reception apparatus used

Comparison of time is made by recording rhythmic time signals and chronometer beatings on the same chronograph.



TURKEY

INDEX OF LAPLACE STATIONS

Established Laplace stations

Laplace stations to be established, May 1958

Instruments used: Wild T3 Universal theodolite

Method used: Transit of stars for longitude, Harlow-Talcott for latitude, hour angle of Polaris for azimuth.

Figure 16

There was a lag of 0.05 second caused by the magnetic relay. After this relay was replaced by an electronic relay (vacuum tube) in 1945, it was possible to receive the following time signals:

GBR_{10} GBR_{18} DFY_{0} DFY_{12} FYL_{20}.

From 1945 to 1948, the GBR_{10} and GBR_{18} were the only time signals that could be received.

Since 1948, the following time signals have been received: GBR_{10} GBR_{18} FYA_{2} TMD TQG_{5} TQC_{9} FYA_{3} RWM_{1} RWM_{2} RWM_{3} RWM_{4} or sometimes GKU_{10} GIC_{18} and ROR.

The time signals were received over Marconi's wireless, type R.G. 37, receiver and Telefunken Sechskreis Empfanger type E 400 Rö, 15-150 kHz. For time-keeping, Nardin chronometers were used.

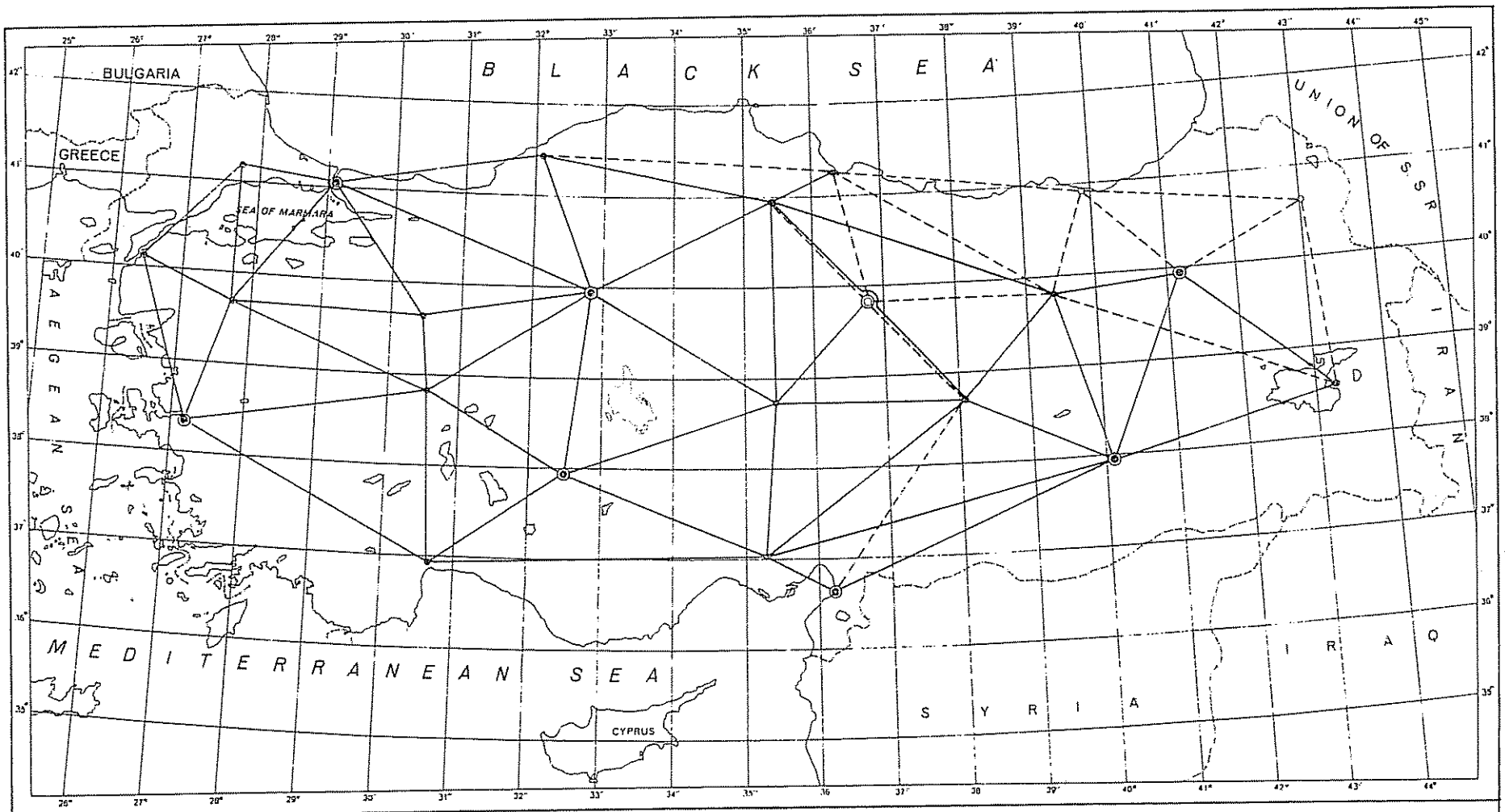
Sidereal times are used throughout the work.

Table 4. Turkey: Mean errors of astronomic observations

Year and name of Laplace station	Mean square errors (±)		
	Latitude	Longitude	Azimuth
	(seconds)		
1942			
Meşedağ (Asmaşik)	0.140	0.210	0.530
1943			
Halimoğlu (Göldağ)	0.118	0.180	0.280
Kozdoruğu (Türkmenkale)	0.095	0.060	0.330
Oflak T. (Erenler)	0.079	0.510	0.400
1944			
Ağil T. (Kaledağ)	0.130	0.270	0.460
Düzkir (Türkmenkale)	0.140	0.195	0.340
1945			
Beyaz İst. T. (Kara T.)	0.121	0.285	0.340
Kurtçal (Demirli)	0.128	0.510	0.420
Kinaliada (Kocataş)	0.051	0.180	0.400
1946			
Hasanbaba (Melekler)	0.159	0.315	0.370
Haciman (Yukariörencik)	0.024	0.555	0.370
Ş. Bozkir (Aliuçuran)	0.138	0.255	0.330
1947			
Tildoruğu (Akçam)	0.025	0.300	0.440
Dideban T. (Tahta)	0.240	0.315	0.610
Cumani (Mendil D.)	0.290	0.450	0.490
Ardiçtepe (Siralidağ)	0.160	0.390	0.310
1953			
Mercimek tepe (Tavur D.)	0.098	0.570	0.270
1947			
Döme T. (Karaçukur)	0.120	0.390	0.220
Sincebayiri (Büyükönlü	0.110	0.105	0.530
Çevrimkaya (Çanta T.)	0.200	0.255	0.340
Kocataş (Kinaliada)	0.160	0.420	0.490
Gelincik Mz. (Çalti)	0.160	0.465	0.260
1948			
Zirombi (Bağita)	0.170	0.165	0.287
Divrik T. (Kösedağ)	0.200	0.060	0.400
Hurlar (Melmekâgü)	0.260	0.135	0.250
Karadağ (Kurtlu T.)	0.410	0.225	0.330
Eşeksirti (Cecan)	0.200	0.165	0.250
Tilalu (Tilhamu)	0.110	0.165	0.250
Saribiye (Kolye T.)	0.440	0.420	0.600
Koyunkiran (Kermuz)	0.150	0.225	0.230
Toprak T. (Muşar D.)	0.420	0.300	0.340
Kurik T. (Kalesonu)	0.320	0.300	0.430

Table 4 *(continued)*

Year and name of Laplace station	Mean square errors (±)		
	Latitude	Longitude	Azimuth
	(seconds)		
1948 (continued)			
Kuzdağ (Akdağ)	0.228	0.105	0.410
Deşihöyüğü (Kanun H.)	0.210	0.090	0.560
Mekedağ (Düden D.)	0.340	0.375	0.410
Kazankaya (Tilân H.)	0.210	0.255	0.210
B. Katranli (Akçadağ)	0.310	0.060	0.340
Emen (Pozanti D.)	0.270	0.45	0.460
1949			
Yediler (Yağarsilar)	0.130	0.210	0.180
Çalibaba (Çaldağ)	0.110	0.090	0.180
Kuşali (Yaylacik D.)	0.200	0.135	0.190
Karadağ (Akdağ)	0.140	0.120	0.220
Kaysan T. (Gözlübaba)	0.100	0.090	0.180
Bademli (Aklayaylasi)	0.160	0.120	0.210
Maltepe (Paşa H.)	0.260	0.315	0.300
Sunaşi (Tiğli)	0.150	0.075	0.200
Kirmizi T. (Seriddağ)	0.360	0.315	0.360
Kurudağ (Hizirilyas)	0.213	0.105	0.310
Miliziyaret (Supulus)	0.380	0.180	0.320
Meryem T. (Hazarbaba)	0.380	0.045	0.340
Fahribaba (Tahkimtepe)	0.270	0.150	0.320
Boztepe (Karageyik)	0.330	0.105	0.360
Karlik (Üçpinar)	0.320	0.660	0.270
Adakasim (Kurşunlu D.)	0.126	0.210	0.300
1950			
Zeybektarla (Paşalar D.)	0.100	0.465	0.200
Oyukludağ (Kartal D.)	0.140	0.150	0.560
Korudağ (Nergis D.)	0.137	0.300	0.300
Kizilyokuş (Katran D.)	0.160	0.285	0.210
Asardağ (Darindağ)	0.140	0.375	0.220
Fazillar (Akdağ)	0.130	0.210	0.280
Tirmir höyüğü (Eshabikehif)	0.120	0.180	0.460
Silifke feneri (Örmeci)	0.130	0.255	0.210
Erenler (Karadiken)	0.200	0.135	0.310
Abdiköy (İsmail S.)	0.220	0.555	0.430
Kepes T. (Toprak T.)	0.100	0.225	0.340
Sövengendağ (Hacili D.)	0.140	0.270	0.370
Çift T. (Cintepe)	0.220	0.270	0.290
Elmalioğlu T. (Hamzasultan)	0.150	0.285	0.290
Kizilyuca (Candili)	0.170	0.210	0.370
1951			
Dumanlidağ (Kümbet T.)	0.320	0.060	0.380
Ciyareşk (Sersin)	0.180	0.090	0.330
Beresbih (İspires)	0.190	0.165	0.340
Haravil (Berimelik)	0.260	0.135	0.260
Zenginziyara (Karanlik)	0.200	0.615	0.430
Karadağ (Aksolik)	0.280	0.480	0.300
Kireç T. (Ağil D.)	0.150	0.195	0.280
Ciplak T. (Kocabakacak)	0.160	0.375	0.320
Hisardağ (Yilacili T.)	0.148	0.285	0.250
Gökseki Hasanyarani)	0.090	0.180	0.320
Dikmen (Kiziltepe)	0.175	0.735	0.230
Küçükilgaz (Mevliyat T.)	0.160	0.285	0.200
1952			
Çatal T. (Madran)	0.262	0.060	0.330
Buzdağ (Oyuklu D.)	0.199	0.090	0.405
Eren T. (Çal D.)	0.186	0.330	0.220
Çarikkuyu (Karincali)	0.173	0.075	0.266
Rahatdağ (Koreş)	0.184	0.285	0.204
Eflani (Gök T.)	0.160	0.480	0.242
Dönekdağ (Mamo)	0.337	0.270	0.445
Höbekbaba (Göldağ)	0.299	0.060	0.410



TURKEY

INDEX OF FIRST-ORDER GRAVITY NET

⊛ Pendulum stations

▪ ▪ Gravity differences, already measured

o - o Gravity differences to be measured

Gravimeters used: Nörgaard TNK 425 and TNK 468

Gravity differences between stations were measured 3 times and measurement of the same line was carried out on the same day; gravimeters were transported by aeroplane.

Figure 17

Table 4 *(continued)*

Year and name of Laplace station	Mean square errors (±)		
	Latitude	Longitude	Azimuth
	(seconds)		
1952 (continued)			
Keldağ (Yelecik)	0.207	0.720	0.306
Ayana (Meşedüzü)	0.133	0.315	0.311
Triyal (Dudube)	0.163	0.015	0.253
Emiroğlu (Böberek)	0.141	0.120	0.200
Karadağ (Gemin D.)	0.193	0.330	0.288
Kakeninkaya (Boğa D.)	0.185	0.150	0.407
Kasimtiği (Kizmeza T.)	0.247	0.240	0.320
Suphandağ (Kizil D.)	0.372	0.225	0.402
1953			
Erenler (Karataş)	0.140	0.075	0.151

IV. Gravity Determinations

General

Gravity determinations in Turkey, especially relative measurements, were started in 1956. They were and still are being carried out by the Turkish Geodetic Survey. Prior to this date, some regional measurements were made for mineral research, for determination of deflection of vertical at geodetic datum station near Ankara, and also for the connexion of pendulum station with airports at Ankara, İzmir and İskenderun.

These measurements were repeated in 1956. In addition, pendulum stations were established by the Kandilli Observatory in İstanbul at evenly distributed points within the country, namely:

İstanbul	980,296 ± 0.001 gals
Ankara	979,938 ± 0.001 gals
İzmir	980,060 ± 0.001 gals
Konya	979,742 ± 0.001 gals
İskenderun	979,855 ± 0.001 gals
Sivas	979,779 ± 0.001 gals
Erzurum	979,611 ± 0.001 gals

The values are referred to the gravity in İstanbul as 980,296 gals. This is connected to Potsdam gravity value of 981,274 gals (see "Calibration of the Gravimeters" below).

The Turkish reference station has been defined as the top of a pier in the Kandilli Observatory, İstanbul.

The relative gravity measurements within the country have been based on the value 980,296 gals at this station, which is obtained by means of a direct pendulum connexion to Potsdam.

Relative measurements of gravity

It is planned first to complete the primary network (gravity base net) which is established at twenty-four airports.

The determinations of fifteen stations were completed in 1956 and the remaining nine stations will be completed in 1957.

Instruments and transportation used

Two Nörgaard gravimeters, TNK325 and TNK468, were used in establishing the network; they were transported by aeroplane.

Figures and methods used

Successive stations have been interconnected in such a way as to form closed figures, mainly triangles or loops with diagonals.

Distances between stations are small enough to allow three uninterrupted flights (two measurements at each, initial and end stations) to be made within a single day. Two gravimeters are simultaneously employed at all stations. At each station, ten sets of readings of micrometers are recorded and reduced to millimetres, and the means are taken as the final values of the measurements. After the measurement described above has been finished at the starting station, using two gravimeters at the same time, these are immediately transported by aeroplane to the next point, that is, the station on the second airfield, and the same measurement is carried out at this station, and again the instruments are flown to the initial point (first station) and back to the second station, completing three trips and two sets of observations at each station with two gravimeters simultaneously within a single day, which can be indicated as follows:

TNK325: 1-2-1-2, 2-3-2-3, 1-3-1-3, 3-4-3-4

TNK468: 1-2-1-2, 2-3-2-3, 1-3-1-3, 3-4-3-4

and so on.

Calibration of the gravimeters

To evaluate and control the constants of the gravimeters, linearity and stability of the drift, it is customary to connect the pendulum stations at İstanbul and Ankara of 344 milligals and those of Ankara and Erzurum of 316 milligals, which are the greatest gravity differences existing between pendulum stations in Turkey. These lines can be covered by air travel in two and four hours, respectively. The index map in figure 17 shows the first-order gravity net.

Computations

The preliminary computations, including constants of the instruments and drifts, have been carried out, but the final evaluation must still be made. The constants of the gravimeters thus found are in close agreement with those given by the factory, although not entirely so. However, the results of the measurements in milligals of both instruments for all lines are in very close agreement—less than ±0.2 milligal.

The final calibration of the gravimeters still remains to be determined. It is hoped and intended to calibrate the gravimeters in question against the well-established calibration line or lines in Europe. It is also desired and expected that the Turkish net can be connected to some stations in Europe. The recommendation of the International Association of Geodesy would be highly appreciated in this and other similar problems.

The last digits of the gravity differences, in milligals, and misclosure of the gravity triangles or loops preliminarily computed are given in table 5.

Table 5. Turkey: Observations of TNK468 calibrated against TNK325

Line	Last digits of milligals and decimals	
	TNK325	TNK468
Ankara – Kayseri	7.56	7.62
Kayseri – Malatya	5.98	5.96
Malatya – Erzincan	3.36	3.34
Adana – Malatya	7.58	7.24
Malatya – Merzifon	4.60	4.80
Merzifon – Ankara	3.07	3.46
Erzurum – Van	9.33	9.33
Van – Diyarbakir	4.88	4.70
İstanbul – Balikesir	3.06	3.01
Balikesir – Afyon	0.30	0.26
Afyon – Ankara	9.52	9.52
Afyon – İzmir	4.62	4.87
İzmir – Çanakkale	0.97	1.08
Kayseri – Adana	3.24	3.24
Malatya – Diyarbakir	3.54	3.44
Erzurum – Erzincan	8.58	8.53
Diyarbakir – Erzincan	6.71	6.65
Kayseri – Marzifon	0.50	0.92
İstanbul – Ankara	3.55	3.48
İzmir – Gaziemir	8.84	8.61
Ankara – İstanbul	3.27	3.32
İstanbul – Çaycuma	1.42	1.48
Çaycuma – Merzifon	1.38	1.46
Merzifon – Samsun	4.76	4.69
Kayseri – Konya	2.03	2.37
Adana – İskenderun	0.60	0.84
İskenderun – Diyarbakir	4.76	5.14
Adana – Diyarbakir	4.54	4.50
Çorlu – Yeşilköy	4.06	4.36
Çorlu – Çanakkale	3.26	3.48
Çanakkale – Balikesir	5.96	5.71
Balikesir – Çorlu	9.36	9.32
Çaycuma – Ankara	4.62	4.93
Konya – Antalya	4.68	4.86
Afyon – Konya	0.17	0.48
Antalya – Adana	9.48	9.33
Afyon – Eskişehir	6.50	6.50
Eskişehir – Balikesir	4.15	4.15
Balikesir – İzmir	5.32	5.12

Table 5 *(continued)*

Reference station

The Turkish Gravity Base Net was linked with the international station at the Kandilli Observatory at İstanbul.

AGENDA ITEM 7

Establishment of a Regional Intergovernmental Cartographic Commission or Organization for Asia and the Far East

PROPOSAL SUBMITTED BY CHINA [1]

With respect to the implementation of the resolution of the first United Nations Regional Cartographic Conference for Asia and the Far East, held in Mussoorie in 1955, recommending the setting up of regional machinery to assist Governments in carrying out cartographic work, it is suggested that the functions of the regional intergovernmental body, if established, should be:

(*a*) To study common cartographic problems and standard specifications;

(*b*) To promote the use of cartographic data in developing economic resources;

(*c*) To facilitate the training of technicians in the various branches of cartography—this to include establishing a training centre; and

(*d*) To act as a central clearing house for the exchange of technical information on cartographic activities and developments.

[1] The original text of this paper appeared as document E/CONF. 25/L.79.

PROPOSAL SUBMITTED BY JAPAN [1]

Background

Conclusion of the Committee of Experts on Cartography

A Committee of Experts on Cartography, appointed by the Secretary-General in pursuance of Economic and Social Council resolution 131 (VI), met in March and April 1949 and discussed *inter alia* the possibility of working out uniform international cartographic standards by a cartographic office to be set up within the United Nations Secretariat. The Committee, considering that it was not advisable for the United Nations to enter this field directly, suggested that the interested bodies already in existence should be encouraged to continue their work in the relevant field.

Burmese Proposal at the First Session of the Regional Conference

At the first United Nations Regional Cartographic Conference for Asia and the Far East, held in India in 1955, the Government of Burma introduced an item, " Organization of International Co-operation ".

The views of the Burmese delegation [2] may be summarized as follows:

(*a*) Vast areas of the earth remain still unsurveyed or inadequately surveyed, while their economic development is becoming increasingly dependent on accurate maps.

(*b*) Such international organizations as the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), the International Labour Organisation (ILO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) have been operating in various spheres such as food and agriculture, health, labour, and science and education. In the field of cartography, also, there should be an intergovernmental organization which would respond to the pressing needs of less developed countries.

(*c*) As stated in the Report of the Committee of Experts, the main obstacles to the development of mapping which can best be overcome by the establishment of an international organization are as follows:

Lack of an organization where advice and assistance can be sought;

Lack of technical knowledge, equipment and technicians;

Lack of appreciation by national Governments of the fundamental need for maps;

Financial limitations to providing funds for mapping.

(*d*) The proposed organization could be the most effective medium for establishing uniform international standards.

At the Conference, the representative of Burma, answering a question of the Chairman, stated that he preferred an inter-

[1] The original text of this paper appeared as document E/CONF. 25/L.78.

[2] *See* E/CONF.18/A/L.23 and E/CONF.18/A/L.25.

governmental organization on the world plan to one on a regional plan, and stressed the pressing need to establish a central research organization.

Views of the Representative of the Netherlands

At the Conference, the representative of the Netherlands was in favour of establishing a regional organization on an intergovernmental level, in view of the fact that the authority of existing international scientific unions is insufficient to have standards accepted by the Government concerned.[3]

As to a central research organization, the representative of the Netherlands suggested that each country in the region might establish contact with the European Organization for Experimental Photogrammetric Research (EOPER).

In the course of discussion at the Conference, the representative of the Netherlands, referring to a question of funds for the creation of intergovernmental regional organizations, expressed his view that, in respect of the organization to be established within the framework of the United Nations, all financial burdens should be borne by the United Nations.

Conclusions of the Conference and Resolution of the Economic and Social Council

(*a*) *The organization should be intergovernmental.* After the discussion, it was recognized that the proposed organization should be on an intergovernmental level so that it could perform not only technical (for example, standardization) functions but also such general functions as are required to obtain the recognition of Governments in the region of the importance of cartography and, in particular, of national cartographic institutions.

(*b*) *The organization should be regional.* In view of the fact that cartographic conditions and interests differed widely in the various regions of the world, the Conference recognized that, at least as an initial step, such an organization should be established on a regional basis.

(*c*) *The organization should be established within the framework of the United Nations.* The Conference agreed with the views of the representative of the Netherlands that the organization should be established within the framework of the United Nations.

In accordance with the conclusions mentioned above, the Conference adopted resolution 17, and the Economic and Social Council, at its twenty-first session, recommended that the regional economic commissions should establish cartographic committees if they wished to do so (resolution 600 (XXI)).

As to the question relating to a central research organization or office, the Conference, recognizing the difficulties involved in setting it up, merely suggested that the Governments of the region should organize a committee covering certain fields of cartography.

PROPOSAL OF THE JAPANESE GOVERNMENT

The Japanese Government fully appreciates the valuable contribution contained in the Burmese proposal and the constructive views expressed by the representative of the Netherlands at the Mussoorie Conference.

The Japanese proposal, as expressed in the draft resolution annexed hereto, intends merely to follow up the initiative taken by the Burmese proposal and to put it on a practical basis so that the proposed organization may be established as soon as feasible in accordance with the resolutions of the Mussoorie Conference and the Economic and Social Council.

Those resolutions have made it clear that the matter of establishment of the proposed organization is left to the discretion of the regional economic commissions and that such an organization is to be established as an intergovernmental regional organ, under the aegis of the relevant commission.

The details of structure of the proposed organization—namely, its staff, terms of reference, financial implications and so on—would have to be considered against the over-all background of the activities of the regional economic commission concerned, that is, the Economic Commission for Asia and the Far East (ECAFE), as a part of the United Nations. Under the circumstances, the Japanese Government considers it appropriate and opportune that the present conference should express its hope that the coming session of ECAFE will study, paying full attention to Economic and Social Council resolution 600 (XXI), the possibility of taking concrete steps for organizing intergovernmental and regional channels of co-operation in the field of cartography, including establishment of an appropriate regional machinery.

Annex—Draft Resolution[4]

The Conference,

Recalling that the first session of the United Nations Regional Cartographic Conference for Asia and the Far East held in India in 1955 recommended the setting up of regional intergovernmental cartographic organizations for advising Governments of the region on their cartographic problems and other vital needs for giving primary importance to cartographic self-sufficiency as a prerequisite to orderly economic development,

Recognizing that the Economic and Social Council of the United Nations drew the attention of the Member Countries, at the various sessions since 1948, to the importance of international co-operation and co-ordination for mapping and recommended to take appropriate measures therefor, in its resolutions 131 (VI), 261 (IX), 476 (XV) and 556 (XVII),

Appreciating that the Council further recommended, at its twenty-first session in 1956, in its resolution 600 (XXI) that those regional economic commissions which think it desirable consider the question of establishing cartographic committees for the purpose of periodic consultation among their members, in view of the keen interest therein of the Member Countries expressed during the deliberations in the present Conference,

Expresses the hope that this matter will be taken up at the next session of the Economic Commission for Asia and the Far East to be held in Australia in 1959, and that the Commission will study, paying its full attention to the Council's resolution 600 (XXI), the possibility of taking concrete steps for organizing intergovernmental and regional channels of co-operation in the field of cartography, including establishing of an appropriate regional machinery.

[3] *See* E/CONF.18/A/L.7.

[4] The text of the resolution, as adopted, may be found on page 7 of *Second United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 1, *Report of the Conference* (Sales No.: 59.I.9).

AGENDA ITEM 8

Geodesy *

ESTABLISHMENT OF LONG STANDARD BASE LINES FOR CALIBRATING GEODIMETERS AND OTHER RADIO-ELECTRIC AND ELECTROMAGNETIC DEVICES, AS WELL AS FOR ENSURING THE ACCURACY OF NETWORKS [1]

Background paper submitted by Japan

As a result of modern scientific and technical progress, Shoran and similar systems and such electronic instruments as the tellurometer are now being used more and more in surveying work. While recently developed electronics have provided means of measuring frequency, time interval and the like with a degree of accuracy sufficient for the purpose of geodetic surveying, the same cannot be said with regard to ascertaining the current value of the velocity of electromagnetic waves, as techniques for determining corrections due to atmospheric effects have not been developed to astage which would ensure the precision required for primary geodetic survey. Thus, even using the international value of light velocity adopted at the eleventh general assembly of the International Union of Geodesy and Geophysics held in Toronto in 1957, it is still very important to determine both the instrumental constant and the atmospheric corrections with adequate accuracy.

The first United Nations Regional Cartographic Conference for Asia and the Far East, held in Mussoorie in 1955, recommended the establishment of a few standard base lines in this region.[2]

In order to obtain the full benefit of the recommendation of the Mussoorie Conference, it is proposed that the standard base lines be established with a length longer than ten kilometres, together with permanent facilities for measuring atmospheric temperature, pressure and humidity, as well as wind velocity. It is further proposed that at least two such base lines in this region be completed as soon as possible—one on the continent and the other on an island in the Far East. Existing suitable base lines could be adapted for this purpose by adding the required facilities.

[1] The original text of this paper appeared as document E/CONF.25/L.3.

[2] *See United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 1, *Report of the Conference* (Sales No.: 55.I.29), page 8.

ESTABLISHMENT OF LONG BASE LINES [1]

Technical paper by the Geographical Survey Institute, Japan

Owing to recent developments in electronics, which have permitted the introduction of many electronic devices, geodetic instruments have been greatly improved. New surveying methods for measuring distance in terms of the velocity of electromagnetic waves have been popularized in triangulation survey, in place of the conventional methods of base-line measurement by means of Jaderin wire and angle measurement by theodolite. At the present time many kinds of instruments for these new surveying methods, such as the geodimeter and tellurometer, have been developed and manufactured and systems such as Shoran and Decca have been evolved. The common basis of these devices is the constant velocity of electromagnetic waves, whereas conventional instruments are based on the one-metre standard bar. Since the velocity of electromagnetic waves has been determined directly or indirectly in comparison with a definite length which was originally determined by means of the one-metre standard bar, there should be no discrepancy between the results obtained by the new method and those arrived at by conventional methods. Actually, however, because of the many difficulties of determining with sufficient accuracy the velocity of electromagnetic waves and atmospheric corrections, and the correct value of the length of the measuring wire and its temperature coefficient, considerable discrepancies may be found between the results obtained by new and con-

[1] The original text of this paper, submitted by Japan, appeared as document E/CONF.25/L.44.

* *See* also E/CONF.25/L/51 under agenda item 6, "Brief Reports by Governments on the Cartographic Activities of the Respective Countries, Outlining Work Achieved, Technical Developments and Difficulties Encountered in Technical Work since the Mussoorie Conference".

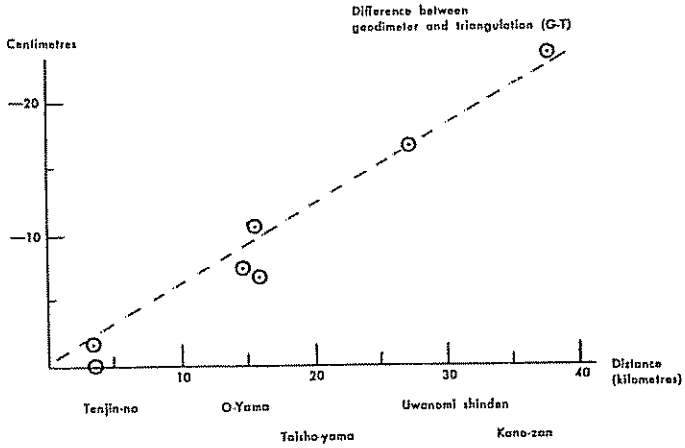


Figure 18. Japan: Relation between the differences (G-T) and the distances measured

ventional surveys. Though these discrepancies may include observational and instrumental errors, the most essential factor is the systematic error due to the difference between the two surveying systems, one being based on the velocity of electromagnetic waves and the other on the mechanical extension of the one-metre standard bar.

In Japan the geodimeter survey was commenced by the Geographical Survey Institute in 1956, in order to measure the base line and the distance between triangulation points directly, instead of measuring the base line by means of Jaderin wire and its enlargement. The instrument was tested at the Tenjin-no base line, located in the Chugoku district of western Japan. Since then measurements have been carried out in several places, which have been recently re-covered by the conventional triangulation survey, in order to revise the values of positions of the triangulation points and to study land deformations caused by the earth's crustal movements, including earthquakes.

In geodimeter survey the adopted light velocity was 299,792.5 kilometres per second and its atmospheric corrections were calculated using the following refractive index of air according to the manufacturer's instructions.

$$na = 1 + (n - 1/1 + \frac{+}{273}) \cdot p/760 - 5.5.10^{-8} \cdot e/1 + \frac{+}{273}$$

where

ng = refractive index of air at normal state (0°C, 760mmHg);
t = temperature in degrees centigrade;
p = atmospheric pressure in mmHg;
e = humidity in mmHg.

The atmospheric conditions—temperature, pressure and humidity—were observed at the two end points of the measured line.

The results obtained by both the geodimeter and triangulation surveys are shown in table 6. It was observed that the differences between the results obtained by geodimeter and triangulation surveys have increased in proportion to the distances measured, as shown in figure 18.

Table 6. Japan: Results of the geodimeter and triangulation surveys

Place	Geodimeter survey		Old value by triangulation (T) (metres)	G-T
	Date	Result (G) (metres)		
Tenjin-no base line	October 1956	3,515.786	3,515.7955	−0.0095
	October 1957	3,515.794	3,515.7955	−0.0015
From Taisho-yama to Hanko-yama	November 1956	18,383.306	18,383.380	−0.074
	October 1957	18,383.269	18,383.380	−0.111
From Kano-zan to Bodai-zan	November 1957	36,113.732	36,113.956	−0.224
From Uwanomi shinden to Fumaki-yama	May 1958	26,975.250	26,975.407	−0.157
From O-Yama to Futatsumaru-yama	September 1958	15,166.311 [a]	15,166.387	−0.076

[a] Provisional.

It is thought that the differences may be due to many errors in both surveys, including instrumental and observational ones. However, taking into consideration the fact that the systematic differences are in proportion to the distances, the main causes might be in the uncertainty of the basic values in both surveying systems, such as the adopted value of the light velocity and its atmospheric corrections in geodimeter survey and the calibrated values of the one-metre standard bar, the five-metre sub-standard bar and the twenty-five-metre Jaderin wire and their temperature coefficients in the conventional method.

Owing to the recent progress of electronics, it is assumed that electronic survey methods will, in the near future, replace conventional methods in geodetic surveys, especially in distance measurements, in order to ensure greater accuracy, save time and reduce costs of field work.

Considering these circumstances, we think it is necessary that the comparison between new and conventional methods should be carried out in suitable ways at as many places as possible, in order to compare data obtained by new methods and those obtained by conventional methods and to unify both, as well as to ensure the accurate value of the velocity of electromagnetic waves and the corrections for atmospheric conditions in geodetic long-distance measurement.

This is the main reason for our proposal to establish long base lines.

REPORT ON THE MEASUREMENT OF THE BURMA-EAST PAKISTAN JUNCTION LEVELLING LINE ALONG THE UKHIA (EAST PAKISTAN) - TAUNGBRO (BURMA) ROAD [1]

Technical paper submitted by Burma

Observation of the international levelling junction stretch on the Burma-East Pakistan border was carried out jointly by the Survey of Pakistan and the Burma Survey Department from 19 to 20 September 1958, under the personal direction of United Nations Technical Assistance Administration experts, Mr. L. Pettersson (in Pakistan) and Dr. T. J. Kukkamaki (in Burma).

The Burma party consisted of two observers and six chainmen in addition to the United Nations geodetic expert.

The level line was observed, backwards and forwards, as a high precision line, by two observers. The Wild N3 level and invar precision staves were used in carrying out the measurement.

Three bench-marks were established on either side of the boundary line, at average distances of about 240 metres apart. The length of line thus measured was 1.2 kilometres. Iron pipes of 1¼-inch diameter, inserted into the ground to a depth of 3 metres, were used as bench-marks.

The mean errors of the two sets of measurements made are, respectively, 0.468 millimetre per kilometre and 0.316 millimetre per kilometre.

The measurements of elevations—relative to bench-mark 58001—are given in table 7. The area containing the three bench-marks 58001, 58002 and 58003 is covered by the one-inch map, sheet number 84 $\frac{C}{4}$, and by aerial photograph, number 84 $\frac{C}{4}$ 7 $\frac{448}{59}$.

The Burma Survey Department would like to express its gratitude to the Survey of Pakistan for its kind co-operation.

[1] The original text of this paper appeared as document E/CONF. 25/L.66.

Table 7. Measurements for the junction of the levelling line along the Ukhia (East Pakistan) - Taungbro (Burma) road

L or R—Left or right side of the road facing towards the increasing mile-post number.

Bench-mark number	*Nearest mile post*	*Distance from the mile post*	*Distance from the central line of the road*	*Height above road level*	*Height above ground surface*	*Distance from the bench-mark post*	*Elevation*
		(metres)					
(PAK) 3							−0.38170
(PAK) 2							+0.00486
(PAK) 1							+1.74558
58001 [a]	97	433 [b]	L22.3	+0.2	−0.4	1.0	0.00000
58002	97	120 [b]	R18.6	−0.7	−0.3	1.0	−0.73019
58003	97	73 [c]	L28.0	+0.7	−0.2	1.0	+2.32935

[a] Distance along Burma-East Pakistan Road: 46 metres to Burma from the Central Line of the Naf River.
[b] Towards the increasing mile-post number.
[c] Towards the decreasing mile-post number.

INTERNATIONAL CONNEXION OF GEODETIC CO-ORDINATES [1]

Background paper submitted by Japan

Recognizing the importance of establishing a homogeneous world-wide system of geodetic co-ordinates, the International Union of Geodesy and Geophysics has recommended, in several instances, international connexion of national geodetic nets.

In most cases such a connexion can be achieved by direct observation of the well-known triangulation method, but in the case of long distances between a continent and an island, or between two islands, other techniques and equipment, such as Shoran, Decca, flare-triangulation, astronomical occultation, or even artificial satellite, are considered necessary.

With regard to this region, the first United Nations Regional Cartographic Conference for Asia and the Far East

[1] The original text of this paper appeared as document E/CONF. 25/L.4.

studied this question and, in resolutions II and VII, made recommendations to Governments regarding the arrangements for the geodetic measurements involved.[2] Important progress has already been reported on several international connexions, but all the required geodetic connexions in the region have not yet been achieved, among which mention may be made of those between the continent and significant islands.

In view of the need for international geodetic connexions not only by cartographic agencies in preparing accurate maps, particularly in areas bordering two or more countries, but also by scientists in studying the figure of the Earth, a further consideration of this question by all countries concerned would undoubtedly facilitate the planning and arrangements for the measurements.

[2] *See United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 1, *Report of the Conference*, pages 7 to 10.

CONNEXION OF GEODETIC CO-ORDINATES BY OCCULTATION [1]

Technical paper by the Geographical Survey Institute, Japan

Occultation Observation for Geodetic Purposes

As the moon's sidereal period of orbital revolution around the earth is about twenty-seven and one-third days, it moves eastward with reference to the stars at an average rate of more than half a degree per hour. In its passage over the stellar background it is continually interposing its disc between us and the stars, and the sudden disappearance of a star in this way is called the occultation of the star by the moon. After an interval, the star reappears (reappearance). The occultation is an instantaneous phenomenon, and when its time is measured accurately, there exists at that instant a definite relation between the moon's position in the sky and the position of the observer, it being assumed that the star's position is known accurately.

Our standpoint is such that, assuming the positions of both the star and the moon are known, we can determine our position on the surface of the earth. Usually our position on the map (geodetic position) is referred to a particular geodetic system which is developed on the surface of the local reference ellipsoid.

The reference ellipsoid which is adopted by each country or area may be, largely for historical reasons, one of several, such as the Bessell, Clark or Hayford ellipsoid. These ellipsoids have different dimensions, and, moreover, uniform orientation of the various ellipsoids to the earth has not been completed, though this was recommended in the resolution adopted at the general meeting of the International Union of Geodesy in 1930. This seems to be inevitable, since there exists no concrete surface which represents the true surface of the earth. Consequently, each geodetic co-ordinate is different not only in its relationship to other co-ordinates, but also in its relationship to the ideal surface of the earth, if the existence of such a surface is accepted.

The positions of many isolated islands in the ocean are also thought to be very doubtful owing to the adoption of an astronomical position which may contain, as a datum of the geodetic co-ordinate, a considerable amount of vertical deflection.

We can say that our final aim is to obtain a unified mathematical form of the earth which approximates the actual surface as nearly as possible, and to set each geodetic co-ordinate on this surface. It is very difficult, however, to define the problem correctly at a single stroke. As a first step we should detect the differences between two or more geodetic systems, or find the positions of the isolated islands in the ocean with respect to known islands or continents. There have appeared recently many excellent electronic devices for use in such a survey, but it is not possible, or at least not practical, to utilize such methods for the case of connexion between continents, or between continents and islands, in which the distance between the two positions is too great. The success of the artificial satellite gave brilliant hope to our geodetic purpose, but several years will be necessary to solve many difficult problems. In the present circumstances, observation of occultation seems to be most practical and economical for the above-mentioned connexion.

Equal Limb Line of the Moon

When we apply the observation of occultation to geodetic purposes we have to consider uncertainties involved in the moon's position, and irregularities of the limb of the moon. In order to remove these two influences simultaneously, the line on which the occultation of a star is seen at the same position angle in the selenographical co-ordinates is projected on the surface of the earth, and observations are made along this line, the so-called equal limb line of the moon.

Methods of predicting the equal limb line were developed in papers by H. Hirose [2] and J. A. O'Keefe.[3] The details of their investigations are not needed in the present explanation and so only the main points will be described. If we calculate the prediction of an occultation for a base station, we shall obtain the time for the occultation, together with the position angle of the moon's centre. Then the selenographical co-ordinates of the two contact points at the moon's limb are computed. Next the prediction of the position of a second station where the same occultation will be seen at the same position angle is made. If a more strict treatment is required,

[1] The original text of this paper, submitted by Japan, appeared as document E/CONF.25/L.45.

[2] H. Hirose, "On the Prediction of the Equal Limb Line for an Occultation", *Annals of the Tokyo Astronomical Observatory*, second series, vol. III, 1953, pages 218 to 222.

[3] J. A. O'Keefe and J. T. Anderson, "The Earth's Equatorial Radius and the Distance of the Moon", *The Astronomical Journal*, vol. 57, 1952, pages 108 to 121.

the expression of S. W. Henriksen [4] concerning the moon's libration can be utilized, and as to the topocentric variation of the position angle, there is H. Hirose's discussion.[5]

In order to connect the islands in the Pacific Ocean to Japan, and to detect the locality of the Japanese geodetic co-ordinate systems, observations of occultations on the equal limb line were commenced several years ago in co-operation with the Tokyo Astronomical Observatory, the Geographical Survey Institute, the Hydrographic Office (Japan) and the Far East Army Map Service (United States), and data are accumulating gradually. Some results were discussed by H. Hirose for the Japanese data,[6] and the revised position of the Palau Island in the Pacific Ocean was derived by S. W. Henriksen and his associates.[7] Generally speaking, if several observations are utilized for one station, the mean error will be less than a few seconds in arc for both longitude and latitude.

In connexion with these observations, many improvements have been made in Japan both in the telescope and attached instruments. We appreciate the support of the Far East Army Map Service in the development of these instruments.

Development of Instrumenis

Recently, Y. Tsukamoto in the Hydrographic Office of Japan designed a convenient predictor of occultation to carry out the prediction very quickly. If the motion of the moon's shadow on the surface of the earth and the rotational motion of the earth are realized through some means, the prediction of an occultation is possible. In the same way as the usual graphical method, this predictor adopts the co-ordinate system in the fundamental plane and, using a terrestrial globe and a projector of the moon's shadow, the time of immersion or emersion and the position angle can be read at once.

With a hand-operated calculating machine about three hours are usually needed for the calculation of a prediction, but this predictor takes only a few minutes; moreover, in the case of predictions at several stations for one star, efficiency is still better.

As to observation equipment for field survey, we are now using the GSI type occultation telescope, which was designed by I. Tsubokawa of the Geographical Survey Institute. This is the Cassegrainian type reflector whose main mirror has an aperture of 30 centimetres, and a resultant over-all focal length of 500 centimetres. The body can be dismantled into seven parts, namely, the main tube of the telescope, the guiding telescope, the shell of the main mirror, two parts of the mounting, counterpoise weights and a base plate. The polar axis is adjustable for use in regions from the equator up to the latitude $\pm$ 60 degrees. The telescope is driven very accurately by a synchronous motor of 4 watts and, moreover, fine adjustment in the direction of right ascension is possible by a small D.C. motor and an apparatus of differential gears.

The light receiver has a rotatable reflecting plate with six holes ranging from 0.25 to 2.00 millimetres in diameter, the smallness of which greatly improves the S/N ratio.

The guiding telescope is a refractor whose aperture is 10 centimetres and focal length 112 centimetres. The field of the eyepiece can be changed in order to catch another star in the case of reappearance; moreover, we add a cross-wire system to this field. This is devised to guide the star under observation to the centre of the main telescope by using the moon's limb instead of guiding another star for a reappearance occultation.

As to the accessory amplifier, short-wave receiver, and pen-motor oscillograph (recorder), details of their mechanism and their characteristics have been published elsewhere.[8] The required electric power consumed is only about 100 watts at full capacity. Consequently, two batteries of 90 AH capacity and an inverter are prepared for operation at any place where the commercial electric line cannot be utilized. In the islands where the geodetic survey was not carried out, we must determine the rough position, but then, if we use an astrolabe with the photoelectric detector, all of the accessories mentioned above except the reflector can be converted for the astrolabe.

With respect to the wireless time signals utilizable in the areas of south-eastern Asia and the Pacific Ocean, there are, for example, JJY (Japan), WWVH (Hawaii) or WWV (Washington). These time signals are emitted continuously throughout the day, their accuracy is within 1/1,000 of a second, and they are, therefore, suitable for the occultation survey.

The gravimeter method is more convenient for gravity tie, but the results will be affected by the uncertainties of drift and scale value of the gravimeter. In order to decrease the effects of these uncertainties it is preferable that two stations with a small gravity difference within a few tens of milligals should be selected, and that the instrument should be carried as fast as possible between the stations for the connexion.

Acting on the resolutions adopted by the International Gravimetric Commission in 1953, the Geographical Survey Institute of Japan in 1955 carried out the gravity connexion between Kyoto and Washington, D.C. by means of a GSI pendulum apparatus with three quartz pendulums designed by the Geographical Survey Institute.[9] The gravity difference between the stations has been determined with an accuracy of 0.3 milligal. The results have been reported in the *Bulletin* of the Geographical Survey Institute.[10] On the other hand, American geodesists made the world-wide gravity connexions, including those between the United States and Japan, with the Worden gravimeter in 1954.[11] As a result of both measurements, the gravity value of the Japanese fundamental gravity station (Kyoto) was confirmed with an error of less than one milligal in the Potsdam system.

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[4] S. W. Henriksen, S. H. Geuatt, M. Q. Marchant, and C. D. Batchelor, "Surveying by Occultations", *Transactions of the American Geophysical Union*, vol. 38, 1957, pages 651 to 656.

[5] H. Hirose, *op. cit.*

[6] H. Hirose, "On the Longitude and Latitude in Japan as derived from Observations of Moon", *Journal of the Geodetic Society of Japan*, vol. 2, 1956, pages 111 to 117.

[7] S. W. Henriksen and others, op. cit.

[8] I. Tsubokawa, "A Method of Photoelectric Observation of a Light Spot and its Application to Geodesy", *Journal of the Geodetic Society of Japan*, vol. 1, 1954, pages 20 to 24; I. Tsubokawa and T. Seto, "A Method of Photoelectric Observation of a Light Spot and its Application to Geodesy", II, and "Electronic Apparatus of E.T.D.", *Journal of the Geodetic Society of Japan*, vol. 4, 1957, pages 6 to 14.

[9] *See* footnote *2*.

[10] *See* footnote *3*

[11] J. A. O'Keefe and J. P. Anderson, op. cit., page 114.

The tie between Kyoto, Singapore and Cape Town was also made by members of the Geographical Survey Institute with the GSI pendulum apparatus as one of the projects of the Japanese Antarctic Research Expedition (JARE) in 1957. The operations of JARE are expected to continue in 1959, in order to make geophysical observations, including a gravity survey, in the polar region.

Japanese geodesists are now planning two international gravity connexions: Kyoto and Melbourne by means of the GSI pendulum apparatus, and Kyoto and Beyrouth by Worden gravimeters. The former is expected to be carried out in the beginning of 1959, the latter in the middle of March 1959.

The observation of occultation is influenced by the weather, but every month we can pick up two or three stars which are suitable for our purpose, and the percentage of successful observations is comparatively high.

ABSOLUTE MEASUREMENT OF THE EARTH'S MAGNETIC FIELD [1]

Technical paper by the Geographical Survey Institute, Japan

The intensity of the earth's magnetic field at the surface of the earth is only from $0.3\,\Gamma$ at the equator to $0.7\,\Gamma$ at the poles—except in a few regions where a large magnetic anomaly exists—and is, in general, uniform throughout a space of some cubic metres round any point. Therefore, its measurement is that of a weak and uniform field.

Most parts of the earth's field—the main field—are of internal origin and are slowly changing; others—the transient field—are partly periodic and partly irregular.

In order to investigate the detailed features of the main and the transient parts of the earth's field, the error of measurement must be sufficiently smaller than the range of the transient field. For this reason, the precise magnetometer must have an accuracy of better than 3×10^{-5} (about 1γ in intensity).

Generally, the declination is measured by using a magnet suspended by a torsionless thread, and the horizontal intensity is still measured mostly by the classical Gauss-Lamont method.

These methods, however, are not so accurate and take a considerable measuring time. Recently, many kinds of magnetometers have been developed which use various principles.

The Geographical Survey Institute is using GSI precise (first-order) and travelling (second-order) magnetometers developed by I. Tsubokawa, the former for observatory and precise field survey, and the latter for field work. In these instruments, a small rotating coil is used for detecting the direction of the magnetic vector by so orienting it that its output may be nullified by using a sensitive amplifier and an output meter. With this detector can be determined not only the direction of the earth's field—the declination and the dip—but also the intensity of the field by detecting the direction of the resultant of the earth's field and the known artificial field which is generated by a Helmholtz-Gangain coil, the coil constant of which is determined by comparing the instrument with the standard magnetometer. The accuracy in measuring the direction is quite excellent, the error being less that $\pm0.'1$, which corresponds to an error of less than $\pm1\gamma$, in intensity. The measuring time for the three components is only a few minutes.

About fifteen sets of magnetometers of this type which have been made up to the present have shown discrepancies smaller than $0.'2$ in the absolute values of the declination and the dip. From this fact it may be considered that the reliability of teh absolute measurement of the direction is so high as to solve the problems concerning absolute values of the declination and the dip. With regard to the absolute measurement of the intensity, it is generally not easy to obtain the accuracy of 1×10^{-5} which is demanded for standard magnetometers owing to a number of difficult and complicated problems in generating a standard field. For this reason, there are considerable discrepancies between the absolute values of the intensity obtained by standard instruments throughout the world, the maximum discrepancy being almost 1×10^{-3}. In order to exclude these discrepancies, continuous international comparison of magnetic standards has been frequently proposed. The execution of this project, however, is very expensive and, in actuality, poses many complicated problems.

Even if the international comparison were to be carried out at some epoch, the amount of discrepancies between the observed values obtained by different magnetometers would become significant after some period of time, owing to the secular changes in the instruments at each observatory.

These problems, however, will be solved by using the nuclear induction magnetometer recently developed, in which the measurement of the intensity of the magnetic field is replaced by that of time by utilizing a nuclear intrinsic constant. Since, with the recent developments of electronic techniques, the measurement of time has become more accurate and easier than that of other fundamental units, this method is quite convenient. In the nuclear induction magnetometer high accuracy of field measurement is obtained independently of the orientation and the temperature of the instrument, and no calibration of the instrument is required.

The principle of the instrument and its development by the Geographical Survey Institute of Japan are explained below.

As is known, in a magnetic field H the magnetic moments of the atomic nuclei precess about the field with the Larmor frequency f given by

$$2\pi f = \gamma H \qquad (1)$$

where γ is a constant, known as the gyromagnetic ratio. The precession of the nucleus induces an e.m.f. in a coil wound around the sample, for example, several hundred cubic centimetres of water.

However, under ordinary circumstances, the contributions from various nuclei in a sample cancel each other and generate

[1] The original text of this paper, submitted by Japan, appeared as document E/CONF.25/L.46.

no signal in the pick-up coil. Though several methods may be used to obtain a detectable signal, the free precession method of the proton in the water sample is considered to be simple and accurate for measuring a weak field such as that of the earth. The principle of this method is as follows. First, the sample is polarized for several seconds by a strong magnetic field H_0 (about several hundred Γ) in the direction which is approximately perpendicular to the earth's field F. Next, the polarizing field is removed suddenly with the result that the nuclear moment is left perpendicular to the earth's field. Then, the protons precess about the latter with the Larmor frequency given by (1). Therefore the precession of moment induces an e.m.f. in a pick-up coil, which may conveniently be the same as the polarizing coil and is connected to a high gain amplifier. The e.m.f. V induced in the pick-up coil is given by the following formula:

$$V = CH_o\,(\gamma_p F)\,\sin^2\theta e^{\frac{l}{T_2}t}\sin(\gamma_p F)t \qquad (2)$$

where C and θ are, respectively, a constant of the specific apparatus and the angle between the direction of the earth's field and that of the polarizing field, and T_2 is called the effective transverse relaxation time, which is about two to three seconds in a sample of water, but is reduced by inhomogeneities in F because of significant incoherence among different parts of the sample and by absorption of energy of the signal by the pick-up circuit.

As seen in equation (2), the frequency of the signal is not dependent on the orientation of the coil, and depends only on the scalar magnitude of F and the gyromagnetic ratio which is free from physical states such as temperature, pressure and the like.

Figure 19 is the block diagram of the apparatus which is used by the Geographical Survey Institute of Japan. By

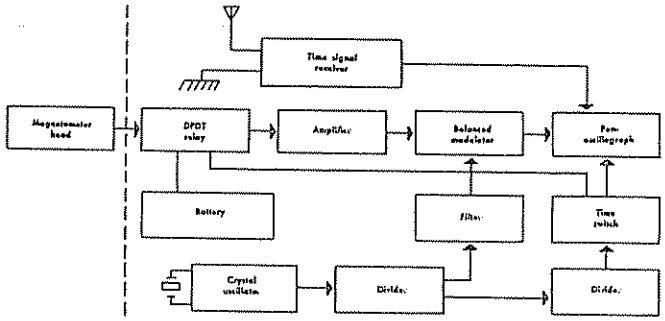


Figure 19. Block diagram of GSI magnetometer

operating a DPDT relay, the polarizing coil is also used as the pick-up coil at the end of the polarizing period by connecting it to the amplifier which is tuned to 1,950 cps. Since the value of the total magnetic force is about 45,600 γ which corresponds to the precessional frequency of about 1,940 cps at the Kano-zan Geodetic and Geomagnetic Observatory of the Geographical Survey Institute, the output of the amplifier is mixed with one of the standard frequencies, 1,930, 1,950 and 1,970 cps, which come from the crystal oscillator. The lower beat frequency, which is below 20 cps, is amplified by the differential current amplifier and is recorded by the pen-oscillograph. Since the amplifier is of narrow band pass feature and the equivalent band width of the oscillograph is about 50 cps, the S/N ratio of the signal is sufficiently large to obtain the accuracy of more than 5×10^{-3}. One example of the records is shown in figure 20.

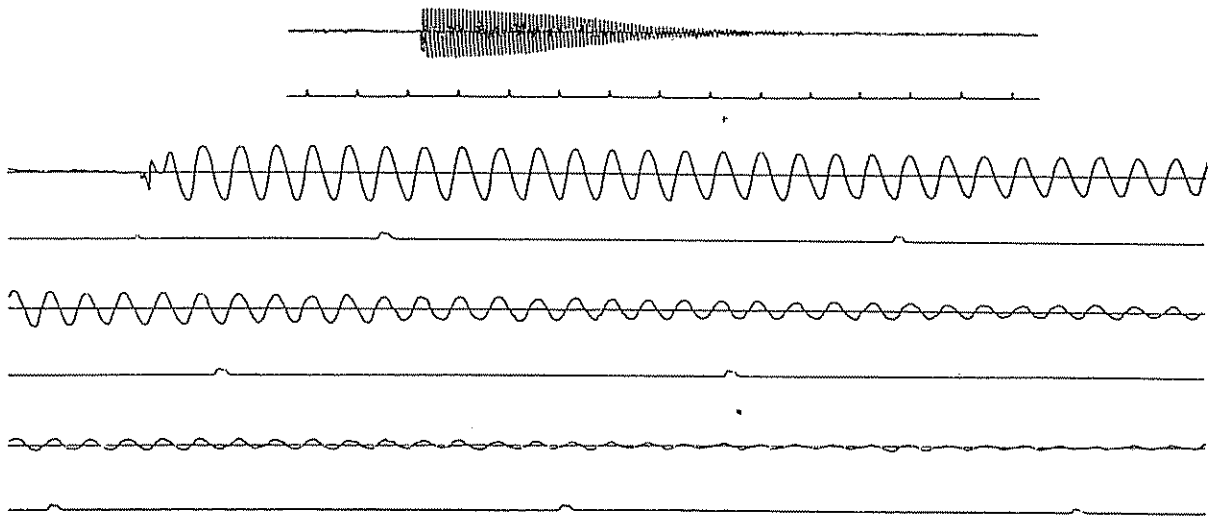


Figure 20. Examples of the oscillogram obtained by the GSI magnetometer

Above: low speed, 2 cm/sec. Below: high speed, 20 cm/sec.

The number of beats is readily measured with less than the uncertainty of 1/25 within a time interval of two seconds; therefore the accuracy of measuring a signal frequency of better than 1×10^{-5} can be obtained quite easily.

In June 1957, the first comparison measurement of the nuclear induction magnetometer with the GSI precise (first-order) and travelling (second-order) magnetometers was made at the Kano-zan Observatory and the results showed that the value of the total force obtained by the nuclear induction magnetometer is smaller than that obtained by GSI magnetometers referred to the Japanese standard, by 27 γ, as shown in figure 21 and table 8.

Table 8. Japan: Results of comparison measurements of nuclear induction magnetometer with GSI precise and travelling magnetometers

Magnetometer	*Total force*		*Horizontal component*		*Vertical component*	
	Discrepancy γ	*Std. dev. os single obs* γ	*Discrepancy* γ	*Std. dev. os single obs* γ	*Discrepancy* γ	*Std. dev. os single obs* γ
No. 41-P.P.M.	+26.5	±1.6	+18.2	±1.4	+19.7	±1.3
No. 26-P.P.M.	27.9	1.6	19.0	1.2	20.6	1.0
No. 27-P.P.M.	27.1	1.8	18.4	1.1	20.3	1.2
No. 30-P.P.M.	27.8	1.8	18.4	1.0	21.0	1.4

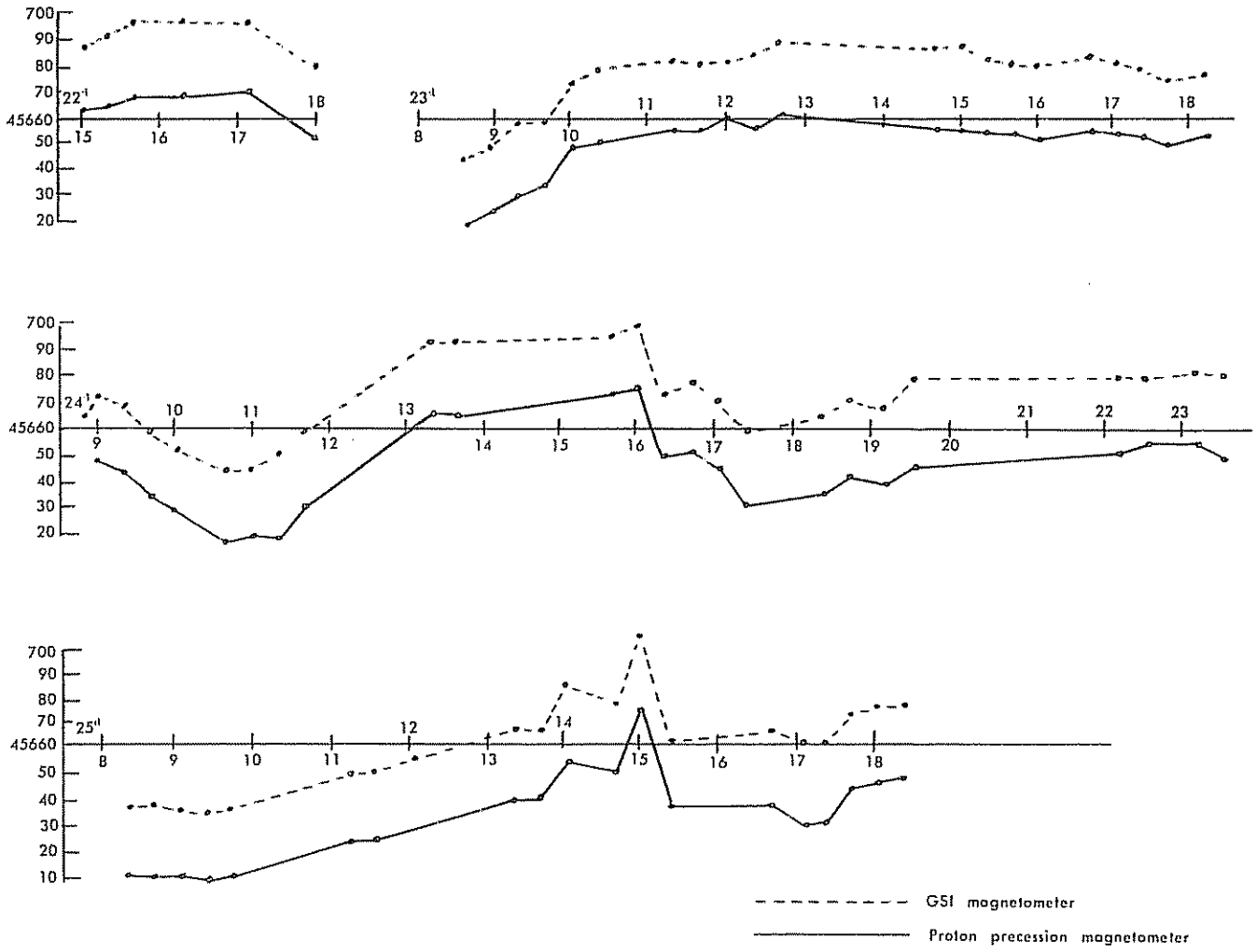


Figure 21. Results of the comparison measurements in the Earth's magnetic field F

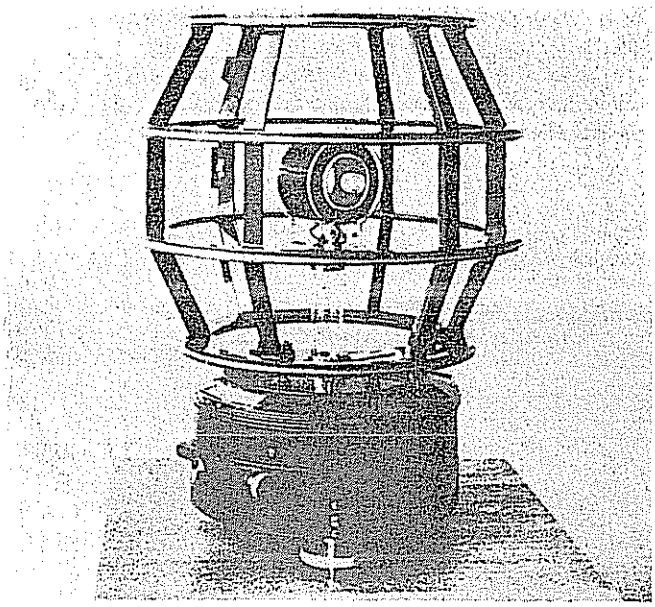


Figure 22 Nuclear induction magnetometer for measuring the horizontal intensity

This discrepancy seems to be caused by the instrumental character of the Japanese standard rather than by that of the gyromagnetic ratio, because the coil constants of GSI magnetometers were determined by comparing them with the Japanese standard in the Kakioka Observatory.

The Geographical Survey Institute has also developed the nuclear induction magnetometer for measuring the horizontal intensity by using a Fanselau-Braunbeck coil which approximately cancels the vertical component of the earth's field in the vicinity of the pick-up head. Figure 22 is a photograph of the magnetometer-theodolite.

Let OZ, OZ', OC and OM (see diagram in next column) be the zenith, the vertical axis of the theodolite, the coil axis of the Fanselau coil and the direction of the geomagnetic vector, respectively.

Let $\widehat{ZZ'} = V$, $< NZZ' = a$, $\widehat{CZ'} = i$ and $< NZ'C = \beta$, then the following formula is given, by neglecting the higher order of v and i,

$$\cos \widehat{CM} = \cos I \,(v \cos a + i \cos \beta) - \sin I \qquad (3)$$

where I is the dip. If F, Fc and Fr represent the total force of the earth's field, the field generated by the Fanselau coil and the resultant of both fields, respectively, we obtain

$$\begin{aligned} F_r^2 &= F^2 + Fc^2 + 2FFc \cos \widehat{CM} \\ &= H^2 + (Z - Fc)^2 + 2FcH\,(v \cos a + i \cos \beta) \end{aligned} \qquad (4)$$

where H and Z are the horizontal and the vertical intensity of the earth's field. Now if we revolve the theodolite 180° round the vertical axis and measure the resultant field Fr', it is given, in the same way as in equation (4), as follows:

$$Fr'^2 = H^2 + (Z - Fc)^2 + 2FcH\,(v \cos a + i \cos \beta) \qquad (5)$$

From (4) and (5) we obtain, neglecting the higher order of $(Z - Fc)$,

$$H = \left\{ \tfrac{1}{2}\,(Fr^2 + Fr'^2) \right\}^{\frac{1}{2}} \left\{ 1 - \tfrac{1}{2} \left(\frac{Z - Fc}{H} \right)^2 - \frac{Fc}{2H}\, v \cos a \right\} \qquad (6)$$

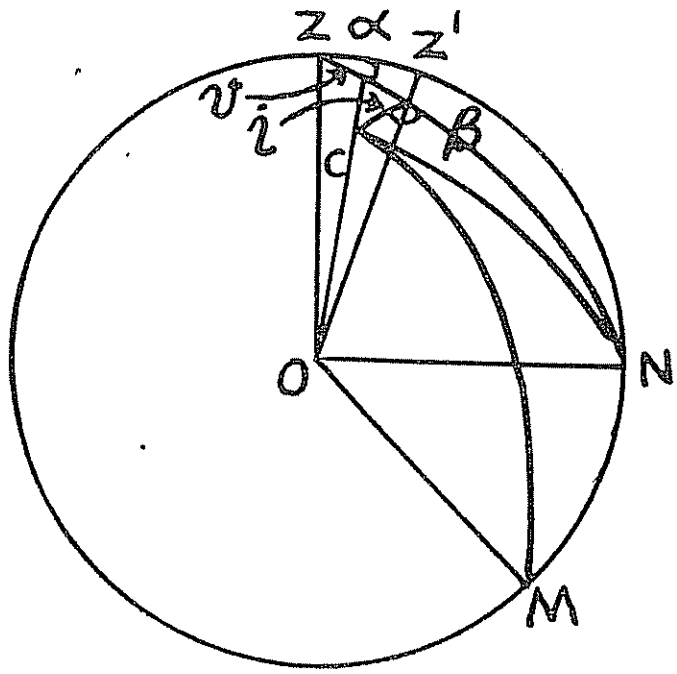
If $\dfrac{Z - Fc}{H} < 4 \times 10^{-3}$ is satisfied, H is obtained from the next formula with the accuracy of better than 1×10^{-5}.

$$H = \left\{ \tfrac{1}{2}\,(Fr^2 + Fr'^2) \right\}^{\frac{1}{2}} \left(1 - \frac{Fc}{2H}\, v \cos a \right) \qquad (7)$$

where $v \cos a$ can be obtained by reading the level which is fixed on the theodolite so that its axis is parellel to the magnetic meridian.

Therefore, we can also compute the absolute value of the dip by combining both the values of F and H obtained by the nuclear induction magnetometer.

In conclusion, by using the GSI precise magnetometer combined with the nuclear induction magnetometer, we can always measure the absolute values of the three elements of the earth's field. Hereafter, it is expected that the most reliable value of the gyromagnetic ratio of the proton should be investigated.



CLASSIFICATION AND STANDARDS OF ACCURACY OF GEODETIC CONTROL SURVEYS [1]

Background paper submitted by the United States of America

Introduction

The Government of the United States makes nation-wide surveys, maps and charts of various kinds. These are necessary to provide basic information for the conduct of public business at all levels of government, for planning and carrying out national and local projects, and programmes for the best use and development of natural resources, and for national defence. Principal types of maps are topographic, geologic, soil, and those which show timber and other natural vegetation. Principal charts are nautical and aeronautical. All maps and charts are originally based on surveys, and in addition the survey category includes surveys of the public lands (cadastral surveys), and hydrologic and meteorological surveys. State and local governments regularly co-operate in various parts of the total surveying and mapping programme, and business and industry not only profit from survey results but, in many instances, make their own surveys.

In making surveys and maps of large areas, whether financed by public authority or by private corporations or individuals, it is first necessary to establish a framework of control survey positions. This not only ensures that the detailed local surveys necessary for the construction of any map or chart sheet will be done most economically, but also that such sheets, when completed, will join properly along their borders. Surveys of large areas must take into account the curvature of the earth. For small areas, such as a farm, a city lot or even a small city, the curvature may be ignored. Larger areas must be surveyed by methods which recognize that the earth is a flattened sphere, or spheroid. Such surveys are called geodetic. They are executed with high precision, and are the framework of surveys to control national mapping and charting operations as well as large engineering projects. " Geodetic surveys " and " control surveys " are terms which are used almost synonymously

Control surveys are of two classes, horizontal and vertical. Horizontal control surveys establish latitude and longitude positions and provide the basis for rectangular co-ordinates, including state co-ordinate systems. Vertical control surveys determine elevations referred to mean sea level.

Horizontal control surveys are carried out by triangulation (a procedure of determining the lengths of the sides of a system of joined or overlapping triangles by measuring occasional side lengths upon the ground and computing the others from angles measured at the vertices), and by transit and tape traverses. The lengths of triangle sides or of traverse distances may also be measured by electronic instruments, which measure the travel time of a beam of light or radio pulse. Recent progress in the development of such instruments indicates increasing use of such procedures.

Vertical control surveys are carried on by precise levelling. The instruments used are of higher precision than those used in ordinary spirit levelling for surveys of small areas, and the computations and final adjustment refer the resultant elevations to mean sea level.

Tables 9, 10 and 11 group control surveys into orders and classes, in accordance with certain standards of accuracy. The recommended spacing or distance between survey stations is also indicated. These standards are primarily intended for the guidance of federal agencies in performing and classifying their control survey operations. They should also be useful to state and local governments, and to private corporations and individuals.

These classifications were prepared by the Bureau of the Budget in co-operation with the federal agencies concerned in making control surveys or in utilizing their results. These include the Coast and Geodetic Survey, Department of Commerce; the Geological Survey and the Bureau of Land Management, Department of the Interior; the Forest Service and the Soil Conservation Service, Department of Agriculture; the Army, the Navy and the Air Force, Department of Defense. After being prepared by representatives of the federal agencies, the standards of accuracy were referred to the American Society of Civil Engineers and to the American Congress on Surveying and Mapping for review and comment. The opinions of other organizations and individuals were also requested and received. After consideration of all comments the original draft was revised in this, its present form.

Basic Geodetic Programme

A basic programme for establishing geodetic control described in these classifications is in progress to provide adequate spacing as well as sufficient strength and accuracy to meet the needs and satisfy the requirements of engineers and scientists engaged in the development and conservation of the resources of the United States.

The horizontal control network of the United States consists of a framework of arcs of triangulation extending from north to south and from east to west and criss-crossing each other at intervals of about sixty miles. The areas between the arcs are subdivided with networks of single triangles, supplemental arcs, or traverses.

The basic programme for the ultimate development of the vertical control net of the United States is to form loops of first-order lines spaced at sixty-mile intervals, divided by lines of second-order levelling spaced at twenty-five-mile to thirty-five-mile intervals. In areas where the interest and need for levelling require closer spacing, the first-order spacing may be less than sixty miles. In areas where conditions require it, a spacing of second-order lines at six-mile intervals may be established. The reference datum shall be mean sea level.

Horizontal Control

Generally, the density of permanently marked control points should be in direct ratio to land values. In metropolitan areas and along interstate highway systems a spacing at one-mile or two-mile intervals may be required, and in rural areas of high land value a spacing of from three to four miles may be desirable. Although wider spacing may suffice for federal topographic mapping, closer spacing may be needed for

[1] The original text of this paper appeared as document E/CONF. 25/L. 37.

property surveys, highway programmes, transmission lines, reclamation projects and numerous other engineering activities. The more closely spaced stations should be so situated that they are readily available to local engineers.

Triangulation

Economic, engineering and scientific progress has brought an increasing number of requests for higher accuracies in basic first-order triangulation. The range of accuracies is so great that it is necessary to divide first-order into three classes so that satisfactory standards of accuracy can be established.

First-order, class I. The high value of land in urban areas, the study of small systematic movements in the earth's crust in areas subject to earthquakes, and the testing of military equipment for national defence require that the triangulation used by engineers and scientists in these varied activities should have an accuracy of at least one part in 100,000. Extensive surveys of this nature should make adequate connexions with the arcs that make up the national triangulation network. Surveys of such accuracy are designated as class I of first-order.

First-order, class II. The basic national horizontal control network consists of arcs of triangulation spaced about sixty miles apart in each direction, forming areas between the arcs which are approximately square. The arcs are planned as chains of quadrilaterals or central point figures, so that the lengths of the sides may be computed through two different chains of triangles. The programme for the completion of the network in the United States includes establishing area networks of triangulation within these squares or loops formed by the arcs. To maintain satisfactory mathematical consistency within the area networks, these basic arcs should be measured with an accuracy of at least one part in 50,000. Most of these primary arcs have closures in length and position which are of the order of one part in 75,000 or one part in 100,000. Triangulation of this standard of accuracy is designated as class II of first-order.

First-order, class III. There are many additional demands for first-order triangulation within this national framework and, in some cases, even independent of the national net. State, county and private engineering organizations, as well as branches of the Federal Government, have need for horizontal control that would have a minimum accuracy of one part in 25,000. Surveys of this accuracy have long been recognized both nationally and internationally as first-order and have attained the status of a widely accepted standard.

In the adjustment of the first-order national network, the surveys of class I will have precedence and they should not be distorted in order to adjust them to surveys executed under the specifications of class II. When the surveys of class III are rigidly adjusted to the basic network, their accuracy should be improved.

The placing of first-order or second-order control points within the loops of the basic network requires the extension of area networks, cross arcs or traverses. These specifications list two classes of second-order triangulation.

Second-order, class I. This class includes the networks covering the areas within the arcs of the basic network and, if area nets are not feasible, it includes the cross arcs which would be used to subdivide the area. The internal closures of this class of survey should indicate an average accuracy of one part in 25,000, with no portion less than one in 20,000.

Second-order, class II. This class of triangulation is used to establish control for hydrographic surveys along the coastline and inland waterways. It may also be used for further breakdown of control within any of the higher classes of triangulation. This class of survey or any of the higher classes may be used by engineers for controlling extensive property surveys. The minimum accuracy to be allowable in class II of second-order is one part in 10,000.

Third-order triangulation. Triangulation of this order should be supplemental to triangulation of a higher order for the control of topographic or hydrographic surveys, or for such other purposes for which it may be suitable. Although it will usually be established as needed for a specific project, third-order triangulation should be permanently marked, and azimuths should be observed to visible prominent objects, so that the work may be available for future projects and miscellaneous uses in the area. Points located by third-order triangulation may be expected to have an absolute position determination within ten feet or less in relation to the adopted datum defined by higher-order positions in the area. The work should be performed with sufficient accuracy to satisfy the standards listed in table 9.

Standards for surveys below third-order are not included in these classifications.

Bases

Bases for the control of the lengths of lines in the triangulation should be measured by appropriate methods and instruments, so that the standards in table 9 are satisfied. Recent developments in electronics indicate that accuracies comparable to those obtained with invar tapes may be expected from the Bergstrand geodimeter or similar instruments. The intervals between bases should be such that the standards regarding strength of figure (ΣR_1) also are satisfied.

Traverse

Traverses are used to supplement all orders and classes of triangulation, and to provide closer and more adequate spacing of horizontal control points. A triangulation net in an urban area provides a framework for a complete traverse network of first-order and second-order accuracies. It is neither economical nor feasible to use triangulation for this closer spacing. There are some sections of the United States in addition to these urban areas where traverse can be used efficiently to subdivide the basic network and provide the fundamental spacing of control specified in the national programme.

First-order traverses should preferably be connected to first-order triangulation stations of class I or class II. If they are connected to class III of first-order they might be used and given some weight in the adjustment of this class of triangulation. The minimum requirement of accuracy for a first-order

traverse is one part in 25,000, yet first-order traverse networks, properly executed, will average about one part in 40,000. This value is expected and desired. Detailed standards are listed in table 10.

Traverses of second-order and third-order accuracy are tied to triangulation or traverse of the same or higher order. They are used extensively for cadastral or property surveys and mapping. For property surveys, the value of the property should, in general, determine the accuracy to be used. For map control, the scale of the map and the positional accuracy required usually govern. Details of these orders of traverse are also listed in table 10.

Trilateration

Electronic techniques are increasingly used for the measurement of distances and, through the geometric combination of these distances, networks of trilateration or traverse are

Table 9. United States: Classification and standards of accuracy—triangulation

	First-order			*Second-order*		*Third-order*
	Class I (special)	*Class II (optimum)*	*Class III (standard)*	*Class I*	*Class II*	
Principal uses	Urban surveys, scientific studies	Basic network	All other	Area networks and supplemental cross arcs in national net	Coastal areas, inland waterways and engineering surveys	Topographic mapping
Spacing of arcs or principal stations[a]	Stations: 1 to 5 miles or greater as required	Arcs: 60 miles; stations: 10 to 15 miles	Stations: 10 to 15 miles	Stations: 4 to 10 miles	As required	As required
Strength of figure:						
ΣR_1 between bases						
Desirable limit	25	60	80	80	100	125
Maximum limit	30	80	110	120	130	175
Single figure						
Desirable limit						
R_1	5	10	15	15	25	25
R_2	10	30	50	70	80	120
Maximum limit						
R_1	10	25	25	25	40	50
R_2	15	60	80	100	120	170
Base measurement:						
Actual error not to exceed	1 part in 300,000	1 part in 300,000	1 part in 300,000	1 part in 300,000	1 part in 150,000	1 part in 75,000
Probable error not to exceed	1 part in 1,000,000	1 part in 1,000,000	1 part in 1,000,000	1 part in 1,000,000	1 part in 500,000	1 part in 250,000
Triangle closure:						
Average not to exceed	1″	1″	1″	1″.5	3″	5″
Maximum seldom to exceed	3″	3″	3″	5″	5″	10″
Side checks:						
Ratio of maximum difference of logs of sides to tabulated difference for 1″ of log sine of smallest angle	1.5	1.5-2	2	2-4	4	10-12
or in side equation test, average correction to direction not to exceed	0″.3	0″.4	0″.4	0″.6	0″.8	2″
Astronomical azimuths:						
Spacing-figures	6-8	6-10	8-10	8-10	10-12	12-15
Probable error	0″.3	0″.3	0″.3	0″.3	0″.5	2″.0
Closure in length (also position when applicable) after side and angle conditions have been satisfied, should not exceed	1 part in 100,000	1 part in 50,000	1 part in 25,000	1 part in 20,000	1 part in 10,000	1 part in 5,000

[a] Additional stations of same accuracy may be interspersed among principal stations.

Table 10. United States: Classification and standard of accuracy—traverse

N is the number of stations for carrying azimuth; M is the distance in miles.

	First-order	Second-order	Third-order
Number of azimuth courses between azimuth checks not to exceed	15	25	50
Astronomical azimuth Probable error of result	0".5	2".0	5".0
Azimuth closure at azimuth check points not to exceed [a]	2 sec. $\sqrt{N}$ or 1.0 sec. per station	10 sec. $\sqrt{N}$ or 3.0 sec. per station	30 sec. $\sqrt{N}$ or 8.0 sec. per station
Distance measurements accurate within	1 in 35,000	1 in 15,000	1 in 7,500
After azimuth adjustment, closing error in position not to exceed[a]	0.66 ft. $\sqrt{M}$ or 1 in 25,000	1.67 ft. $\sqrt{M}$ or 1 in 10,000	3.34 ft. $\sqrt{M}$ or 1 in 5,000

a The expressions for closing errors in traverse surveys are given in two forms. The expression containing the square root is designed for longer lines where higher proportional accuracy is required. The formula which gives the smaller permissible closure should be used.

developed. In general, the same standards in regard to position closure may be applied as are used in triangulation and traverse.

Vertical Control

Levelling

One of the most important items in the development of a control level net is the establishment of marks that will remain stable. Re-levelling has shown that there is considerable vertical movement of bench-marks. In some sections of the country there are many factors contributing to vertical change, such as removal of underground water, removal of underground gas and oil, frost action, settling of the soil due to increased moisture content during the rainy seasons, changes in the underground water table, fault lines, earthquakes and the like. Some of these are so deep-seated that in some areas it is impossible to establish a mark that will remain stable. However, some of these vertical changes can be overcome by installing " super " or " basic " marks at intervals along the line of levelling. The usual practice is to establish a concrete post type of mark at one-mile intervals along a line of first-order or second-order levelling, with a " basic " mark at five-mile intervals. Re-levelling has shown so many vertical changes that it is advisable to consider re-levelling first-order lines at least at twenty-five-year intervals, and, in areas where the vertical change is rapid, re-levelling at least at five-year intervals. Where vertical change has reached a rate of one foot per year, re-levelling every two years may be advisable. In addition to the determination of the elevations of regular bench-marks, which are installed along the routes of precise level lines, supplementary elevations should be determined at points such as road intersections or railroad crossings, which can be readily identified in aerial photographs.

In first-order levelling the requirement is for a forward and backward running that agrees within four millimetres times the square root of the length of section in kilometres. If second-order levelling is run with the same equipment as first-order, it can be single-run, with loop closures within the criterion 8.4 millimetres times the square root of the distance around the loop. In remote areas where a second-order line is longer than twenty-five miles due to the fact that routes are unavailable for an additional network development, the line should be double-run. This is defined as class I of second-order. The single-run area levelling is defined as class II of second-order. Summaries of these classifications are listed in table 11.

Third-order levelling should be used to subdivide the area surrounded by first-order and second-order levelling and should be performed so that the standards in table 11 are satisfied. Trigonometric levelling may be considered as fourth-order levelling, and the elevations thus determined are listed with the triangulation data.

Table 11. United States: Classification and standards of accuracy—levelling

K is the distance in kilometres; M is the distance in miles.

	First-order	Second-order		Third-order
		Class I	Class II	
Spacing of lines and cross-lines	60 miles	25-35 miles	6 miles	Not specified
Average spacing of permanently marked bench-marks along lines, not to exceed	1 mile	1 mile	1 mile	3 miles
Length of sections	0.5-1 mile	0.5-1 mile	0.5-1 mile	Not specified
Check between forward and backward running between fixed elevations or loop closures, not to exceed	4 mm $\sqrt{K}$ or 0.017 ft. $\sqrt{M}$	8.4 mm $\sqrt{K}$ or 0.035 ft. $\sqrt{M}$	8.4 mm $\sqrt{K}$ or 0.035 ft. $\sqrt{M}$	12 mm $\sqrt{K}$ or 0.05 ft. $\sqrt{M}$

NOTES ON THE USE OF THE GEODIMETER AND THE TELLUROMETER IN AUSTRALIA [1]

Technical paper submitted by Australia

GEODIMETER—ELIMINATION OF INDEX ERROR

Errors in geodimeter distance measurement due to atmospheric effects can be considerably minimized by repeated measurement over a period of time and preferably under varied atmospheric conditions. Error due to variation of crystal frequency becomes negligible provided normal frequency checks are made. Accepting the adequacy of frequency calibration, standardization of unit of length is, in fact, determined by the velocity of light adopted. The really critical error requiring elimination is that of the index error, which is never really constant due to slight movement of optical and mechanical parts of the light conductor.

It is considered that a practical and satisfactory way of determining index error is now used in Australia when measuring shorter lines or making comparisons with existing first-order survey base lines. This determination is obtained by calibrating the actual light conductor length that is being used in the measurement. A simple contraction is used, consisting of two small mirrors at right angles to each other on a bracket which moves along an axis so that each mirror is at forty-five degrees to the axis—the whole being assembled on a simple portable framework.

Once a light conductor measurement is made from the distant reflector, the index error calibration equipment is set up at an appropriate distance near the geodimeter so that one mirror is centred on the outgoing beam while the other returns the beam to the receiving mirror. The measurement of the light path via these small mirrors is determined by survey tape for two suitable distances and compared with the corresponding measurement as determined by the light conductor. The index correction to the original light conductor reading is then interpolated.

As a further check on the effectiveness of this method the line can be broken into two parts and, if the index and atmospheric corrections have been properly applied, the sum of the parts will equal the over-all distance irrespective of the light velocity used. Practical experience with lines five to six miles long, each measurement consisting of four to eight observations on at least two nights, has shown that the sum of the parts agrees with the over-all measurement within a range of ± 10 millimetres and on the average to ± 5 millimetres. This refinement is not applied on longer lines where the variations in index correction are small relative to the uncertainties of atmospheric corrections

TELLUROMETER—MEASUREMENT OF LONG LINES

In Australia, tellurometer measurement of lines thirty-five to forty-five miles long is not unusual, and the longest distance so far measured has been sixty-eight miles.

Over such lines it is difficult to make comparisons with a standard, particularly when tellurometer measurements have been proved to be as good and in cases better than those determined by first-order triangulation. However, comparisons with geodimeter distances of from four to twenty-two miles have shown a maximum difference of ten parts in one million and an average error of four parts.

Furthermore, a special test figure, consisting of a five-sided figure with three cross braces and an adjoining quadrilateral, was surveyed in Central Australia—all angles and distances were measured. Lengths of sides varied from about fifteen to fifty-two miles. The angular work was particularly good and directional adjustments were small. Side lengths obtained after adjustment were corrected by a constant factor to give the best average fit to the actual tellurometer measurements. The remaining differences between the new computed lengths and actual measurements averaged four parts in one million and varied between ten and 0.5 parts. In addition, the observed distances and angles of the surrounded area were computed as a closed traverse. The resultant misclosure was approximately one foot both in eastings and northings. The perimeter length was 180 miles.

In the light of this general consistency it is thought reasonable to adopt tellurometer measurements for first-order traversing.

The following factors are particularly relevant to the measurement of long lines with the tellurometer. The sharpness of the display, which is characteristic of the instrument at short ranges, deteriorates fairly rapidly at distances over thirty miles. This is a consequence of the fall-off in signal strength which is inevitable with a power of only sixty milliwatts. When this signal strength weakens, the instrumental noises, which are constant in amplitude, commence to swamp the measuring signals. This is seen in the display as a ropiness and a disinclination of the circle to show a clean break. It can be mitigated by reducing the size of the display, and in extreme cases it is necessary to reduce the display until it approximates the size of the inner circle of the graticule. In addition, the deliberate reduction in brightness of the display can assist in making the break visible.

With a display of such a small size, it is necessary to estimate the reading on the graticule, and at first sight this would seem to be unreliable. However, it should be realized that, with long lengths of the order of fifty miles, the estimation of the break to the nearest division represents an accuracy of one part in 500,000, and an error in the estimation of two divisions is quite acceptable. Taking into consideration the number of readings made during a measurement, it is probable that quite a good result could be obtained by estimating to the nearest five divisions.

On occasion it has been impossible to achieve a break in the display. When this occurs it has been the practice to attempt the measurement again at the time of maximum refraction, that is, late at night or in the early morning. This increase in refraction lifts the line of sight above the intervening ground and seems to improve the display considerably.

Instrumental noise can be reduced by careful overhaul of the power pack and the use of vibrators in good condition.

[1] The original text of this paper appeared as document E/CONF. 25/L.77.

Another source of noise is the bonding of the power cable shielding. This should be checked before attempting long measurements.

The form of the crystal control in the first model tellurometer makes it important to revise standard operating procedure when measuring longer distances. The crystal is not controlled, but is free-running, the deviation from standard frequency being determined by thermistor readings. The frequency of the crystal varies in the form of a parabola, as shown on the crystal chart accompanying the instrument. To obtain the best results it is obvious that the crystal should be operated at the " roll-over " point. At this point the thermistor readings can change several points without major alteration of frequency. In all our precise measurements we have operated at roll-over by manual switching of the heater. A new modification is now available in which the crystals are " ovened " and controlled thermostatically.

With older equipment the checking of the crystals by the manufacturer should not be accepted for work of great precision, and a separate check should be carried out. This can be done at a radio frequency testing station by operating the tellurometer and at short intervals recording the frequency of the "A" crystal while it is warmed up to well over the roll-over point and then allowed to cool back over the same point. Plotting the results as a graph will disclose that the warm-up values will differ from the cool-off values, with an agreement at the roll-over point. This disagreement at points other than the roll-over highlights the need to make precise measurements at roll-over. When the instrument has cooled to roll-over, the "B", "C" and "D" crystals should be checked.

Meteorological conditions will always be the subject of speculation, particularly as to how accurately the refractive index is determined. An attempt to assess this accuracy has been made by carrying out measurements of the same line over varying meteorological conditions. The results show that the refractive index varies between 270 and 340 parts per million in the local area of operations. It is believed that under normal conditions the refractive index as deduced from psychrometer measurements should be accurate to within two parts per million. Normal conditions would imply daylight measurements when the atmosphere is being well mixed by the wind.

The chief factor affecting the refractive index of air is the moisture content. Our Meteorological Service has advised that, although temperature changes can take place rapidly, the moisture content of the air changes much more slowly, and abrupt changes are to be expected only when a " front " crosses the area. The daily synoptic charts can help in this respect.

It should be noted that when extreme refraction is used to assist in measuring a line the atmosphere may tend to stratification, with a possible error in the determination of refractive index. It is normal practice on first-order traverses to measure lines in opposite directions and on different days. Usually large " swings " can be reduced by re-siting the equipment.

USE OF THE GEODIMETER AND TELLUROMETER IN GEODETIC MEASUREMENTS [1]

Background paper by Rear Admiral H. Arnold Karo,
Director, United States Coast and Geodetic Survey

The Coast and Geodetic Survey has always had a keen interest in new developments of geodetic measuring equipment and techniques, particularly with respect to electronic systems and their employment in geodetic and hydrographic surveying. The developments of the geodimeter and the tellurometer were early recognized as monumental contributions to geodetic surveying and the instruments have become welcome additions to the field equipment of the Coast and Geodetic Survey.

The Geodimeter

A model I geodimeter was obtained in 1953 and a model II in 1956. Through June 1958 seventy-one lines have been measured by the Coast Survey with these instruments over various types of topography, such as water expanse, mountains, desert, rolling hills and flat cultivated areas. The average line length was 16,480 metres (about ten miles). The maximum and minimum lengths were 42,036 metres (twenty-six miles) and 1,114 metres (0.7 mile). The minimum probable error of a result for all seventy-one lines was 2.2 millimetres; the maximum was 9.9 millimetres.

Four first-order taped bases were measured with the geodimeters and checks of 1/508,000, 1/535,000, 1/158,000 and 1/177,000 were obtained. These comparisons contain the errors in taping as well as the geodimeter errors. On three occasions—each in a separate quadrilateral—a line was measured with the geodimeter in a quadrilateral in which one line had been taped. The comparisons were 1/160,000, 1/1,470,000 and 1/143,000. Most of the geodimeter lengths have been used directly in triangulation adjustments and have proved satisfactory as first-order bases. The geodimeter has also been used occasionally to check adjusted triangulation lines to determine whether any distortion has been introduced by the adjustment.

Effect of meteorological conditions

An uncertainty of one degree centigrade in temperature, or one-tenth of an inch of mercury in atmospheric pressure, will cause a one part per million error in the length measured. The relative humidity has a small effect, never more than a fraction of one part per million. Rain, mist or haze will prevent measurement and for lines of the order of twenty miles or greater, extreme darkness is required. Hence, for practical purposes, lines about twenty miles long are considered maximum.

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.34.

Optimum conditions for making observations are a dark night with good visibility under heavy overcast sky or with a strong breeze blowing across the line, since temperature and pressure will then tend to be uniform.

Field operation

From the five years' experience with the geodimeter, the Coast and Geodetic Survey has adopted a standard of twelve measurements, taking six measurements on each of two nights, as sufficient to give a first-order base length. One length determination is made by using four fine delay readings on the light conductors (one in each phase position), four fine delay readings on the mirror (retrodirective prism bank reflector) and then four fine delay readings on the light conductors. Relative humidity is determined at the beginning and end of a night's work. The mean of temperature and pressure readings taken at each end of the line are used with the mean relative humidity to determine the refraction correction.

The Coast and Geodetic Survey experience indicates that a set of six measurements of a line should be made in seventy-five to ninety minutes. A trained operator can work at that speed and better results will be obtained than when the observations are made over a long period of time. Experiments indicated that if the instrument is operated properly there should be no personal error.

Both geodimeters, models I and II, were found to be reasonably rugged, but vibration or rough handling would break electrical connexions. A short connexion on one of the fuse boxes broke repeatedly. The neon bulbs had to be replaced every two or three weeks. On one occasion a thermometer controlling a crystal oven froze. Photomultiplier tubes had to be replaced about six times over the period of operation (about five years). The small focusing mirrors in the model I had to be replaced and the large mirrors in both models have to be resilvered about once a year (standard procedure). The model I, while being used in extremely hot weather, developed an oil leak in the zero indicator instrument. The saturable reactor of the primary power circuit in the model I had to be adjusted on several occasions. In both models some of the capacitors in the fine delay circuit had to be replaced with negative coefficient capacitors to eliminate drift in the fine delay circuit. One of the frequency crystals in the model II had to be replaced. On only one occasion, for photomultiplier tube malfunction, was it necessary to bring the instrument into the shop. All other repairs were made in the field. The maintenance required was considered normal for this type of equipment.

In operation with model I or II one end of a line to be measured should be a drive on station, or the instrument should be transported by air, preferably by helicopter, since its weight and auxiliary equipment, such as the electric generator, makes back packing difficult, if not impossible.

The geodimeter has been used successfully on twelve-foot wooden towers, but attempts to use it from a 103-foot Bilby steel tower were unsatisfactory. The observer's platform is not designed for so large an instrument; a boom is required on the tower to swing the instrument into position. Vibration in the tower makes it extremely difficult, if not impossible, to null the instrument. However, the retrodirective prism bank reflector may be used from the Bilby tower and vibrations even in wind will not affect results.

Modifications

The Coast and Geodetic Survey has made the following modifications in its geodimeters.

Holes were drilled through the back of the lamp assembly so that the adjustment screws on the lamp would be accessible without disassembling the instrument.

Insulated jacks were installed so that the bias voltage on the photomultiplier tube could be read without removing the bottom plate of the geodimeter case. (Excessive bias voltage indicates that a change of neon bulbs is needed.)

A removable plug was installed in the side of the photomultiplier case allowing adjustment of the RF voltage in the photomultiplier circuit without disassembly.

In the first year of operation it was found that the addition of extra desiccating material—silica gel—to the light conductor box and to the phototube unit prevented moisture from affecting the crystals and the high impedance circuits of the phototube unit. The Geodetic Survey of Canada also found this to be effective for moisture control in the instrument.

Recommendations

Since the geodimeters, models I and II, are capable of consistently measuring lengths up to about thirty miles with a proportional part accuracy of 1/300,000 or better, they are recommended for first-order triangulation base-line measurements with twenty-mile lines considered an optimum maximum, and ten-mile lines an optimum minimum.

The geodimeters, models I and II, can be used for trilateration or traverse, but transporting the equipment becomes a real problem, particularly in rough terrain. These instruments may be used to calibrate other distance measuring instruments, such as the tellurometer.

The Tellurometer

The Coast and Geodetic Survey received its first tellurometers in June 1957 and these were immediately dispatched to the Coast Survey Ship *Explorer*, operating in Alaskan waters, for use in making a second-order tellurometer traverse survey along the rugged south coast of Atka Island in the central Aleutians. Traverse stations were about two miles apart with several ten-mile legs. The field computations showed that a proportional part accuracy of about 1/19,000 was attained over the forty-eight-mile traverse.

The tellurometer equipment was then transferred to the State of Virginia for use in traverse surveys to establish basic control needed in connexion with the federal highway programme. Traverses averaged about twelve miles, with intermediate stations at three-mile intervals, end points of the traverses being Coast and Geodetic Survey second-order triangulation stations. Field computations for this project show that the position closure of the tellurometer traverses averaged about 1/40,000.

To check the repeatability of the tellurometer on a relatively short line, a taped base of 1.7 miles, which had also been measured with the geodimeter, was measured thirty-two times

over several days during October 1957 and March, April and May of 1958. Several master units were used and measurements were made under a variety of meteorological conditions. Proportional part accuracies varied from 1/11,000 to 1/500,000, with a mean of about 1/25,000. Only five measurements were short. Ground swing varied from 4.8 to 25.5 inches with a mean of 12.8 inches. There was no apparent correlation of ground swing with proportional part accuracy. The ground swing of the worst check obtained, 1/11,000, was only nine inches. The lowest ground swing, 4.8 inches, gave a check of 1/24,000. The highest, 25.5 inches, gave a check of 1/20,000. On some of the measurements the master unit was placed on line but three, six or nine metres towards the remote or three or six metres away from it. There was no improvement except at six metres towards the remote where a check of 1/78,000 was obtained.

Four geodimeter measured geodetic lines of 15.7, 12.7, 12.6, and 21.3 miles were measured with the tellurometer. The 15.7 and 12.7 mile lines were each measured twice with each of two master units. The 12.6 mile line was measured twice and the 21.3 mile line once. The lowest single measurement check was 1/82,000, the highest 1/4,991,000. The mean proportional part checks for 15.7, 12.7, 12.6 and 21.3 miles were 1/490,000, 1/103,000, 1/781,000 and 1/510,000, respectively.

The sides (3.1, 5.0, 7.5 and 2.7 miles) and diagonals (5.2 and 7.0 miles) of a quadrilateral, which is part of an adjusted triangulation net, were measured with the tellurometer with checks of 1/375,000, 1/47,000, 1/37,000, 1/64,000, 1/215,000 and 1/300,000, respectively.

From these results it would appear that the tellurometer, when used on relatively short lines, is capable of first-order geodetic accuracy occasionally, but that it cannot be depended upon to give a first-order measurement every time even over longer lines.

Effect of meteorological and topographical conditions

The effect of temperature and pressure errors is about the same as for the geodimeter. Humidity determination is about 100 times more critical for the tellurometer, small errors in its determination causing very large errors in the wave-length determination. An error of 1°F in the humidity determination will cause an error in length of the line being measured of about $7/10^7$; an error of 0.1 inch of mercury in atmospheric pressure will cause an error of $1/10^6$; an error of 0.006 inch in vapour pressure will cause an error of $1/10^6$. The main cause of error is that the mean of the meteorological readings taken at each end of the line may not correspond closely with the average conditions along the line; that is, an irregular gradient is more likely as the line length is increased; hence a practical limit to length is about thirty miles.

Refracted waves and unwanted reflection being returned because of local topography affect the accuracy of reading and repeatability of the partial wave-length in the tellurometer. Hence a line to be measured with this instrument should have little ground clearance and should be covered with vegetation which absorbs the ground waves. Lines with terminals on sharply elevated points above a flat, smooth, highly reflective surface, such as water, should be avoided, although such lines may be measured satisfactorily if the master and remote units can be shifted so as to cause the line to graze at each end.

Obstructions such as trees and telephone poles have no effect unless they are near the instrument. Measurements are often possible when the line of sight is blocked by a bump or shoulder. But a clear line of sight through a woods clearing or through a gap in a wall may not be measurable. However, the instrument may be operated successfully in areas of concentrated microwave operations.[2]

The Coast Survey found that in Alaska, open line operation was not always best. A tundra knoll near one station weakened the signal. Over water, the rippling would cause the signal on the cathode ray tube to oscillate circularly. It was found best to work with skyline stations—background bare hills gave reflections.

The tellurometer can be used day and night but best results are obtained on a dry clear day with a wind blowing along the line being measured and with the line free of objectionable topographical features. Ground swing should never exceed four feet and should preferably be less than two feet.

Field operations

Experience of the Coast and Geodetic Survey indicates that two coarse sets of readings and twelve fine readings are sufficient for exploiting the inherent accuracy of the instrument in a single line measurement. The time for a measurement is about forty minutes, which includes setting up the equipment, making the observations, and repacking the equipment. Included in this time are careful measurements of humidity, pressure and temperature made at both ends of the line, at the beginning and end of a set of observations.

Three men are at present employed to operate one master unit and one remote unit—two at the master, one of these recording the observations. A modification, if practical, by eliminating eye accommodation fatigue, should make it possible for the observer to record his own measurements in about the same time. A man can be taught to operate a remote instrument in one day and to operate the master unit in three days.

While the instrument is portable, the total weight of a unit (tellurometer, carrying case, power pack, tripod and battery) is eighty-five pounds; modifications can reduce its weight.

The instrument is rugged, but rough handling will cause circuitry wires to loosen. Tubes have to be replaced occasionally. On one occasion a Coast Survey unit was accidentally dropped from a height of about ten feet. Resoldering of a few broken electrical connexions and adjustment of the klystron restored the unit to operable condition. On another occasion a transformer in the power supply had to be replaced in a Coast Survey unit. Such maintenance is considered normal for this type of equipment.

With respect to the tellurometer traverse work done by the Coast Survey in Alaska, the following observations were made. The tripod furnished with the equipment was considered to be too weak. The carrying case, although compact, was not waterproof. The straps and buckles fell off and were replaced by web straps. The back packs supplied by the manufacturer of the tellurometer were found to be inadequate and were replaced by army packs (Nelson packs).

[2] Determined by the United States Army Map Service in tests conducted near Boston, Massachusetts, in September 1957.

Suggested modifications

The following modifications, although not imperative, would improve the operations associated with tellurometer measurements:

(1) A stronger tripod with better plumb bob suspension;

(2) A head-supported telephone system to free the observer's hands;

(3) Plug-in connectors for power packs;

(4) Lighter, more easily portable batteries;

(5) Improved illumination of the reticle on the cathode ray tube (The Coast Survey is experimenting with an illuminated plastic reticle for the face of the tube in an attempt to eliminate the required shade and the reflection from the observer's face which would then permit him to do his own reading without eye fatigue from constant accommodation. The Coast Survey found that magnifying spectacles with a focal length of the sun shade helped in reading the reticle);

(6) Printed and transistorized circuitry to reduce size and weight of the instrument;

(7) Crystal oven to keep the temperature of the crystal at its normal operating range of 23 to 32°C. (The Geodetic Survey of Canada has already accomplished this modification.[3] The Coast Survey is in process of making this change);

(8) Separation of the parabolic antenna from the instrument, which will allow the antenna to be placed on a telescoping mast for elevation above trees and obstructions and eliminate the necessity for tower construction (The National Research Council, Division of Applied Physics, Ottawa, Canada, has already accomplished this modification).[4]

Expected accuracy and recommendations

Since the tellurometer accuracy depends on favourable topography and meteorological conditions to minimize reflections and refractive waves, the highest accuracy cannot be depended on for any particular line. It is capable of giving results of the order of $1/10^5$ or better and is considered accurate enough for traverse work and second-order base lines. It can be used for trilateration, but with all lines of the order of fifteen to twenty-five miles, it can be safely said only that the resulting accuracy will be equivalent to or better than second-order triangulation.

Summary Conclusion

Since the microwave propagation characteristics in the tellurometer system are more sensitive to topographical and meteorological conditions than in the geodimeter system, repeatability of the tellurometer approaches but cannot equal that of the geodimeter. The smallest division on the cathode ray tube of the tellurometer corresponds to 0.15 metre or about six inches. The instrument was not designed to be all-purpose but to give high accuracy over ranges from ten to thirty miles.

The geodimeter and the tellurometer are very useful additions to the geodetic instruments of the Coast and Geodetic Survey. The geodimeter is being used continuously for measurement of first-order triangulation base lines and tellurometers are being employed constantly in traverse line measurements. The maintenance requirements of these pieces of equipment are considered no more than those to be expected from electrical equipment. Certain modifications to the tellurometer, while not imperative, would enhance its flexibility and operation.

APPENDIX

Deflection Caused by the Earth's Magnetic Field

In recent Coast and Geodetic Survey applications of the tellurometer in conducting surveys in the State of Maine, a magnetic effect created a special adjustment problem associated with the horizontal positioning adjustment of the circle. This phenomenon is encountered mainly in the higher magnetic latitudes where magnetic vertical intensity is strongest.

In observing the master tellurometer oscilloscope in this environment, it was noted that the circle was deflected to the left and could not be centred with the equipment centring controls. This condition appeared to result from the deflection of the horizontal electron beam of the cathode-ray tube in crossing the downward component of the earth's magnetic field. The limited range of the positioning control changes (only about two centimetres) was too small to offset the magnetic deflection in this region where the geomagnetic vertical intensity is about 0.55 oersted.

The same difficulty has been experienced by Canadian and English users of similar equipment. There is, of course, some vertical deflection of the beam, the effect of the horizontal geomagnetic component (the shift being upward or downward depending on the orientation of the oscilloscope). However, this displacement seems to be within the working range of the centring controls; the values of horizontal intensity are generally less than 0.2 or 0.3 oersted.

The problem of the lateral displacement was referred to the electronics engineers of the Bureau for development of corrective measures to overcome this limitation on the usefulness of the equipment. Their solution was to install a voltage control in the plate-supply circuit for the horizontal control stage. This provides an additional one-centimetre margin in making the circle adjustment for correcting the displacement. The Electronics Laboratory will begin at once to make this modification to all tellurometers now being used in Coast and Geodetic Survey operations.

Close co-ordination in solving operational problems of this nature is maintained among field personnel carrying on the geodetic work, geophysicists who now have the elaborate laboratory at the new Fredericksburg Magnetic Observatory and other observatories of the Bureau to aid in solving geomagnetic problems, and personnel of the Electronics Laboratory who engage in a broad research programme towards developing instrumental equipment and devising new techniques to meet the increasing demands for greater accuracy in mapping operations.

[3] A. G. Mungal, " Modifications of the Tellurometer ", *Canadian Surveyor*, April 1958.

[4] *Idem*.

MAINTENANCE OF NATIONAL STANDARD MAGNETOMETERS AND THEIR COMPARISON[1]

Background paper submitted by Japan

In order to ensure the comparability of surveying data, it is necessary that each country have a standard magnetometer for comparison both with other magnetometers in the country and with the standard magnetometers of other countries concerned. International comparisons should be carried out periodically with the most reliable instruments and procedures.

In the past it was found difficult to ascertain the absolute value of a magnetic force because of the problems encountered in determining the dimensions of coil, wire and other elements. Since the development of the proton precession magnetometer, it has been possible to measure the absolute value of the intensity not only without such difficulties but also with sufficient accuracy. It is suggested that the possibilities of such a magnetometer in obtaining standard value of geomagnetic intensity should be taken into account when planning survey work.

Magnetic surveys on sea, which have been very difficult with the classical instruments hitherto used, can now be carried out with comparative ease by means of this new type of magnetometer.

Comparisons of magnetic instruments between countries have been carried out hitherto mainly for unifying the standard values of the intensity in the countries concerned. However, it is equally desirable that a similar comparison be carried out with the aid of appropriate instruments for declination and dip.

[1] The original text of this paper appeared as document E/CONF. 25/L.5.

OBSERVATION OF NATIONAL GRAVIMETRIC NETS AND THEIR INTERNATIONAL CONNEXION

Report submitted by Burma [1]

The study of the force of gravity has become important to almost every branch of science and is of inestimable value and interest to geologists and geodesists. Gravimetric measurements are being carried out the world over for investigating the true shape of the earth as well as the constitution of the earth's crust. The countries of Asia and the Far East have been asked to contribute their share and to carry out these operations over their portion of the earth's surface.

A geodetic division under the Burma Survey Department was created in September 1958, and one of its immediate tasks was the re-observation of the country's gravimetric net. (No gravity observations have been made in Burma since 1940.)

The services of a geodetic expert, Dr. T. J. Kukkamaki of the Finnish Geodetic Institute, were obtained under the United Nations Technical Assistance administration scheme to assist the Government of Burma in implementing its geodetic programme. In addition, one Worden gravity meter was made available to the Burma Survey Department through United Nations aid.

Dr. Kukkamaki, who arrived in December 1957, has been giving certain officers of the Burma Survey Department specialized training in this branch of survey. On receipt of the gravity meter in September 1957, observations were immediately commenced and gravity differences between seventeen different stations in Burma were observed, the local airlines being used as a means of transportation. Observations of the remaining three stations will be completed before the end of October 1958. These gravity stations will form the main framework for the additional network of gravity stations which will cover the whole of Burma.

A list of stations where gravity observations have been made is given below.

Number and place of station		*Latitude*	*Longitude*
580001	Mingaladon	16°.9	96°.1
580002	Magwe	20°.1	94°.9
580003	Lanywa	21°.0	94°.8
580004	Meiktila	20°.9	95°.8
580005	Mandalay	14°.1	98°.6
580006	Monywa	22°.1	95°.1
580007	Gangaw	22°.2	94°.1
580008	Kalaymyo	23°.2	94°.1
580009	Heho	20°.7	96°.8
580010	Keng Tung	21°.3	99°.6
580011	Katha	24°.2	96°.3
580012	Moulmein	16°.5	97°.6
580013	Tavoy	14°.1	98°.2
580014	Mergui	12°.4	98°.6
580015	Bhamo	24°.3	97°.2
580016	Myitkyina	25°.4	97°.4
580017	Lashio	22°.9	97°.8

[1] The original text of this paper appeared as document E/CONF. 25/L.64.

Background paper submitted by Japan [1]

The International Union of Geodesy and Geophysics and the International Gravimetric Commission recommended in 1951 and 1956, respectively, the observation of national gravimetric nets and their international connexion. The implementation of these recommendations in Asia and the Far East requires the measurement of the intensity of gravity at the points of high density in all parts of the region and the

[1] The original text of this paper appeared as document E/CONF. 25/L.6.

comparison of the intensities observed at fundamental stations of the respective countries. Such comparison has to be carried out with high precision pendulum apparatus or with other equivalent gravimeters.

With regard to the vast area of deep waters in the region for which no up-to-date gravimetric data are available, conditions prevailing at the time of the Mussoorie Conference still exist. International co-operation, which is essential in the measurement of gravity on the sea, must be further developed to accomplish the technical and scientific work in this region, in view of the fact that not all the necessary equipment for such measurement is available in most of the countries concerned.

Report by the Geographical Survey Institute, Japan [1]

I. International Gravity Connexion

It is of great importance to ensure the homogeneity of all gravity data used for geodetic purposes throughout the world. The International Gravimetric Commission (IGC) was established in 1953 for the purpose of international collaboration to ensure such homogeneity of world gravity nets. At the first meeting of the IGC, thirty national fundamental gravity stations were selected as international first-order gravity stations, as well as a reference station of gravity measurements in each country (see figure 23). Among these stations, Beirut, Delhi, Singapore, Kyoto, Melbourne, Christchurch and Honolulu are key points of the world gravimetric nets in Asia and the Far East.

As is well known, there are two different methods of gravity comparison; one is by pendulum apparatus and the other by gravimeter. At the present time the pendulum method is thought to be the best means for gravity connexion between distant stations with large differences in gravity values, because pendulums can be kept very stable for a long time, and the gravity difference is found to depend only on the periods of the pendulums measured at the two stations.

Considering the great importance of establishing a more substantial international gravity net in this region, where the density of gravity stations is rather low, we consider it highly desirable to make gravity connexions between the countries concerned (see figure 24).

[1] The original text of this paper, submitted by Japan, appeared as document E/CONF.25/L.47.

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INTERNATIONAL FIRST-ORDER GRAVITY STATIONS



Figure 23

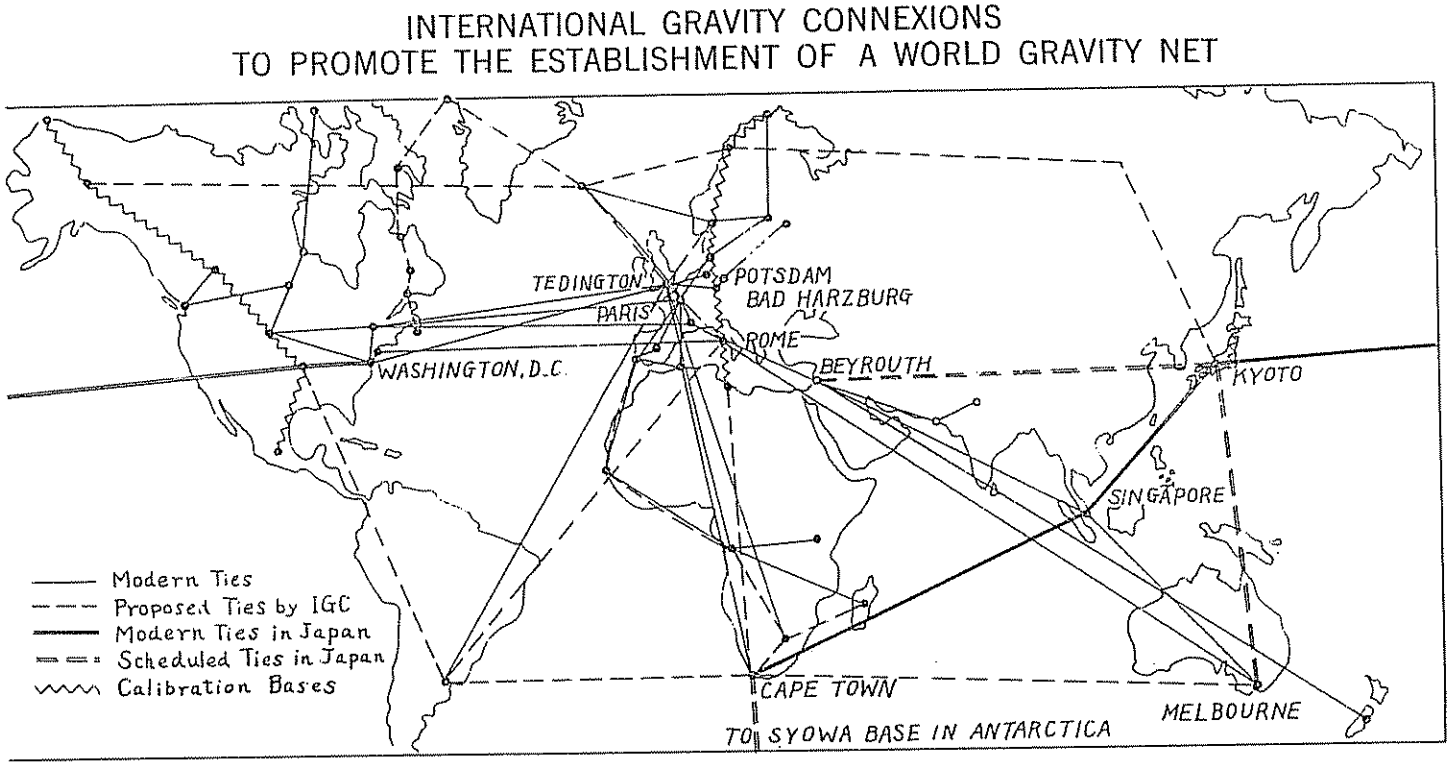

Figure 24

II. Present Status of Gravity Works by the Geographical Survey Institute of Japan

Since 1952 gravity survey with high density and high accuracy has been carried out throughout Japan by means of both a GSI pendulum apparatus and a North American gravimeter. The stations occupied are all bench-marks, such as triangulation points and other points of which the heights are known. (See figure 25.)

The GSI pendulum apparatus has been used for the establishment of the gravimeter calibration base and local reference pendulum stations. The calibration base contains several pendulum stations, and the largest gravity difference among these stations is about 800 milligals. The observations of the North American gravimeter have been made twice, forward and backward, at each station along the levelling routes in order to eliminate the effect of the instrumental drift. After making the correction for drift and the reduction of the earth tide effect to the observed value in each station, the gravimetric net has been adjusted by the least square method, referring to the gravity values at the local pendulum stations.

The values of the local pendulum stations, including those of the gravimeter calibration base, have been determined with an accuracy of from 0.3 to 0.5 milligal approximately. By recent improvements in some parts of the apparatus, such as the recording device, time standard, temperature control box and certain mechanical devices for setting pendulums, the accuracy is expected to be considerably increased, perhaps to 0.1 milligal. The observational error in gravimeter survey is usually less than 0.1 milligal, but, because of the effects of uncertainties in the drift and scale value of the gravimeter, uncorrected values observed by the gravimeter may have some errors, sometimes of over one milligal in an area far from the fundamental station. After making the net adjustments based on the values of the local pendulum stations, the accuracy of the gravity values at the gravimeter stations may become nearly equal to that of the pendulum stations referred to.

The survey was begun in the Hokkaido district, the northernmost area of Japan, and was carried out towards the southwest. Up to 1958, all the levelling routes throughout Hokkaido, Honshu and Shikoku Islands had been surveyed, and only Kyushu Island and certain other small islands remain uncovered. After the survey on all the levelling routes in Japan is completed, it is expected that the survey at suitable triangulation points in the blank areas enclosed by the levelling routes and revision surveys on selected levelling routes will be made on a continuing basis.

The national fundamental station of Japan is located at Kyoto University, Kyoto, and its sub-fundamental stations are in Sapporo, Mizusawa, Kakioka and Kumamoto. The gravity station at Tokyo University, Tokyo, the former fundamental station, and the Kano-zan Geodetic and Geomagnetic Observatories of the Geographical Survey Institute, Chiba prefecture, also have been used as reference stations of gravity survey in Japan.

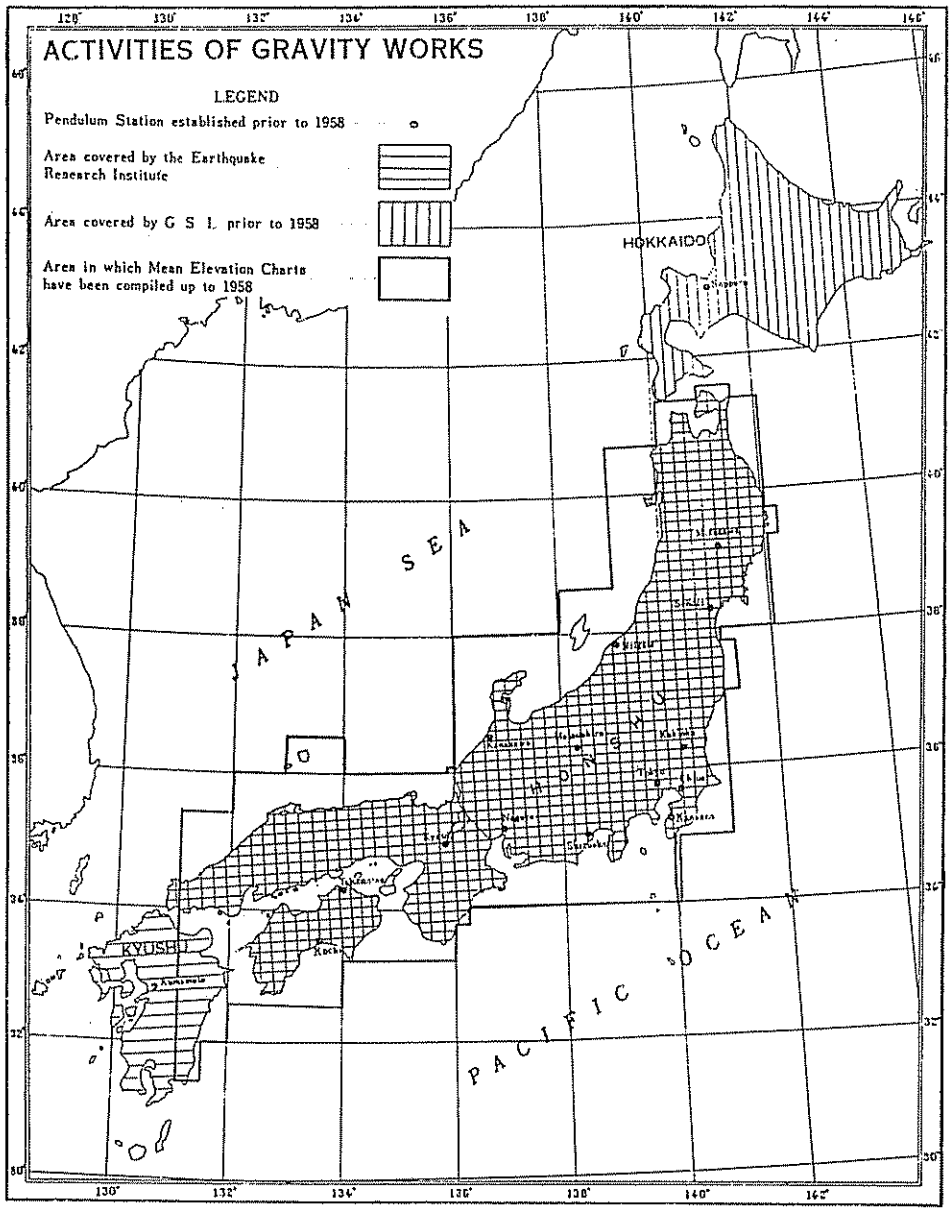

Figure 25

In order to connect, precisely, the standard gravity value of Japan with the international gravity value, as well as to promote the establishment of the world-wide gravity net, the gravity tie between Kyoto and Washington, D.C., was made in 1955, and that between Kyoto, Singapore and Cape Town in 1957 as one of the projects of the Japanese Antarctic Research Expedition.

Concerning gravity surveys, for calculating topographic corrections, average elevation maps on the scale of 1 : 200,000, elevations within 1′ (latitude) by 1.5′ (longitude) and 2′ (latitude) by 3′ (longitude), expressed with the accuracy of about ten metres, are now under compilation at the Geographical Survey Institute. The work is progressing satisfactorily, and is expected to be completed in the near future.

GEODETIC CONNEXIONS BY OBSERVATIONS OF ARTIFICIAL EARTH SATELLITES AND OF LUNAR OCCULTATIONS [1]

Background paper by the United States Army Map Service

In simple terms, geodesy is the business of finding out where things are. More formally, the determination of position on the surface of the earth is the subject of two branches: field astronomy and geodesy. It is the function of field astronomy to provide the initial orientation and position for the surveys which determine geographical position. Geodesy then extrapolates these positions by means of measurements on the ground to cover a whole country, or even a whole continent, without further reference to the stars, except for orientation.

Vast nets of triangulation have thus developed which must, for the best results, be adjusted simultaneously. The feat of adjusting systems of equations that involve several thousand unknowns has been accomplished repeatedly in the last few years.

Because of the atmospheric refraction, however, the geodesist cannot measure vertical angles with anything like the precision with which horizontal angles are measured. The difficulty arises from the bending of light by the atmosphere as in mirages and other manifestations of refraction. In comparison with instrumental accuracies, the bending is colossal. The setting sun, for example, is refracted through 1,800 seconds of arc, while many modern instruments have errors of a few tenths of a second. The result of atmospheric refraction is that vertical angles cannot be relied upon over anything except the shortest distances, with the exception of some special observations made simultaneously in both directions over the same line at the same time. Most of the peculiarities of classical geodesy are the results of the effort to avoid measuring vertical angles.

The programme of classical geodesy is to measure heights above sea level by means of a null method in which the telescope is always level and the curvature of the ray is taken out by balancing the backsights and the foresights; to measure horizontal positions as if they were projected on the sea-level surface, especially its prolongation under the land; and, finally, to discover the shape of the sea-level surface by astronomic and gravimetric measurements. The last step is greatly neglected, since under most circumstances it turns out that practical requirements do not call for knowledge of the sea-level surface. In most of the civilized areas of the world, it is possible to state the height above sea level within a few inches, though the form of the sea-level surface is not known within a hundred feet.

All this complex and subtle system of ideas has been shaken up by the launching of the satellite.

The most drastic change is that we shall now have vertical angles which can be relied upon. The artificial satellites appear at elevation angles up to the zenith, in contrast to the typical geodetic targets, which are lights along the horizon. The steep angles mean that less atmosphere must be traversed, and hence the errors of refraction are reduced. Moreover, by measuring the satellite against the stars, as Professor Whipple, Director of the Smithsonian Astrophysical Observatory, plans to do, it will be possible to determine rather exactly the direction of the long stretch of the ray which lies outside the atmosphere. What little uncertainty remains is in the last mile or so of air. This is a much sounder approach than the ground-based approach of measuring the direction of the last bit of the ray, and deducing the rest by applying refraction corrections, as would be necessary if one-way vertical angles were used in geodesy.

With precise vertical angles, the old separation between levelling and triangulation loses some of its importance. We are in a position to solve, in a rather neat way, the old problem of the shape of the sea-level surface of the earth, of the so-called mathematical world, or the space configuration of the surface upon which the geodesist works.

Intimately connected with this is the question of the distances between the continents, or, more precisely, the relative positions of the continents. Our ideas of the distances and azimuths between pairs of points in North America are rather precise; they are accurate within four or five parts per million over distances from 200 miles up to the longest measured arcs in North America. The same is true within those parts of Europe which are connected to European datum. But the relationship between Europe and North America is not now known within fifty parts per million.

The fundamental reason is that the astronomic determinations give directly only the space direction of the perpendicular to the sea-level surface at a point. From this the position is deduced, on the assumption that the sea-level surface is a perfect ellipsoid. The deviation of the perpendicular to the sea-level surface—that is, the deviation of the vertical—may amount to as much as one minute of arc at isolated points. Even over extended areas, deviations of as much as a tenth of this amount may persist. For example, our geodesists have shown that in Europe the slope of the geoid (sea-level surface) in the Mediterranean area is systematically about five seconds different from that of the North German plain.

The satellite provides us with a direct method of attacking this problem three-dimensionally, since it will be visible in both continents. Predictions of its path made on the basis of information obtained in North America can be compared with observations in Europe. The discrepancies will reveal the systematic difference between the two continental triangulations. The satellite thus paves the way for the unification of the triangulation of the whole world on a single datum.

Underlying the single datum there must be a precise figure of the earth, that is, a precise measurement of the constants of the ellipsoid which best fits the sea-level surface of the earth everywhere. This is the most ancient of all geodetic problems, the most famous and the one on which the influence of the satellite is the most decisive.

There are two constants required for the determination of an ellipsoid of revolution. These, in geodesy, are usually taken to be the semi-major axis of the generating ellipse and its flattening. The flattening is specified numerically by giving the difference between the equatorial and the polar radius in units of the equatorial radius.

It was pointed out some years ago by Lyman Spitzer that the satellite will yield an extraordinarily good determination of the

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.14.

earth's flattening. The method is one which has been widely used in astronomy to determine the flattenings of the planets. It depends on the fact that the plane of the orbit of a close satellite precesses, owing to the attraction of the earth's equatorial bulge. The same effect exists, of course, for the moon, but since the force involved decreases as the cube of the distance, the effects on the moon are much smaller. Moreover, in the case of the moon it is necessary to allow for a similar motion caused by the sun's attraction, which increases in proportion to the distance of the satellite from the earth. Naturally, the force exerted by the sun does not vary in any such way, but the *difference* between the force on the earth and that on the moon, which is what counts here, *does* vary in proportion to the distance from the earth. Hence, the precession of the satellite orbit is much faster than the precession of the lunar orbit, and is nearly uncontaminated by solar influences.

In fact, the motion of the satellite orbit amounts to about 400 miles per day. Since there is a difference of one part in 200 between the plausible values for flattening of the earth, it is clear at once that as soon as the motion could be measured even roughly over the course of a few days, we were on the way to having a significant improvement in our knowledge. After the Vanguard satellite had been up for a period of a few weeks, a preliminary determination suggested that a value of 1/298.3 is close to the truth. Other satellites tended to confirm this result; but the Vanguard, because of its height at perigee, has by far the most regular motion.

Under the heading of satellite methods are included the lunar methods, for the moon is a satellite, though a distant one. One of these methods, the lunar occultations, was successfully employed by the United States Army Forces, Far East and the Army Map Service. This technique starts by observing from two ground stations the instant at which a star's light it cut off by the moon's dark limb.

In January 1955, the Army Map Service, at the request of the United States Coast Guard, inaugurated a programme of surveying by occultations between the Philippine Islands and the so-called Marianas chain, including the Mariana and Caroline Islands. At the time the request was made, it was known that the geodetic positions of the Caroline Islands and of the Mariana Islands were incorrect by perhaps as much as ±2,000 metres in latitude and longitude. It was deemed necessary for navigational purposes to correct the positions of the islands so that the probable error of their co-ordinates would not exceed ±300 metres in both latitude and longitude.

Because the distance between the geodetic systems ranged from approximately 500 miles, at their closest approach (with nothing but the Pacific Ocean in between), to 1,600 miles, at their farthest, the photo-electric method of occultation observations was chosen as the only one practicable to attempt a tie between the two systems. In this method, the instruments used are the Brush Model 202 oscillograph combined with the Brush Model 932 amplifier, both of which are attached to a twelve-inch Cassegrainian telescope behind whose focal point a 1P21 RCA phototube is placed. The data are recorded on a double channel paper tape. In one channel there is a recording of the light intensity of the star involved in the occultation while in the other channel there are usually WWV or WWVH time signals.

The theory behind the method is as follows. If we imagine the moon to pass between an observer on the earth and a star, a shadow of the moon can be visualized as thrown into space and intersected by the earth. As the moon revolves eastward around the earth this shadow traces a path across the earth. From any point within this path, the star will be occulted. If we concern ourselves with one specific observer, he will see the occultation occur at a particular point on the moon's edge. This particular point can then be imagined as tracing a line on the earth such that every observer on that line would notice the occultation of this star occurring at the same point on the moon's limb. This line is defined as an equal-limb line. The effect of the moon's motions during the interval of time that it takes one point on its shadow's edge to pass eastwards between two specific observers can be computed and allowed for. Knowing the angular rate of revolution of the moon around the earth and the rate of rotation of the earth, combined with a knowledge of the size of the equatorial radius of the earth and the parallax of the moon reduces the problem to one of knowing the velocity of the moon's shadow during that interval of time, and computing the distance.

Observations of satellites and the moon are indeed a revolutionary approach to geodetic problems. Not only will we be able to span large distances more rapidly and more efficiently—that is, determine widely separated points—but geodesists can hope to work out a more precise value for the flattening of the ellipsoid, and with it, a more realistic size of the earth.

SOME RECENT DEVELOPMENTS IN GEOMAGNETISM AND GRAVIMETRY [1]

Background paper by Rear Admiral H. Arnold Karo,
Director, United States Coast and Geodetic Survey

This paper is confined chiefly to developments with which the Coast and Geodetic Survey has been closely identified, rather than dealing with world-wide advances in geomagnetism and gravimetry.

This is a time of ferment and excitement for geophysicists, with many new ideas and instruments being developed and tested in a vast co-operative endeavour known as the International Geophysical Year or IGY. Calibration of new instruments and training of personnel for the IGY programme has been a pressing and formidable concern of the new Fredericksburg Magnetic Observatory and Laboratory ever snce its establishment in 1956. A valuable aid in this work has been the large set of Braunbek coils with which the observers can reproduce over a sizable working space the magnetic conditions of any part of the globe.

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.36.

The IGY programme in geomagnetism is directed primarily towards the study of the electric currents in the upper atmosphere that are responsible for the transient fluctuations of geomagnetism. The programme developed by the United States National Committee includes a chain of stations in Alaska, another chain in the western part of the United States, five low-latitude stations on Pacific islands, a north-south chain of stations in Peru, and five stations in Antarctica, as well as special rapid-run recording instruments of a new design at all but one of this country's seven permanent magnetic observatories. A special installation in the vicinity of Fairbanks, Alaska, is the tripartite array known as the differential magnetograph. This consists of instruments installed at three places about eleven kilometres apart and connected by cables in such a way that a record is produced of the differences between the magnetic elements at the main station and the corresponding values at each of the outpost stations. This system was developed by J. H. Nelson of our Washington staff and implements a proposal advanced a few years ago by Professor Sydney Chapman for the installation of a three-station magnetic observatory. It was set up at a site along the auroral zone, where it is expected to contribute in important ways to our understanding of the complexities of the overhead line currents. The records are already under scrutiny in an effort to unravel some of this mystery.

An even more fundamental development in instrumentation is that based on the precession of atomic particles. Two aspects of this are under study at Fredericksburg. One is an effort to adapt the proton precession idea to the measurement of vector components of the earth's field as well as the total intensity. The other involves the use of optical absorption in the vapour of rubidium as a probe of the electron precession that serves as a magnetic field indicator. This application, a co-operative effort between scientists of our Fredericksburg Observatory and of the National Bureau of Standards, promises to extend the useful range of measurement down to very weak fields, on the order of one gamma. The perfection of such an instrument would have important bearings not only on geomagnetism proper but on space exploration as well.

Meanwhile, more conventional instruments still hold the stage. It is hoped soon to complete auxiliary controls for use with the universal magnetometer of E. A. Johnson, with spinning-coil detector. The sine galvanometer of the Carnegie Institution of Washington was transferred from Cheltenham to Fredericksburg and continues to serve as an accurate reference standard of horizontal intensity. One of the most highly valued instruments at Fredericksburg is the universal electromagnetic magnetometer acquired from a Japanese firm and built to the design of the Geographical Survey Institute of Japan. Small, portable instruments using the saturable-core principle are also under study for possible field use.

One of the IGY stations is on the island of Koror in the Palau group. This station shows very strongly the effects of the equatorial electrojet, and the records are under study so as to learn more of the nature of these effects and possibly of the manner in which they are generated. It appears that diffuse overhead currents flowing eastward in low latitudes are concentrated at midday into a narrow band along the magnetic equator. The reasons for this zone of enhanced conductivity are not fully understood, but they may become clear with a study of data from a number of stations such as the one at Koror. This station, incidentally, is not strictly a new site, because observations of a somewhat different scope were taken there for several years by the Hydrographic Department of Japan.

One of the vital segments of our long-term magnetic observing programme is the repetition of observations at selected field stations over the United States for the purpose of filling in regional details of the secular changes. A new scheme has been put into effect this year. A portable magnetograph (Askania variograph) is set up and operated at a chosen site for a period of days or weeks during the occupation of all repeat stations in the adjacent region, then it is moved to a new location in the midst of the next region to be covered, and so on. This procedure reduces substantially the uncertainty in removing transient effects from the repeat observations.

One of the chief aims of all our magnetic work is the improvement of magnetic charts. The Coast and Geodetic Survey compiles regularly several series of magnetic charts covering the United States, Alaska and the entire world. The world charts are published by the Navy Hydrographic Office. Preparations are already in progress for the compilation of the 1960 isogonic charts, and special efforts are being made to co-ordinate our work with that of some of the foreign agencies concerned. The mechanical effort involved in assembling the available data and reducing them to the desired epoch is again being held to a minimum through the use of punch card procedures. However, it is still necessary to make exhaustive studies of all available secular-change data so that the best possible reduction constants may be fed into the machines. The method of impulsive epochs is used in these studies.

A related application of mechanical processing is involved in preparing the tabulations of hourly magnetic values and derived mean values from the observatory data. The ordinates of the curves are still read off with the aid of an engraved glass scale which must be manipulated by hand; but the readings so obtained are entered on punch cards and all subsequent calculations are done by machine.

The Coast and Geodetic Survey is also engaged in carrying out another important assignment for the IGY in the operation of three segments of the World Data Center A for the exchange and dissemination of IGY results in geomagnetism, gravity and seismology. Here, original data in those three disciplines originating throughout the western hemisphere and in some other areas are being catalogued and microfilmed for exchange, so that soon after the close of the IGY it will be possible for scientists to consult a world-wide assemblage of data at a convenient, central location, or to procure at nominal cost copies of those portions that are of particular concern in the study at hand. From data already obtained it is becoming clear that significant changes will be necessary in the prevailing concepts of the overhead currents, and that the tremendous effort devoted to the IGY is going to pay large dividends in terms of new understanding of our environment.

Extensive gravity surveys have been conducted by the Survey during the past few years in the north-central part of the United States. Areas now completed, when combined with previous coverage to the south, provide a north-south belt about 1,500 miles long with a minimum width of 400 miles. These data will be employed in a detailed study of the geoid profile between the Canadian boundary and the Gulf of Mexico.

The gravity base network of the United States is being extended and strengthened in the light of modern needs. As

is well known, gravity meter calibration must be carefully controlled at all times to achieve the accuracy necessary in a basic network. This is especially true in the United States, where large areas and gravity ranges are involved. A further critical requirement is that gravity base values of high accuracy must be determined in various regions to meet year-to-year operational requirements, though several years may elapse before an integrated nation-wide network can be completed. To meet these problems, a fundamental gravity base line has been established in the central United States approximately along the 98th meridian, and extending northward to the Canadian base station at Winnipeg, Manitoba. The line consists of thirty-six stations spaced about fifty miles apart and covering a gravity range of 1,950 milligals. The calibration standard is provided by pendulum observations at six primary stations equally spaced along the line. Gravity at these stations was measured by the Coast and Geodetic Survey (Brown invar apparatus), the Dominion Observatory of Canada (Cambridge invar apparatus) and the University of Wisconsin (Gulf-Woollard quartz apparatus). Statistical comparison of results of the three systems indicates a calibration precision of about two parts in 10,000.

The fundamental line is connected to the national base in Washington, D.C., by pendulum and gravity meter observations, the latter accomplished by east-west air transport, thus minimizing drift and calibration uncertainties. Having this system of accessible gravity bases distributed over the total gravity range, it is possible to extend rapidly the base coverage into any desired region. This can be done with high accuracy by gravity meter, employing predominantly east-west connexions. During 1958 a second north-south base line was completed from Washington, D.C., to Key West, Florida, and controlled near the southern end by direct air connexion to Houston, Texas, on the mid-continent base line.

A new calibration base was established near Washington, D.C., for periodic evaluation of gravity meter performance. This base, consisting of two stations having a gravity difference of about seventy-four milligals, has been found more effective than the longer base previously employed. Environmental conditions can be more uniformly controlled, thus helping to localize minor irregularities in the operation of individual meters. For example, some evidence has accumulated that some meter calibration factors are appreciably influenced by ambient temperature and by other variable conditions encountered in normal field operations.

A continuous programme is maintained for recovery of the 1,200 Coast and Geodetic Survey pendulum stations, most of which were established prior to 1940. More accurate values at these stations are necessary, as they have served as base points for many local surveys by various organizations since the advent of the gravity meter in the mid-nineteen-thirties.

Automatic computing machines are employed in processing the masses of gravity meter data. Scale reading, time, elevation, position and gravity base values are punched on IBM cards for individual points occupied. From these basic data the principal facts for each station are automatically computed and listed in a form suitable for reproduction. An important advantage is that the final data can be quickly and easily revised if changes are later made in the meter scale factor or gravity datum of a particular survey.

The Coast and Geodetic Survey has co-operated with the Geophysical Observatory of Trieste, Italy and the Dominion Observatory of Canada in determining a triple gravity connexion between America and Europe. The elements New York-Rome, Montreal-Geneva and Gander-Paris were individually measured by repeat air shipments of Worden gravity meters without transportation of personnel. In each case the gravity difference between stations was very small, thus effectively eliminating calibration uncertainties and yielding connexions of high precision. Such connexions, if carefully planned, can be done rapidly and economically. It is understood that a similar east-west connexion is planned to link Rome with Kyoto, Japan, during October, 1958. Beirut, Lebanon, will be employed as an intermediate point in the operations, to be conducted jointly by the Geophysical Observatory of Trieste and Kyoto University. On completion of this link, Japan-United States will be the only remaining gap in a globe-circling loop of very high precision. It is hoped that the Coast and Geodetic Survey can in the near future participate in a trans-Pacific connexion to close the circuit.

Recent instrumental developments are of great significance in the measurement of gravity at sea. The LaCoste-Romberg submarine gravity meter has successfully met test requirements and is now in operational use by the United States Navy. In principle, this instrument is an adaptation of the long-period seismograph with a nearly linear characteristic over a gravity range of several thousand milligals. The null-type spring system is mounted in gimbals and kept oriented with the apparent vertical by a servo system with electrical damping. Vertical accelerations are removed by automatic averaging of the readings over a period of fifteen to thirty minutes. The troublesome problem of horizontal acceleration has been solved by refinement of the Vening Meinesz system. The motions of a pair of long-period pendulums are electrically recorded and fed into a computer system which determines the instantaneous horizontal acceleration effect and applies it continuously to the gravity meter reading. The operational accuracy of this instrument is comparable to the Vening Meinesz apparatus, but it has important advantages in the ease of operation and the rapidity with which numerical data can be obtained.

Another sea gravity instrument, developed by Anton Graf of Munich, has potential for measurement on surface vessels in moderately calm seas. As part of the USA-IGY programme, J. Lamar Worzel of Columbia University conducted successful test measurements off the Atlantic coast with the Graf instrument in November 1957. The instrument was mounted on a gyro-stabilized platform on the USS Compass Island. The measuring element is an aluminium boom supported by horizontal cylindrical springs at one end, with a photo-cell system to detect motion of the boom. A near-by permanent magnet produces eddy currents which dampen the boom motion, and further damping is provided in the electrical recording system. The over-all damping is such that five to ten minutes are required to record a change in a gravity reading.

An extensive programme of earth tide measurements is being conducted during the IGY period by the University of California at Los Angeles. Special LaCoste-Romberg recording gravity meters have been employed at ten stations around the world. These meters have an accuracy of nearly one microgal under ideal conditions. The programme has been especially oriented to study the anomalous nature of earth tides as correlated with distance from the oceans.

AGENDA ITEM 9

Aerial photography: Status of aerial photography programmes

(No papers were presented under Agenda item 9)

AGENDA ITEM 10

Topographical mapping

TOPOGRAPHIC MAPPING IN THE AMERICAS [1]

Background paper by George D. Whitmore,
Chief Topographic Engineer, United States Geological Survey

The nations of North America and South America differ widely in language, customs, area and climate. The great majority have this in common, however: they have large areas of land at present inadequately mapped, and they have a growing appreciation of the importance of good topographic maps in planning the use of their natural resources. Some of the programmes and methods used in the various countries to prepare modern maps have been described in detail in past issues of the United Nations publication *World Cartography* and in other publications devoted to surveying and mapping. Here, I propose to review briefly the most significant of these activities and to point out the advantages these American nations have realized from working together in their topographic mapping programmes.

Co-operation among the American Nations

Pan American Institute of Geography and History (PAIGH)

An important keynote in western hemisphere mapping is international co-operation. Mapping in the American continents is encouraged, facilitated and oriented through the activities of the Pan American Institute of Geography and History.[2] Although the Institute was not created until 1928 at the Sixth International Conference of American States, its origin reaches back to 1898, when the Latin American Scientific Conference in Buenos Aires proposed a congress on geography and history to promote progress in those fields. In 1949, the Institute was the first to acquire the status of a specialized organization of the Organization of American States. In 1941, the Institute established its Commission on Cartography, the earliest of three commissions, the other two being in the specialized fields of geography and history.

The Pan American Institute of Geography and History states that its objective is to bring about co-operation and collaboration among the American nations in their scientific and cultural work in the fields of cartography, geography and history.

Several committees have been established under the Commission on Cartography, which are intended to assist in and to encourage the following activities: [3]

Speeding progress in the standard topographic mapping and aerial photography programmes of each country; interchange of technical data to obtain uniform standards, improved map quality and lower costs;

Establishment of a common geodetic datum for the American continent and eventual determination of the best "figure of the earth," for the western hemisphere;

Sponsoring the preparation and dissemination of technical data and specifications in the field of special or small-scale maps; promoting the preparation of national atlases;

Stimulating the preparation of aeronautical charts and the interchange of information on such charting;

Prosecution of systematic hydrographic surveying programmes, expeditious publication of results and interchange of hydrographic information;

[1] The original text of this paper, submitted by the United States of America, under the title "Topographic Mapping in the Western Hemisphere", appeared as document E/CONF.25/L.38.

[2] Pan American Institute of Geography and History, publication No. 180, 1954.

[3] Resolutions of the Eighth Pan American Consultation on Cartography, Havana, 12 to 21 February 1958.

Expansion of the programme of tidal investigations and related reports;

Promulgation of standards for urban-area maps and expediting progress in their production;

Stimulation and co-ordination of gravimetric and geomagnetic surveys;

Establishment of more first-class seismograph stations and compilation and publication of seismological histories.

Inter-American Geodetic Survey (IAGS)

The Inter-American Geodetic Survey [4] was created in 1946 to accomplish the collaborative programme of mapping in the Latin American countries. Operations are conducted under diplomatic agreements with most countries of Central America and South America.

The objectives and functions of IAGS involve the several facets of map-making. Among them are:

Providing technical advice on all phases of cartography, and on-the-job training for the mapping personnel of collaborating Governments; otherwise assisting the cartographic agencies of Latin America to become self-sufficient. (For example, the IAGS operates a Cartographic School at Fort Clayton, Panama Canal Zone, which provides cartographic training to selected Latin American nationals and IAGS personnel.)

Obtaining or assisting in the procurement of aerial photography, geodetic control, and other data with which to produce maps and charts; collection of map data.

Standardization of mapping equipment; loan of equipment to mapping agencies.

Undertaking necessary mapping operations which are currently beyond the capabilities of the responsible mapping agency of the country.

Accomplishing a strong geodetic connexion between North America and South America.

Co-operation in the establishment of a common geodetic datum started about 1913 when the geodetic triangulation of Canada and Mexico was connected to that of the United States. The common net of the three countries was called the North American datum to denote its international character. With the establishment of the Inter-American Geodetic Survey, activity in precise triangulation was expanded with the objective of establishing a common system through all the American nations. As a result, there now exists a complete framework on which to construct topographic and other maps, extending from the Bering Straits to southern Chile and from the Atlantic to the Pacific. In addition, the Republics of the Antilles have been tied geodetically to the mainland by a Hiran trilateration system extending from Florida in the United States to Trinidad, British West Indies.[5] The basic net is unique in that it constitutes the longest measured arc in the world; new calculations of the shape of the earth will be based on this arc.[6]

Relationships on the United States Borders

The United States Geological Survey works closely with the Surveys and Mapping Branch of the Canada Department of Mines and Technical Surveys in the preparation and publication of maps along the international boundary. The country having the larger area within each quadrangle map lying astride the border assumes the responsibility for overall production and maintenance of the map. Normally, each country performs the original mapping within its own borders; responsibility for the colour separation and editing of the full quadrangle is assigned to one or the other.

Mapping activities along the Mexican border have been co-ordinated through the Office of the Chief of Engineers, United States Army, the Joint United States-Mexican Defense Commission and the Inter-American Geodetic Survey. The International Boundary and Water Commission has recently agreed to place in the custody of the United States Geological Survey, for its official work and public release, most of the Commission's available aerial photography and topographic coverage. Excepted from general release are certain areas designated by the Mexican Ministry of Defense.

Map Scales and Contour Intervals

With the exception of maps for civil use in the United States, the prevailing publication scales [7] for topographic maps throughout the western hemisphere are in the 1 : 25,000 to 1 : 250,000 scale group, each being an even multiple of the largest scale used. Generally speaking, the 1 : 25,000 scale is used for maps where engineering studies are planned, or in areas of intensive development or intricately detailed terrain. Among even larger scales in occasional use are 1 : 5,000, 1 : 7,500, 1 : 10,000, 1 : 12,500 and 1 : 20,000. Contour intervals for the 1 : 25,000 scale maps generally range from 2 to 25 metres.

For more general uses, where less detail is needed, the usual scale adopted is 1 : 50,000. Other comparable scales used for this purpose have been 1 : 40,000, 1 : 75,000 and 1 : 100,000. Contour intervals for the 1 : 50,000 scale maps generally run from 2 to 50 metres.

For wider coverage at reconnaissance scales, most countries, including the United States, appear to be turning to 1 : 250,000. At this scale the representation of relief occasionally changes from contour intervals in the 50 to 100 metre range to the use of such methods as relief shading and layer tints.

In the United States, the military scales compare closely with the scales prevailing throughout the Americas. For many years, however, scales have been used for civil-use maps which are slightly different from those on the present United States military maps. For the mapping of 7½-minute quadrangles, the predominant scale is 1 : 24,000, or one inch equals 2,000 feet, an even inch-foot relationship which readily lends itself to engineering measurement. The long-standing scale for 15-minute quadrangles is 1 : 62,500, except for Alaska, where a scale of exactly one inch to the mile, 1 : 63,360, has been adopted.

[4] *Inter-American Geodetic Survey-Mission, Organization, Activities*, 9 June 1958.

[5] *Progress Report on Cartographic Activities of the United States, 1954-1957*.

[6] Pan American Institute of Geography and History, publication No. 180, 1954, pages 3 to 4 and 13.

[7] Country progress reports made at the Eighth Pan American Consultation on Cartography, Pan American Institute of Geography and History.

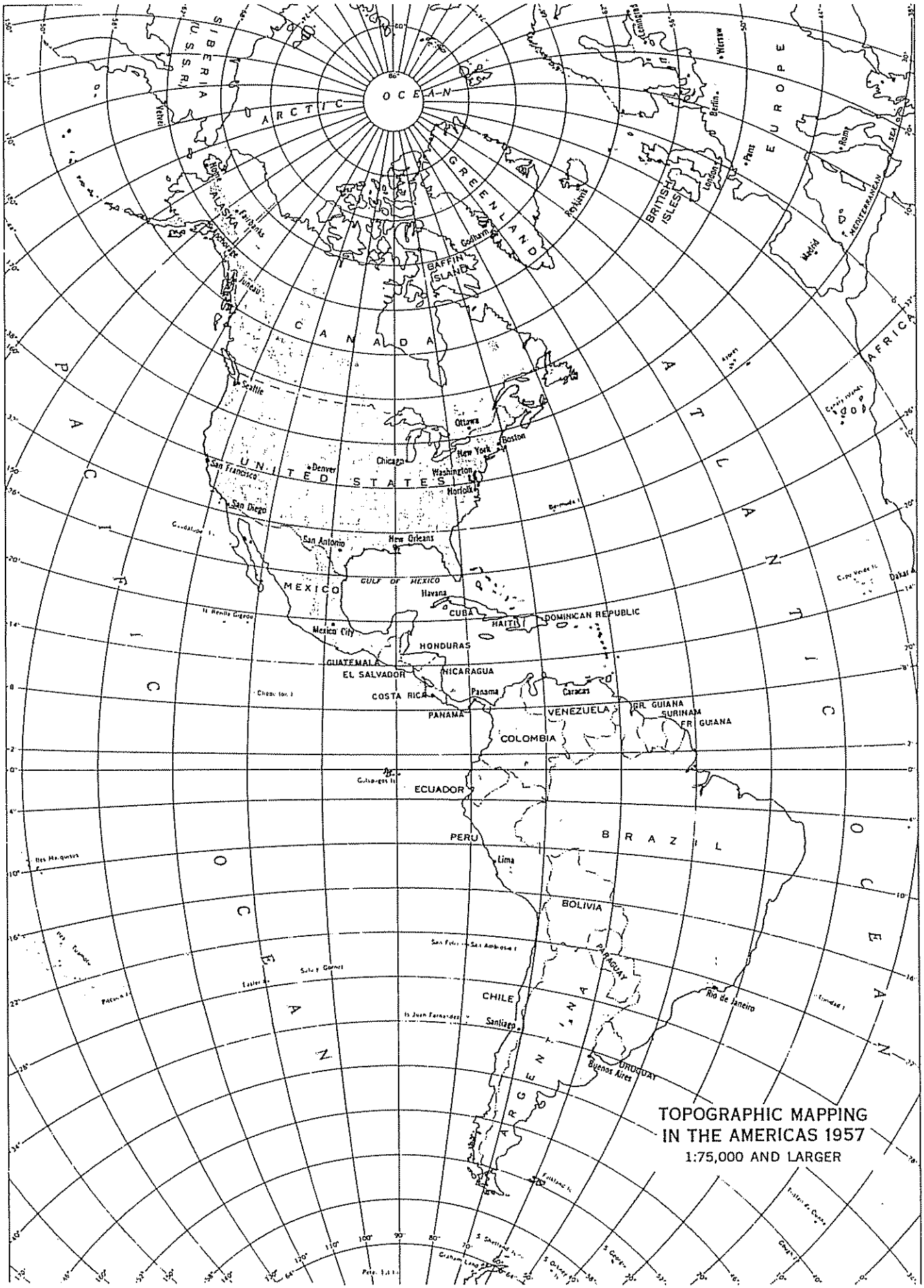
TOPOGRAPHIC MAPPING
IN THE AMERICAS 1957
1:75,000 AND LARGER
ARCTIC OCEAN
SIBERIA (U.S.S.R.)
GREENLAND
BAFFIN ISLAND
CANADA
UNITED STATES
MEXICO
GULF OF MEXICO
CUBA
HAITI
DOMINICAN REPUBLIC
HONDURAS
GUATEMALA
EL SALVADOR
NICARAGUA
COSTA RICA
PANAMA
VENEZUELA
GR. GUIANA
SURINAM
FR. GUIANA
COLOMBIA
ECUADOR
PERU
BRAZIL
BOLIVIA
PARAGUAY
CHILE
ARGENTINA
URUGUAY
BRITISH ISLES
EUROPE
AFRICA
PACIFIC OCEAN
ATLANTIC OCEAN
Seattle
San Francisco
San Diego
Denver
Chicago
Ottawa
New York
Boston
Washington
Norfolk
San Antonio
New Orleans
Havana
Mexico City
Panama
Caracas
Lima
Santiago
Buenos Aires
Rio de Janeiro
Juneau
Anchorage
Fairbanks
Nome
Godhavn
Reykjavik
London
Paris
Berlin
Warsaw
Madrid
Rome
Dakar

Figure 26

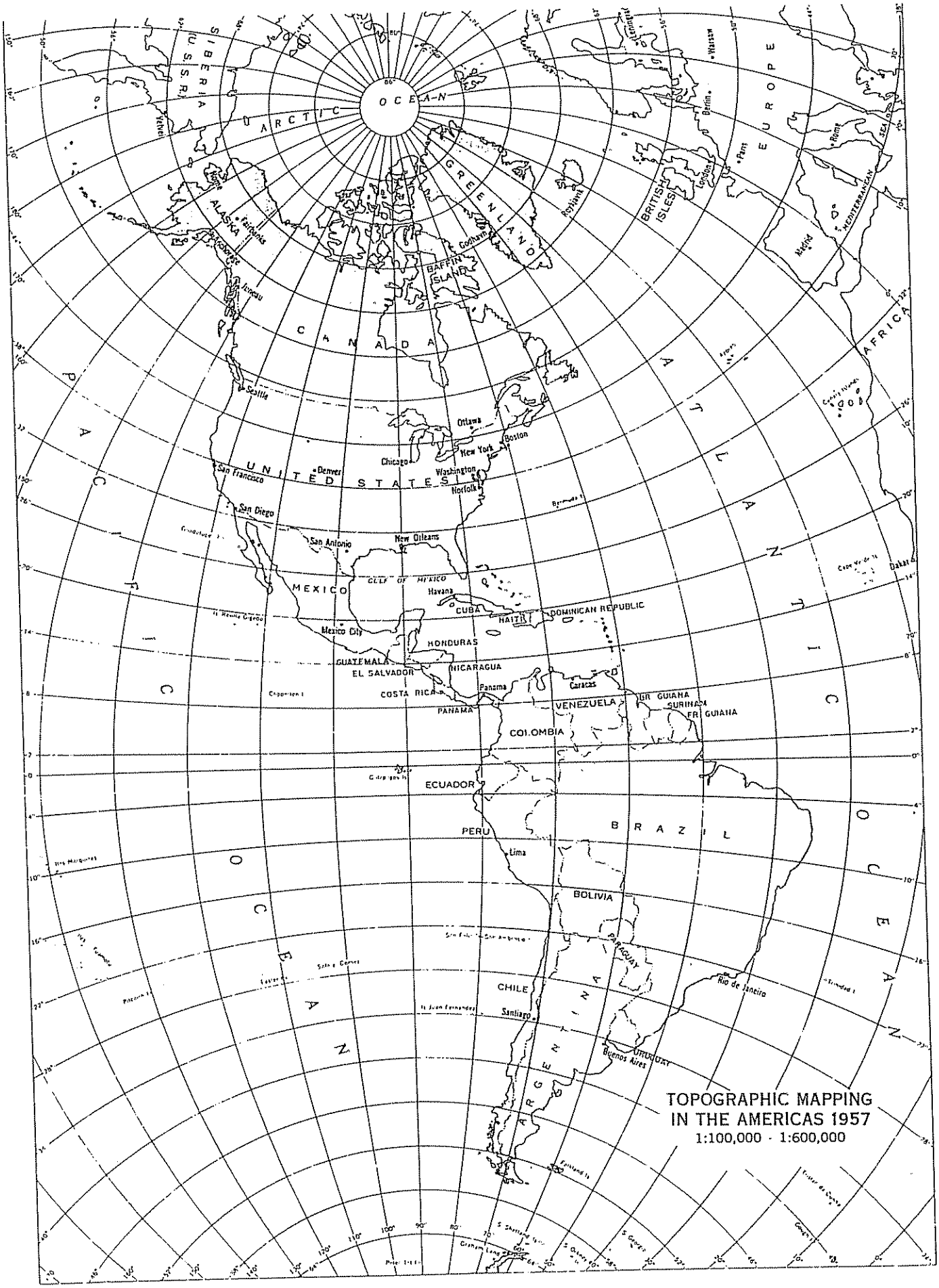

Figure 27

Contour intervals on the 1 : 24,000 scale maps range from 5 to 40 feet; and on the 1 : 62,500 scale maps, from 5 to 100 feet. The only metric contours being used by the United States are in Puerto Rico. That island was completely mapped at a scale of 1 : 30,000; but, as the maps are revised, the scale is being changed to 1 : 20,000.

Most countries produce maps which may be called base or geographic maps, the scales being 1 : 500,000 or smaller. These may or may not contain relief information. In addition, a larger variety of special-purpose maps are being produced which portray such items as urban areas, cadastral information, geologic data, forest cover, soil surveys, vegetation, population, meteorological conditions, census facts, agricultural representations, schools and roads.

For a general picture of the status of mapping in the Americas, figure 26 shows coverage at scales of 1 : 75,000 or larger; figure 27, at scales ranging from 1 : 100,000 to 1 : 600,000.

Methods and Standards

The techniques and instrumentation used for topographic mapping in the western hemisphere are extremely diversified. Not only are there differences in procedures from one country to another, but within a given country, as for example the United States, can be found a great variation in methods used by different organizations and, indeed, within a single organization. This diversification should by no means be ascribed to a failure to understand the value of standardization. Rather, it arises from a receptive attitude towards new ideas and an enterprising willingness to try different techniques. Thus, one can find in use in the Americas practically every principal variety of mapping equipment available on world markets.

Notwithstanding this over-all diversity, there is a distinguishing trend in the western hemisphere with respect to photogrammetric mapping equipment. Whereas in Europe there is an accent on the more complex instruments of Zeiss, Wild, Poivilliers, Santoni and Nistri, the prevailing equipment in the Americas is the double-projection anaglyphic type of instrument, such as the multiplex, ER-55 and Kelsh plotter. The reason for this instrumentation is not hard to find. The American nations have the problem of mapping vast areas in a brief period of time. To do this they must have many plotting units. As the double-projection anaglyphic instruments give adequate results in relation to American standards, and as the capital investment in each plotting unit is relatively small, it is quite natural that this type of equipment is used most extensively.[8] At the same time, the more complex instruments are to be found in significant numbers in the principal mapping organizations for use on special projects.

Because of the nature and extent of the terrain to be mapped, standards in the western hemisphere differ from European standards. In Europe, with its intensive land development, there is great emphasis on the cadastral aspects of topographic maps. In the Americas, on the other hand, the primary emphasis is on extending topographic coverage as rapidly as possible, with less exacting standards. An indication of the difference in standards may be obtained from the following comparison of the specifications for international tests of 1 : 50,000 photogrammetric compilation (reflecting current European thought) with United States National Map Accuracy Standards:

Allowable standard error

	Horizontal		*Vertical*	
	In metres	*In feet*	*In metres*	*In feet*
International specifications	7.5	25	1+7.5t [a]	3+25t
United States standards	—	50	—	10+50t

[a] t = tangent of slope angle.

Figure 28, showing a comparison of American and international vertical tolerances, indicates clearly the more rigid requirements of the international specification.[9]

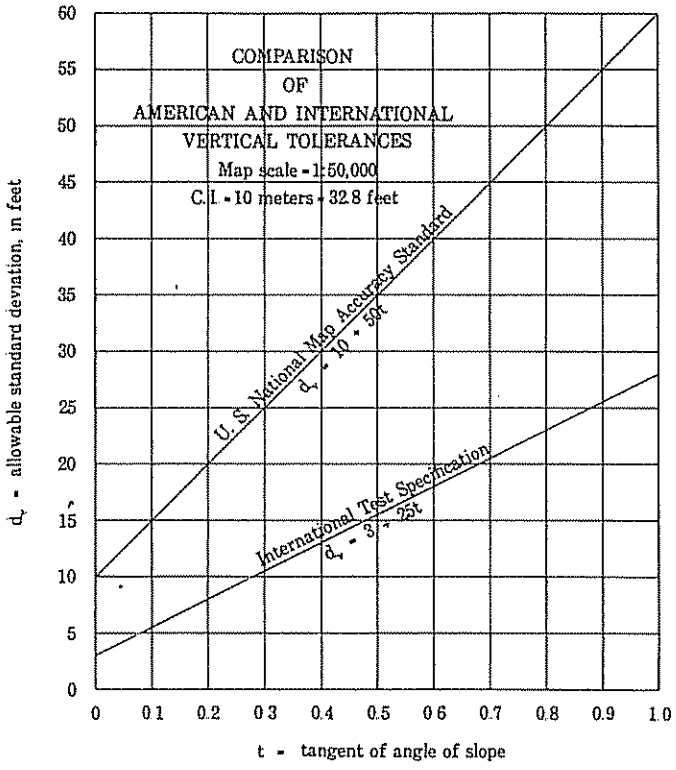

Figure 28

New Trends in Mapping Techniques

In the past few years, mapping organizations of the western hemisphere have been very active in introducing new instruments and methods in all phases of topographic mapping. This emphasis on improvement is an indication of a sense of urgency and a determination to reduce the time and cost of topographic mapping. The list of the innovations that have

[8] G. D. Whitmore, "Economic Factors in the Integrated Photogrammetric System of the U.S. Geological Survey", *Photogrammetric Engineering*, April 1956.

[9] M. M. Thompson, "How Accurate is that Map?", *Surveying and Mapping*, April-June 1956.

been put into practice recently is impressive. Some of these are described briefly below:

Field surveying methods and instruments

Tellurometer

The tellurometer,[10] an electronic instrument for measuring distances, is being used operationally in the United States, Canada, Alaska and in several countries of Central America and South America. The instrument is portable, battery-operated and capable of accuracies equal to those obtained by first-order triangulation.

Geodimeter

The geodimeter,[11] an instrument for measuring distances by means of light waves, is finding increasing use in geodetic surveys of the highest precision—in the measurement of base lines, for example. Probable errors ranging from 1 : 500,000 to 1 : 4,000,000 have been reported. The saving of time and effort compared to conventional taping procedures is enormous.

Automatic level

Automatic levels,[12] in which the spirit bubble is replaced by a tilt-compensating pendulum device, have come into use for control surveys for topographic mapping. In these instruments the line of sight is level even though the telescope is slightly tilted. Since only approximate levelling of the instrument is necessary, field operations are considerably faster.

Pendulum alidade

Plane table alidades[13] also employing the pendulum principle have been developed by the United States Geological Survey and are available commercially. Instead of a spirit bubble, these instruments use a pendulum suspension to establish a level reference plane for measuring vertical angles. Greater accuracy and faster operation are the principal advantages.

Elevation meter

The elevation meter, a development of the Sperry-Sun Well Surveying Company of the United States, is being used by the United States Geological Survey to establish supplemental control for mapping large projects where there are adequate road nets. The device consists of a four-wheel-drive, four-wheel-steer vehicle, on which is mounted a fifth wheel to measure distance and a pendulum to measure slope. The slope and distance values are fed into an electronic computer in the truck, which determines elevation differences continuously. Travelling at normal driving speeds, the instrument establishes supplemental control elevations accurate enough for stereocompilation of ten-foot contours. Although the elevation meter is not yet extensively used, it is believed to have considerable possibilities in speeding up mapping in suitable areas.

Photo-trig control elevations

Photo-trig, a method of determining elevations by combining vertical angles measured in the field with distances determined photogrammetrically, has become standard practice in recent years in mapping rugged mountainous areas. In this procedure the instrument stations are carefully identified on the mapping photographs, in some cases by panelling the points and photographing them from a helicopter. When possible the vertical angles are measured by simultaneous reciprocal readings to minimize the effects of curvature and atmospheric refraction. In the office, distances between stations are scaled from the base manuscripts, and the elevations are computed trigonometrically.

Helicopters and other aircraft

The modern helicopter,[14] with a service ceiling high enough to land almost anywhere, has become a standard means of transportation for field survey parties in terrain with few or no roads. Although operating costs are high, the speed with which a project can be carried out, compared with one using ground transportation, more than compensates for the additional expense. Experience has shown that helicopters are best in pairs so that one machine is available for repair or rescue work in case of a break-down at an inaccessible station.

Fixed-wing aircraft also play an important role in field surveying in remote areas where there are lakes or other landing facilities. In Canada and Alaska and in other areas, such aircraft have been used successfully to supply and transport field parties in difficult terrain.

Radio communication

Field-survey operations with helicopters and airplanes would not be efficient without radio communication. In these projects, several field parties function as a team under the leadership of an engineer at a base camp. The men keep in touch with each other and with the base camp by portable, battery-operated two-way radios.

Photogrammetric techniques and devices

Twin low-oblique photography

For many years vertical photography was generally assumed to be the most efficient medium for topographic mapping. It was known, however, that twin low-oblique photography [15] would have certain inherent advantages if suitable instrumentation were available. With the development of the ER-55 projector and the Twinplex plotter, the way was opened for a complete twin low-oblique system for precise map compilation. Extensive mapping projects have been successfully completed and others are under way involving both convergent and transverse twin low-oblique photography.

New lenses and cameras

Until recently, most of the aerial photography for mapping in the western hemisphere was of the metrogon type. Recent

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[10] F. W. Hough, "The Tellurometer—Some Uses and Advantages", *Surveying and Mapping*, July-September 1957.

[11] M. E. Compton, Jr., "Surveying with the Velocity of Light", *Surveying and Mapping*, July-September 1954.

[12] C. L. Peckinpaugh, Jr, "The Zeiss Opton NI-2 Automatic Level", *Surveying and Mapping*, April-June 1954.

[13] C. S. Maltby, "Alidade Development in the Geological Survey", *Surveying and Mapping*, April-June 1954.

[14] G. FitzGerald, "Helicopter Revolutionizes Topographic Mapping of Remote Areas", *Surveying and Mapping*, January-March 1955.

[15] United States Geological Survey, Topographic Division, *Twin Low-Oblique Photography and the Twinplex Plotter*, Circular 222.

advances in the production of high-resolution, low-distortion lenses have opened the way for improvement in both the photographic and geometric qualities of aerial photography. Leading mapping organizations in the Americas are now insisting on the use of high-quality cameras with low-distortion lenses, such as the Aviogon, the Pleogon and the Planigon.

ER-55 projectors

The ER-55 projector,[16] known commercially as the Balplex, to a large extent is replacing the multiplex in mapping establishments in the western hemisphere. Designed to be used with either vertical or twin low-oblique photography, the ER-55 projector utilizes an ellipsoidal reflector to provide efficient illumination of the projected images forming a stereoscopic model.

Gamble plotter

An interesting new type of anaglyphic double-projection instrument is the Gamble plotter, a Canadian development. In this instrument an auxiliary device projects a pattern of dots directly onto the surface of the map manuscript. Multiplex or ER-55 projectors, aranged so that the projection distance is adjustable, are used to project the stereoscopic model. When the model is viewed stereoscopically, the dot pattern defines a horizontal plane whose intersection with the terrain represents a contour. The contour thus represented can be sketched directly on the manuscript.

Orthophotographs and photo-contour maps

Two parallel developments aimed at producing a similar product—a uniform-scale aerial photograph on which contours can be plotted to give an accurate photo map—have been worked out independently in the United States. One of these, the photo-contour map,[17] is based on a technique developed by the R. M. Towill Company of Honolulu. The other, the orthophotograph, is obtained by means of the orthophotoscope,[18] an instrument developed by the Geological Survey. In either case, the product combines the horizontal and vertical accuracy of a precise map with the wealth of detail afforded by aerial photographs.

Computer-controlled plotting instrument

A new Canadian instrument, the analytical plotter,[19] promises to afford important advantages in topographic mapping. In this instrument, corrections for lens distortion, film shrinkage refraction and the like are stored in the memory units of an electronic computer. As the plotting proceeds, appropriate corrections to the position of the plotting pencil are actuated by the computer.

[16] R. K. Bean, "Development of the ER-55 Projector", *Photogrammetric Engineering*, March 1953.

[17] R. O. Mahan, "The Photo-Contour Map", *Photogrammetric Engineering*, June 1958.

[18] R. K. Bean and M. M. Thompson, "Use of the Orthophotoscope", *Photogrammetric Engineering*, March 1957.

[19] U. V. Helava, "New Principle for Photogrammetric Plotter", Communications at the International Conference on Aerial Triangulation in Ottawa, August 1957, National Research Council, Ottawa.

[20] M. B. Scher, "Stereotemplet Triangulation", *Photogrammetric Engineering*, December 1955.

Aerotriangulation techniques and auxiliary devices

Stereotemplets

The stereotemplet system,[20] a variation of radial triangulation, is a highly effective means of extending horizontal control accurately. In this technique, the basic data are derived from spatial models formed by stereoscopic plotting instruments. Displacements due to tilt and relief are virtually eliminated. Stereotemplets are of special value in areas where the amount and distribution of existing horizontal control is not suitable for effective stereotriangulation by individual flight strips. The system is used principally in the United States and Canada.

Airborne controlled aerial triangulation

An improved system of horizontal and vertical aerotriangulation utilizing auxiliary data[21] recorded during the photographic flight has given good results in Canada. The auxiliary data recorded during the flight include terrain clearances obtained by the airborne profile recorder (a type of radar altimeter) and oblique photographs fore or aft in the flight direction to control azimuth.

Electronic positioning methods

Experimental projects are now in progress to determine the effectiveness and accuracy of electronic positioning techniques for determining the co-ordinates of aerial photograph exposure stations. Among the systems under consideration in the Americas as an aid in aerotriangulation are Shoran, Hiran Raydist and Decca.

Analytical methods

Several different approaches to a general solution of the aerotriangulation problem by analytical methods are being investigated in North America. In some instances the research has reached the stage in which tests of the mathematical analysis and the related electronic computer programme are now under way.

Electronic computers in topographic mapping

The speed and accuracy of the big electronic computers have been applied to topographic mapping in several phases other than those mentioned above—particularly in the adjustment of control surveys.

Triangulation adjustment

For several years now the United States Coast and Geodetic Survey has carried out the adjustment of both arc and area triangulation on the IBM 650 computer. They use the variation of co-ordinates procedure, by which the setting up of condition equations is made a function of the computer. Triangulation in the countries of South America participating in the IAGS is adjusted by the UNIVAC computer operated by the Army Map Service.

The Army Map Service also uses the UNIVAC computer to convert geodetic control from many countries to the UTM grid system, to compute a new size and figure of the Earth, to compute satellite orbits and to adjust stereotriangulation data by the strip method.

[21] I. Blachut, "Use of Auxiliary Data in Aerial Triangulation over Long Distances", Communications at the International Conference on Aerial Triangulation in Ottawa, August 1957, National Research Council, Ottawa.

Interconversion between geographic and plane co-ordinates

The Geological Survey, using the Datatron, has in operation a programme to convert most of the geodetic control in the United States from geographic to plane co-ordinates. Plane co-ordinates, by simplifying computations, make geodetic control more useful to local surveyors.

Cartographic procedures

Scribing

Negative scribing,[22] by replacing fine-line drafting, has revolutionized map finishing techniques in the Americas. In negative scribing, a transparent image is delineated through an actinically opaque material. The scribing medium is a sheet of clear glass or plastic to which a coating has been applied. Working over a light table, using special tools called gravers, the operator cuts out image lines or symbols to produce a transparent image on an opaque background, giving an effect similar to that of a negative.

Scribing on coated plastics is superior to pen and ink drafting, copperplate engraving and other traditional methods in many ways. The training period for new employees is shorter and the production rate of trained employees is higher. Despite increased production rates, the quality of the finished product is improved to a surprising degree. Scribed negatives at publication scale make possible simple phototransfer procedures, eliminating most of the copy camera work formerly required. Furthermore, scribed plastic negatives lend themselves to revision work conveniently and are handy to ship and store.

Electroluminescent light tables

An interesting new development that may have considerable application in the future is a light table less than one centimetre thick that develops no heat and uses very little current. The new table is an electroluminiscent panel made of a sandwich of glass, conducting coatings, phosphors and other materials on a metal base. Various arrangements of materials are possible, depending on the colour and intensity of light desired. Light is produced by applying a high-frequency alternating current to two of the layers, which act as electrodes. The light produced may be green, blue, yellow-orange or white. Green is the most efficient and apparently the most suitable for light-table application. The panels are now being tested by the Geological Survey.

Examples of Modern Mapping

The nations of the western hemisphere have made good use of their research by applying the results as soon as possible on current mapping projects. As examples of the application of new techniques, are described two projects recently completed, one by the United States and one by Canada.

Brooks Range project

The mapping of 121,000 square miles of extremely rugged terrain in the Brooks Range area of northern Alaska presented a formidable challenge to the United States Geological Survey.[23] Because of the remoteness of the area, the sparseness of control and the difficulty of obtaining aerial photography, it was necessary to apply unusual methods in virtually every phase of the project.

By applying the new technique of transverse twin low-oblique photography, the Geological Survey succeeded in obtaining good photographic coverage of 85 per cent of the area in a single flying season, notwithstanding the scarcity of photographic weather and some difficult technical problems. In some instances, temperatures as low as 85 degrees below zero Fahrenheit were encountered at the flight altitudes of 30,000 to 40,000 feet.

A field task force, equipped with both helicopters and fixed-wing aircraft, obtained elevation data on which the photogrammetric extension of vertical control could be based. These data were secured by running parallel lines of photo-trig traverse by the methods of simultaneous reciprocal vertical angles. These lines were spaced at forty-mile intervals, running in a north-south direction, perpendicular to the east-west flight lines. By setting up twelve-model bridges spanning the forty-mile intervals, on the Twinplex or ER-55 instruments, vertical control for each transverse model was developed.

The available horizontal control at the start of the project consisted of a series of triangulation arcs on the perimeter of the area. To provide a stronger basis for control extension, an additional north-south arc was executed by the Coast and Geodetic Survey, dividing the area into two approximately equal parts, each surrounded by perimeter triangulation. The extension of this control to provide horizontal positions for orienting stereoscopic models was successfully accomplished by means of stereotemplet assemblies based on the perimeter control.

Compilation of the Brooks Range maps was accomplished entirely with ER-55 instruments, which lend themselves very well to the use of either transverse or convergent low-oblique photography. Thanks to bold planning and a willingness to take some calculated risks, the project was completed well ahead of schedule. The 1:250,000 scale maps are now being published, with contour interval of 200 feet in most areas and 100 feet in selected areas.

The Ungava Peninsula

Extending northward towards the Northwest Territories and bordered by the waters of historic Hudson Bay, Hudson Strait and Ungava Bay, is the rugged and treeless Ungava Peninsula,[24] an area of about 70,000 square miles. In a region where communications are difficult, there being no roads or railroads, the electronic techniques which are so much a part of modern communications were applied instrumentally to the mapping problem by the Topographical Survey of Canada.

The Ungava Peninsula had been completely mapped at the reconnaissance scale of eight miles to the inch, using trimetrogon photography. In the first use of electronic methods in the area, the Geodetic Survey had established a network of

[22] United Nations, C. F. Fuechsel, "Some Current Trends in Cartography in the U S A", by *World Cartography*, vol. III, 1953 (Sales No.: 55 I.31)

[23] H. B. Loving and J. E. Mundine, "Mapping Alaska's Brooks Range", *Surveying and Mapping*, July-September 1957.

[24] S. G. Gamble, "Mapping of the Ungava Peninsula", *Photogrammetric Engineering*, June 1958.

Shoran stations. The Topographical Survey had accomplished a net of triangulation along the 71° meridian to control 1 : 50,000 scale mapping along the east coast, and some triangulation was extended westward along the Payne River. This was the background for the new project.

The mapping plan called for complete coverage of the peninsula at 1 : 250,000 scale with 100-foot contours and an east-west strip across the northern part at 1 : 50,000 scale with fifty-foot contours. The larger scale mapping was required to cover an important mineral-bearing zone. The aerial photography was planned for a flight altitude of 20,000 feet. The contract included a requirement for radar altimetry profiles along each flight line, this being the second use of electronics on the Ungava project.

The field work began in 1957, and in one field season all the mapping control required was accomplished with the aid of helicopter and fixed-wing aircraft support. The ground control consisted of tellurometer traverse, the third application of electronic methods, with transits providing directions. Average closure on 500-mile loops was one part in 35,000. Trigonometric levels were carried along the traverse lines to control the radar altimetry. In addition to the traverses, 600 miles of tellurometer distance measurements were taken to control selected trimetrogon flights.

Perimeter control for blocks measuring approximately fifty miles by fifty miles was established by using a precise photogrammetric plotter and the tellurometer distances to obtain good latitude values along the old flights of north-south trimetrogon photography. Precise plotters with radar altimetry data were used to provide good longitude values along the east-west flights of new photography. Further extension of control was accomplished by means of slotted templets.

Contouring of the 1 : 250,000 scale maps was performed directly on the photographs, using radar altimetry for height control; subsequently the data were transferred to the manuscript by means of the vertical sketchmaster. For the 1 : 50,000 scale maps, bridging and compilation were accomplished by means of multiplex.

Conclusion

In this paper I have attempted to summarize the progress in topographic mapping that has taken place in the western hemisphere in the past few years. Map-making today is a rapidly changing science, and many interesting developments that could be mentioned have been omitted from this short account. However, the principal thought I want to leave with you is the urgency of our collective responsibility as surveying and mapping engineers. We live in a world that is growing smaller in relation to our population and to our means of transportation and communication. We must plan wisely to make the best possible use of our land and other resources. To accomplish this, we must have adequate surveys and maps.

The nations of the western hemisphere have come to realize this need, and, through the Pan American Institute of Geography and History and other organizations, they have developed a fine spirit of co-operation. This spirit, coupled with necessary scientific and technical developments, has made it possible to implement a forward-looking programme of topographic mapping.

SELECTED PUBLICATIONS RELATING TO TOPOGRAPHIC MAPPING IN THE UNITED STATES [1]

Background paper by George D. Whitmore,
Chief Topographic Engineer, United States Geological Survey

A considerable body of literature pertaining to topographic mapping and related subjects has been developed in the United States. Because of the extensive scope of this literature, few members of the mapping profession have the opportunity to digest more than a fraction of it. To meet the need of the reader who desires a brief survey of principal articles in this field, the Geological Survey presents these abstracts of selected publications. This compilation is not exhaustive by any means; it is intended only as a summary of representative articles on topographic mapping.

The compilation is divided into three parts, as follows:

Part I—Selected publications relating to standards in the production of topographic maps in the United States;

Part II—Selected publications relating to techniques and methods used in the production of topographic maps in the United States;

Part III—Selected publications relating to recent developments in photogrammetric plotting instruments in the United States.

For the convenience of readers desiring more information regarding specific articles, the addresses of the journals and other publications mentioned are listed below:

Photogrammetric Engineering, American Society of Photogrammetry, 1515 Massachusetts Avenue, Washington 5, D.C.

Surveying and Mapping, American Congress on Surveying and Mapping, 905 Washington Building, 1435 G Street, NW, Washington 5, D.C.

Reference Guide Outline, Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, Bureau of Public Roads, United States Department of Commerce, Washington 25, D.C.

Topographic Instructions, United States Geological Survey, Washington 25, D.C.

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.39.

Part I

Selected Publications relating to Standards in the Production of Topographic Maps in the United States

Coulthart, D. E., "Map Accuracy Evaluation Procedures at Army Map Service", *Photogrammetric Engineering*, December 1957

Funk, L. L., "Specifications and Use of Topographic Maps in Highway Work", *Surveying and Mapping*, July-September 1953

Funk, L. L., "Photogrammetric Map Accuracy", *Photogrammetric Engineering*, June 1958

Lyddan, R. H., "How Much Topographic Detail", *Surveying and Mapping*, January-March 1954

Marsden, L. E., "Shortcomings of Contour Lines", *Surveying and Mapping*, April-June 1955

Panel, American Congress on Surveying and Mapping, "Selection of Contour Intervals", *Surveying and Mapping*, October-December 1952

Reference Guide Outline, Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, United States Bureau of Public Roads

Thompson, M. M. and Davey, C. H., "Vertical Accuracy of Topographic Maps", *Surveying and Mapping*, January-March 1953

Thompson, M. M., "How Accurate is that Map?", *Surveying and Mapping*, April-June 1956

Topographic Instructions of the United States Geological Survey

Whitmore, G. D., "Contour Interval Problems", *Surveying and Mapping*, April-June 1953

Coulthart, D. E., "Map Accuracy Evaluation Procedures at Army Map Service", *Photogrammetric Engineering*, December 1957

Abstract: The need for reliable map accuracy evaluations of existing maps of foreign areas is discussed. Procedures to provide a preliminary accuracy evaluation and to select the areas for further investigation are outlined. A summary of the stereophotogrammetric procedures currently in use at the Army Map Service is given. Statistical methods used in the reduction of the test data to specific map accuracy classifications and the application of these results to future map planning are discussed.

A report is prepared upon the completion of the test and a film positive of the test compilation is included in the report to provide a graphic indication of the evaluation. The information made available from a photogrammetric map test provides a reliable evaluation of the accuracy of the tested maps, and the reliability and adequacy of the basic control, as well as information on the adequacy of the photo coverage of the area. Such data are invaluable in establishing mapping priorities and the planning of mapping projects.

Funk, L. L., "Specifications and Use of Topographic Maps in Highway Work", *Surveying and Mapping*, July-September 1953

Abstract: Requirements for the planning and design of modern turnpikes go far beyond the old concepts of highway location. The highway locator has been, to a great extent, replaced by a staff of specialists in planning, design and construction. Topographic maps are the basic indispensable tools for such studies. For preliminary studies and general route selection they may be in the form of aerial photographs, mosaics or planimetric maps. The modern 7½-minute quadrangle sheets at 1 : 24,000 scale with 10-foot or 20-foot contours are ideal. Specifications for large-scale topographic maps to be used for final highway location and design should conform to National Map Accuracy Standards. Particular importance is attached to the ground control survey. Monuments are carefully planned. It is generally advisable to have monuments at intervals of 1,000 to 2,000 feet in urban areas and not more than one-half mile in rural sections. Standards of horizontal accuracy for ground control surveys conform to the ACSM American Congress on Surveying and Mapping Control Surveys Division *Policy on Highway Surveys*. The use of aerial survey methods as described has resulted in substantial savings in time, money, and manpower.

Funk, L. L., "Photogrammetric Map Accuracy", *Photogrammetric Engineering*, June 1958

Abstract: The past few years have seen widespread acceptance of photogrammetry as a means of obtaining large-scale topographic maps for the design of major highways. For this purpose the maps must have sufficient horizontal and vertical accuracy so that the highway, designed from the maps, will fit the actual terrain. At the present time photogrammetric mapping is an expanding, highly competitive field; there is a shortage of trained personnel at the higher levels. The paper describes the work of the California Division of Highways in making a statistical analysis of the vertical accuracy of photogrammetric mapping obtained under contract. The information is derived from a comparison of field elevations with elevations interpolated from contour maps. The data developed for each project include the arithmetic mean, standard deviation, calculated C-factor and a comparison of the frequency distribution with the theoretical error or probability curve. Analysis of some twelve projects shows general conformity to error theory and indicates that present specifications are adequate from the practical standpoint. There is nevertheless strong reason to question their basic soundness. Many highway engineers want greater accuracy than is afforded by specifications which permit the horizontal shift within the permissible horizontal error. Effective checking of maps must include tests in every model. Experimental work by the California Division of Highways has indicated that checking with a stereo plotter might be the most satisfactory solution. Investigation of map errors should lead to methods of preventing them and result in increased map accuracy. As projects designed from photogrammetry are staked for construction, they afford a convenient, inexpensive source of information concerning map accuracy.

Lyddan, R. H., "How Much Topographic Detail", *Surveying and Mapping*, January-March 1954

Abstract: The readiness with which a map can be understood is definitely a measure of its quality, or the expertness of the map-maker. The understanding of a map, in turn, is a measure of its readability. Map-makers are prone to see the problem of readability through their own eyes rather than through the eyes of the map users, who may be a lot less adept at reading maps and extracting information from them. A specific study of the readability of maps is suggested, on a scientific basis, to determine whether definite changes are in order better to accommodate the map user. A comparison is made, in the paper, between the appearance of maps made in the United States and those published in Europe. The French, Swiss and, to some extent, British maps appear to show a greater quantity and variety of information. While mapping costs, in general, increase with the gathering and publishing of more map detail, there might be an opportunity to lower costs by greater use of symbols and less use of contours to show special features. It is pointed out that European maps, in general, show much larger contour intervals than do United States maps. The larger contour interval permits the showing of more planimetric detail. The author notes a trend towards a less rigid attitude in the use of small contour intervals in the United States. A systematic study of the use of maps and the reactions of the "consumer's choice" should yield very beneficial results to map-makers.

Marsden, L. E., "Shortcomings of Contour Lines", *Surveying and Mapping*, April-June 1955

Abstract: Many means have been devised for showing the shapes of the ground on topographic maps; so far, contour lines are the most versatile and the most widely used means for this purpose. The extent to which contours are successful in showing shapes of the landscape depends largely on the fidelity of drawing and the selection of the contour interval. Contour lines, when used alone to portray relief, have many shortcomings. Small, but prominent, features, for example, which fall between contours, or intersect only one contour, cannot be shown satisfactorily. Some examples of deficient representation of shapes by the use of contours are discussed in the case of terraces, hilltops and saddles, cliffs, broken terrain and areas of extreme relief. A combination of hachures, contours and relief shading, and the use of special symbols to augment contour lines have been developed by European map-makers to give a better pictorial representation of the ground. New methods of depicting relief should be adopted when it can be demonstrated that they improve the quality of the map. Special symbols are one of the practical means for representing some types of topographic features, without adding appreciably to cost. If symbols can be used to show features now shown through the use of small contour intervals, larger contour intervals could perhaps be adopted, thereby reducing the over-all costs of mapping.

Panel, American Congress on Surveying and Mapping, " Selection of Contour Intervals ", *Surveying and Mapping*, October-December 1952

Abstract: The critical relationships between scale, contour interval, accuracy and cost are discussed by five experts as these relationships apply to several particular types of maps or surveys.

In special-purpose mapping, the accuracy may be far above, equal to, or far below standard accuracy. The scale and contour interval may have a completely unorthodox interrelationship. Maps for the construction engineer, on the other hand, must generally be of large scale with one-foot, two-foot or five-foot contours and must be of at least standard accuracy. Because general-purpose maps, such as topographic maps, are made for a variety of uses, the scale, contour interval and accuracy must be more or less standardized.

A practical answer to the problem, in each case, is to make each map adequate for the purpose intended, at the lowest possible cost. For sound economy, the smallest scale, the largest contour interval and the lowest accuracy that will provide the necessary data should be specified.

Reference Guide Outline, Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, United States Bureau of Public Roads, 1956

Abstract: This publication, prepared by the Photogrammetry for Highways Committee, a joint committee of the American Society of Photogrammetry and the American Congress on Surveying and Mapping, is intended as a guide for highway engineers in the writing of specifications for aerial surveys and for mapping by photogrammetric methods. The specifications cover the procurement of such items as aerial photographs, ground control surveys, topographic and planimetric maps, profile and cross sections, spot elevations and horizontal positions. The specifications are intended as an outline or guide, and are subject to modification by the user to fulfil his special requirements.

The specifications are divided into two parts. Division I, General Requirements and Covenants, is legal or administrative in character and covers those items which are generally applicable to every type of contract for aerial photography or mapping by photogrammetric methods. Division II, Item Specifications, contains the sections of item specifications. For each item to be obtained, the guide provides a description of the item, specifies the materials to be used, outlines the requirements and stipulates the method of measurement and the basis of payment.

THOMPSON, M. M. and DAVEY, C. H., " Vertical Accuracy of Topographic Maps ", *Surveying and Mapping*, January-March 1953

Abstract: This paper suggests that a full understanding of the real meaning of American vertical accuracy standards ought to become more general. There is a widespread notion among map-makers that the first part of the accuracy specifications, adopted in 1941, that " not more than 10% of the elevations tested shall be in error more than one-half the contour interval " is the whole specification. This notion should be corrected; the second part of the specification which deals with the effect of horizontal displacement within the permissible horizontal error for a map should be axiomatic knowledge to those who are concerned with map accuracy. A discussion of basic concepts of accuracy in terms of " standard deviation " is given as well as the mathematical expression for its derivation. A table of allowable standard deviations for commonly used contour intervals is derived. Also, a comparison is made of the application of the present accuracy specification with that of an equivalent stated in terms of standard deviation. Further analysing the true meaning of standard deviation as measure of map accuracy, tables are again computed for vertical tolerances, taking into account the allowable horizontal shift. The effect of the allowable shift on the vertical tolerance is strikingly obvious, and becomes more and more important as the slope of the ground increases. A comparison of American standards of vertical accuracy with British and German standards—French data were not available at the time—is presented for the purpose of determining any significant differences in the respective approaches on the subject. It is concluded that the British 1 : 25,000 maps with 25-foot contour interval are approximately comparable to the common American 1 : 24,000 maps with a 20-foot interval. Official German specifications are not given for 1 : 25,000 maps. Schwidefsky [2] presents data which lead to the conclusion that the German theoretical tolerance is almost identical with the American.

It is concluded that we need to re-examine the language of our present accuracy specification with the goal of making it more scientific, and more in line with universal practice.

THOMPSON, M. M., " How Accurate is that Map? ", *Surveying and Mapping*, April-June 1956

Abstract: Different map users employ different criteria for establishing the quality of a map. The fisherman considers a topographic map of a local area to be accurate on a set of values that are different from those of, for example, an engineer using the same map for laying out a road. Faced with the economic facts of planning or executing a mapping operation, map-makers must have accuracy specifications that are clear, informative and scientific. This paper examines methods of specifying map accuracies for the purpose of seeing what changes, if any are necessary, may be advocated for providing clearer or more precise specifications. No increases or decreases in accuracy are considered. The paper describes the principal components of map accuracy: (1) accuracy of factual information, (2) horizontal accuracy and (3) vertical accuracy.

Part of the problem of defining map accuracy is the problem of accuracy checking. In order that a clear picture of accuracy can be established, the checking procedure should: (1) be uniform; (2) have a higher order of accuracy than the compilation procedure; (3) be extensive enough to provide a statistical analysis and (4) be chosen so as to represent the over-all quality. Among the conclusions reached are: (1) that horizontal and vertical accuracy should be expressed in scientifically-accepted language—the standard deviation, or root-mean-square error; (2) that "allowable horizontal shift " should be replaced by a term which includes vertical accuracy as a function of ground slope, and (3) that accuracy-checking procedures should be standardized and made a part of the accuracy specifications.

[2] K. Schwidefsky, *Grundriss der Photogrammetrie* (Bielfeld, 1950).

Topographic Instructions of the United States Geological Survey

Abstract: The Topographic Division of the United States Geological Survey is primarily responsible for preparing maps in the National Topographic Map Series. This manual of topographic instructions is a guide to members of the Division in the preparation of maps of this series to prescribed standards. It serves also as a textbook for the new employee during his training period.

Detailed and comprehensive instructions are given for all phases of the work in the four following broad divisions: Book 1, General Policies, includes a table of contents and general specifications and procedures; Book 2, Control Surveys, includes instructions for triangulation, transit traverse, geodetic levelling, supplemental control, and processing of control-survey data; Book 3, Mapping Procedures, covers map contents, photography, photogrammetric mapping, and field mapping and completion surveys; and Book 4, Cartographic Procedures, covers colour-separation drafting, scribing, map editing and checking, and compilation of small-scale maps. In addition, there are two supplemental books: Book 5 contains pertinent physical, mathematical, surveying and cartographic tables; and Book 6 contains such reference information as definitions, a glossary of topographic forms, and descriptions of projection, grid and public-land survey systems.

Within each book a chapter has been assigned for each topic considered appropriate. The chapters are issued individually, as prepared, for insertion in loose-leaf notebooks. Revisions can thus be made to the individual chapters as needed.

WHITMORE, G. D., " Contour Interval Problems ", *Surveying and Mapping*, April-June 1953

Abstract: At the 1952 meeting of the American Congress on Surveying and Mapping, a symposium on the subject " Selection of Contour Intervals " was presented. Although many important considerations were brought to light during these discussions, no specific conclusions were reached and there was no summary discussion. As the symposium is considered a matter of unfinished business, the author of this paper was requested to review the symposium papers and prepare a summary. The principal questions that seem to be bothering both the special-purpose mappers and the general-purpose mappers have been arranged in a series of ten questions and answers. Certain solutions or courses of action are suggested with respect to the ten questions. Following is a list of some of the topics discussed: 1) difference in criteria used in selecting contour intervals for general-purpose versus special-purpose maps; 2) optimum contour intervals for general-purpose maps; 3) practicability of using several basic contour intervals on general-purpose maps in accordance with ground slope; 4) use of supplemental contour intervals for the flatter slopes of map sheets, regardless of type of terrain; 5) are American accuracy specifications for contours for general-purpose maps satisfactory?; 6) are American accuracy standards for contours more or less stringent than European specifications?; 7) should contour accuracy specifications be more stringent for flat terrain?; 8) should contour accuracy specifications be modified for steep slopes, where contours are crowded?; should there be different criteria in standard specifications for contour accuracy on special-purpose maps?; 10) classification of four categories of contours generally recognized and used in the United States.

Part II

SELECTED PUBLICATIONS RELATING TO TECHNIQUES AND METHODS USED IN THE PRODUCTION OF TOPOGRAPHIC MAPS IN THE UNITED STATES

ALTENHOFEN, R. E., " Photogrammetric and Field Scribing ", *Photogrammetric Engineering*, December 1956

COMPTON, M. E., Jr., " Surveying with the Velocity of Light ", *Surveying and Mapping*, July-December 1954

FITZGERALD, G., " New Reconnaissance Maps of Alaska ", *Surveying and Mapping*, October-December 1952

FITZGERALD, G., " Helicopter Revolutionizes Topographic Mapping of Remote Areas ", *Surveying and Mapping*, January-March 1955

FUECHSEL, C. F., " Recent Developments in Negative Scribing ", *Surveying and Mapping*, October-December 1953

FUECHSEL, C. F., " Scribing Today ", *Surveying and Mapping*, July-September 1954

HARING, W. F., " Improving the Accuracy of Altimetry ", *Surveying and Mapping*, July-September 1955

HOUGH, F. W., " The Tellurometer — Some Uses and Advantages ", *Surveying and Mapping*, July-September 1957

JOHNSON, Q. S., " ERDL Developments in Plastic Scribing ", *Surveying and Mapping*, January-March 1956

KOSOFSKY, L. J., " Investigation of an Integrated Mapping System ", *Photogrammetric Engineering*, June 1958

LOVING, H. B., and MUNDINE, J. E., " Mapping Alaska's Brooks Range ", *Surveying and Mapping*, July-September 1957

MAHAN, R. O., " The Photo-Contour Map: A Topographic Map at Accepted Accuracy Standards where Planimetric Detail is Provided by the Aerial Photographic Image ", *Photogrammetric Engineering*, June 1958

MALTBY, C. S., " Alidade Development in the Geological Survey ", *Surveying and Mapping*, April-June 1954

MCMILLEN, H. J., " An Operational Report on Stereo-Templets ", *Photogrammetric Engineering*, September 1957

PECKINPAUGH, C. L., Jr., " The Zeiss Opton NI-2 Automatic Level ", *Surveying and Mapping*, April-June 1954

SCHER, M. B., " Stereotemplet Triangulation ", *Photogrammetric Engineering*, December 1955

Topographic Instructions of the U.S. Geological Survey.

ALTENHOFEN, R. W., " Photogrammetric and Field Scribing ", *Photogrammetric Engineering*, December 1955

Abstract: The Atlantic Region of the United States Geological Survey, first to convert from drafting to scribing, will extend the benefits, especially that of cost reduction, by introducing scribing into photogrammetric and plane table compilation practices.

Although scribing a stereocompilation was begun on coordinatograph type plotters, instruments with pantographs were also found adaptable by pencil drawing directly on the painted plastic sheet to develop a scribing guide.

Field completion of topo maps by scribing offers the topographer numerous advantages. The procedure results in an increase in quality, production and economy of topographic mapping. Other tasks made easier by scribing include photogrammetric and field revision of old maps and field contouring of planimetric bases and controlled mosaics.

COMPTON, M. E., Jr., " Surveying with the Velocity of Light ", *Surveying and Mapping*, July-September 1954

Abstract: A device of revolutionary nature in the field of geodetic control is currently being evaluated by the Engineer Research and Development Laboratories. This device is the work of Dr. Erik Bergstrand, a Swedish geodesist. Beginning in 1941 Bergstrand investigated the method of Fizeau for measuring the velocity of light, applying modern electronic techniques. In 1948 Bergstrand produced his first distance-measuring instrument; later, it was redesigned by the AGA Gasaccumulator Company of Stockholm, Sweden, for commercial production. The device is designed primarily for the determination of geodetic distances, such as precise base lines used in triangulation; it may be used under special conditions for surveying by trilateration. The distance is

obtained by determining, indirectly, the time interval for the wave front of a light beam to travel from the geodimeter to a distant mirror and return. Under reasonably good visibility conditions, 20 to 30 miles can be measured; under excellent visibility conditions, 40 to 50 can be measured. Basic principles of the geodimeter are discussed. Measurements conducted thus far by the Surveying Branch, Engineer Research and Development Laboratories, show a probable error ranging from 1/500,000 to 1/4,000,000. The instrument, as it now exists, can measure with an accuracy comparable to any known method and with an enormous saving of time and manpower.

FITZGERALD, G., " New Reconnaissance Maps of Alaska ", *Surveying and Mapping*, October-December 1952

Abstract: The completion of reconnaissance topographic maps at 1 : 250,000 scale covering the entire territory of Alaska marks an important milestone in American cartographic history. From 1898 to 1940 most of the topographic maps in Alaska were made principally by field surveys by the plane table method to produce maps at 1 : 250,000 scale which carried contour intervals of 200 feet. As field work can be carried on only for about 100 days, the topographer used every means to expedite his work. Photo-topographic methods were used as early as 1905 to supplement the plane table for reconnaissance mapping. During 1939 and 1940 the multi-lens camera of J. W. Bagley was used to obtain reconnaissance mapping coverage of parts of the Tanana Valley and the area between Nenana and McGrath. The Wilson photo-alidade was developed before the Second World War and was used to map from terrestrial and oblique photographs; it played an important part in the development of the Trimetrogon mapping method. After the beginning of the Second World War, all mapping in Alaska was concentrated on the compilation of aeronautical charts from Trimetrogon photography. In 1947, the Geological Survey began a uniform series of 1 : 250,000 maps to replace the forty sheets of various sizes which were for the most part unjoined and unadjusted to the standard North American datum. The entire compilation programme is being carried out by the Rocky Mountain Region in Denver, Colorado. The new reconnaissance maps will provide full coverage for Alaska, for planning of defence and transportation routes, and will serve as a base for geologic studies and mineral inventory until more detailed maps are required.

FITZGERALD, G., " Helicopter Revolutionizes Topographic Mapping of Remote Areas ", *Surveying and Mapping*, January-March 1955

Abstract: Six years of experience in using the helicopter on surveying by the United States Geological Survey has revolutionized the topographic mapping of rugged and remote areas. It has enabled the field topographic engineer to keep pace with the rapid advance of aerial photography and stereoplotting instruments. In the spring of 1948, the Geological Survey set up an experimental project in Colorado to test the use of the helicopter in surveying and mapping. The results proved that a satisfactory substitute had at last been found for the pack trains of the Old West. Mapping with helicopters has since been carried on over most of south-eastern Alaska, a large part of central Alaska, and over extensive areas in the United States. The paper concludes that use of the helicopter on surveying has clearly demonstrated that this method yields substantial savings in field costs and greatly increases the speed of mapping extremely difficult terrain.

FUECHSEL, C. F., " Recent Developments in Negative Scribing ", *Surveying and Mapping*, October-December 1953

Abstract: In recognition of the noteworthy surge of interest in negative engraving or scribing and its broadening field of application, the Cartography Division of the American Congress on Surveying and Mapping devoted its entire programme at the thirteenth annual meeting of ACSM, held in March 1953, to a complete coverage of this timely subject. Representatives of six United States Government mapping agencies who have objectively examined both scribing and drafting processes participated in a panel discussion and presented papers summarizing the views of their respective agencies regarding the relative merits of the two processes.

This paper presents a cross-section of the facts and opinions expressed by the panel members, with slight modifications to account for subsequent developments. The main advantages of the process are discussed, as well as the several problems facing users of the process. Many base materials have been tried, but the trend is towards glass, fibreglass, or vinyl-glass laminate. In coatings, the preference is for opaque yellows and reds applied by spraying. The trend is towards darker guide-copy emulsions and negative copy. There is an open field for the development of new scribing instruments as well as of a wide variety of short-cut aids throughout the process.

FUECHSEL, C. F., " Scribing Today ", *Surveying and Mapping*, July-September 1954

Abstract: In an earlier paper the author presented a summary of the developments prior to mid-1953 by American mapping agencies in the field of negative scribing. The present paper outlines the present status of the scribing process, the new developments in this field, and the progress made in overcoming the obstacles discussed in the previous paper.

There is rather general agreement that the scribing process, as compared with pen and ink drafting, makes possible substantial savings in operating time and cost, better quality of reproduction, and simplification of revision and correction processes. On the other hand, while coating processes have been improved, they are not yet foolproof. Lettering and stickup pattern applications are not yet as convenient as those used in drafting methods. Mylar, a recent introduction, shows promise for use as a base material. Great opportunities exist in the field of instrument development although much has been accomplished in the recent past.

The Geological Survey is experimenting with the application of scribing at stereocompilation and field-survey stages.

HARING, W. F., " Improving the Accuracy of Altimetry ", *Surveying and Mapping*, July-September 1955

Abstract: Because of its time-saving and cost-saving features, altimetry continues to receive attention as a method which may permit greater accuracies than are generally obtained, provided proper corrections are made. In the quest for higher accuracies, one of the fields for investigation is the study of the vagaries of the atmosphere.

The use of the altimeter itself, rather than that of the thermometer and psychrometer, to determine the true average air density over the area is explained and is recommended. The average air density thus determined should then be corrected, by the methods explained, to allow for the manner in which the air density at any particular level deviates from the average density of the column. A second correction, to allow for the tilt of the equal-pressure plane from the horizontal, can be determined and applied, provided the multiple-base system is used.

HOUGH, F. W., " The Tellurometer — Some Uses and Advantages ", *Surveying and Mapping*, July-September 1957

Abstract: The age of electronics has recently produced for the surveyor a new and practical facility, the tellurometer, which employs radio waves in the measurement of distance. Extensive field tests in South Africa and in England, over lines of known geodetic length, show that the system will measure distances of from 10 to 35 miles with an accuracy of one part in 200,000. Distances between 300 feet and 10 miles and between 35 and perhaps 100 miles may be measured with reduced accuracy. In a demonstration of the measurement of an 8-mile line near Rockville, Maryland, a " rough " reading, obtained in less than 90 seconds after initial set-up, was 2.5 feet in error (one part in 16,000). After final computations of fine readings, the error was reduced to 0.06 metre (one part in 213,000).

The principal advantages of the tellurometer, as compared with other electronic distance-measuring devices, are that it can be used in day-time because it employs radio rather than light rays

and that optical visibility is not required. Some of the practical uses of the instrument are (1) for traverse in rough or brush country; (2) for location of photogrammetric control points (picture points), employing two master units on steel towers and roving remote units; (3) for determination of supplemental base lines to strengthen triangulation figures; (4) for occasional trilateration as a substitute for triangulation when continued bad weather delays progress and (5) for night-time determination of locations of artillery and guided missile installation.

JOHNSON, Q. S., " ERDL Developments in Plastic Scribing ", *Surveying and Mapping*, January-March 1956

Abstract: The Map Compilation Branch of the Engineer Research and Development Laboratories (ERDL) has been actively engaged in the development, design, testing and evaluation of equipment and techniques used in colour-separation drafting by the plastic scribing process. The objectives were the adaptation of the process for military mapping and the development of instruments, accessories and supplies which would meet military requirements.

Sets of scribing equipment were prepared and tested both in the field and at ERDL. The field tests were uniformly favourable. The investigations carried out at ERDL covered climatic tests, coating and base performance tests, instrument wear tests, operational evaluation and engineering design studies.

These tests indicated that one major shortcoming in available tools was their dependence on the operator for correct hand pressure. Spring-loaded scribing tools were developed to overcome this difficulty. This improvement, in turn, made possible the redesigning of cutting points to obtain maximum visibility and minimum cutting pressure. Studies are being continued on coatings, base plastics and on a photochemical system for etching letters and symbols into the base coating.

KOSOFSKY, L. J., " Investigation of an Integrated Mapping System ", *Photogrammetric Engineering*, June 1958

Abstract: This paper reports progress on a continuing investigation of an integrated mapping system conceived around the profile scanning of the stereo model. Experiments and critical examination have narrowed down the selection of some elements of the system. Other experiments which are planned or in progress are described.

The purpose of the proposed mapping system is to extract all information needed for map compilation by examining the stereoscopic model just once, in a systematic scanning manner, and extracting the following products : 1) plot contour information; 2) orthographically positioned photographic detail and 3) store profile data for making terrain relief models. It is believed possible that automatic terrain-following equipment can be developed to reduce some of the mapping operations which now require human judgement.

LOVING, H. B., " Twin Photography for Mapping Alaska's Brooks Range ", *Surveying and Mapping*, July-September 1957

Abstract: During 1955 and 1956 the United States Geological Survey accomplished the planning and execution of precision twin-oblique photography for mapping the 120,000-square mile Brooks Range area of Alaska. The flight plan, based on considerations of weather, final map specifications, and availability of control, resulted in 22 east-west transverse twin-oblique compilation flights at 30,000 feet above mean ground, spaced 14 miles apart. North-south cross flights at intervals of about 40 miles were made in those areas which might have presented unusual control difficulties.

Poor weather, smoke, summer snowstorms and camera malfunctioning caused principally by the large temperature range of 185° were among the major difficulties attending this project.

MAHAN, R. O., " The Photo-Contour Map: A Topographic Map at Accepted Accuracy Standards where Planimetric Detail is Provided by the Aerial Photographic Image ", *Photogrammetric Engineering*, June 1958

Abstract: A photo-contour map is a topographic map whereon the elevations are shown by contours in the conventional manner, and planimetric detail is photographic as projected from the aerial perspective. This type of map has unique advantages, the most important being its versatility. Scale problems are, however, difficult. Mosaics have in general been unsatisfactory when terrain relief is significant. A method of overcoming these problems is presented. A theoretical discussion is included. The method of zone reformation whereby the projection of the aerial perspective meets topographic map accuracy standards for scale and for orthographic characteristics is described. Zone masking and exposing techniques made possible by advances in masking and low-shrink materials are discussed.

MALTBY, C. S., " Alidade Development in the Geological Survey ", *Surveying and Mapping*, April-June 1954

Abstract: Despite the fact that plotting from aerial photographs has largely supplanted plane table sketching, the plane table continues in active service in the Geological Survey for such purposes as contouring areas too flat to map from photographs and for establishing supplemental control elevations.

From the simple but dependable and rugged instrument in use 50 years ago, consisting principally of a striding level telescope, a vertical circle and a straightedge, the plane table alidade has been developed through such successive improvements as the substitution of the Beaman arc for the vertical circle, the replacement of spider web crosshairs with a glass reticle, and the recent introduction of the optical-reading principle, to the introduction of the idea of a pendulum-operated vertical circle. The Geological Survey has recently designed a pendulum alidade as a modification of the present alidade. Tests of the shop models indicate great promise for the field tests which will follow.

MCMILLEN, H. J., " An Operational Report on Stereo-Templets ", *Photogrammetric Engineering*, September 1957

Abstract: Stereotemplets are a new development in photogrammetry. While they resemble radial templets, they are basically more accurate since they are prepared from the stereoscopic model obtained from a precise plotting instrument rather than from a single photograph. The use of stereotemplets in production mapping, as well as in small research projects, indicates that the best accuracy, with a minimum of horizontal control, may be expected when the control is located on the perimeter of the project. For the materials and equipment now in use the most satisfactory scale for the stereotemplets is approximately that of the aerial negative. Additional tests are under way which will probably result in the development of materials, equipment and techniques to utilize more fully the inherent accuracy of stereotemplets.

MUNDINE, J. E., " Field Operations for Mapping Alaska's Brooks Range ", *Surveying and Mapping*, July-September 1957

Abstract: As part of the project of mapping the Brooks Range area of Alaska, the Geological Survey, in 57 days work in the summer of 1956, obtained the vertical and horizontal control needed to augment existing control. The vertical control consisted of 1,654 miles of photo-trig traverse in north-south lines 40 miles apart across the entire project. Leap-frog altimetry was run concurrently with the photo-trig traverses to provide checks. The horizontal control consisted of a 140-mile-long arc of triangulation in the eastern part of the project. All stations were marked with ground panels and identification photos were obtained for each station.

All necessary work for the advance field completion phase, including the determination of over 3,000 new place names, was accomplished at the same time.

PECKINPAUGH, C. L., Jr., " The Zeiss Opton NI-2 Automatic Level ", *Surveying and Mapping*, April-June 1954

Abstract: The Zeiss Opton level represents a departure from previous design practice in that it incorporates an automatic tilt-compensating device so that, in use, the line of sight is level even when the telescope is tilted. Levelling of the line of sight is

accomplished by a compensating mirror suspended on wires between the focusing lens of the telescope and the reticle. The suspended mirror acts as a pendulum. Light rays are deflected to it by a fixed mirror in the telescope; the compensated rays are reflected to a second fixed mirror which deflects them to the reticle and the eyepiece.

The telescope design is an innovation in that the body of the telescope is a heavy aluminium casting within which are contained separate tubes containing the objective lens system and the eyepiece system. The compensator and reticle are mounted on heavy projections integral with the telescope body. Instances of sticking of the compensator have been noted during field testing of the instrument. Two suggestions are advanced for eliminating this condition when it occurs during use.

SCHER, M. B., "Stereotemplet Triangulation", *Photogrammetric Engineering*, December 1955

Abstract: Stereotemplet triangulation is a photogrammetric method for establishing supplementary horizontal control positions. It differs from other techniques of radial triangulation in that the stereotemplet is representative of the horizontal plot of a stereoscopic model rather than a single photograph. The method permits the achievement of scale solutions by area and is not restricted to solutions of individual flight strips. The preparation of stereotemplets, options in their design and techniques of their assembly are discussed. The advantages of the stereotemplet over the conventional slotted templet are stated. Several of the scale solutions achieved by the method are presented. It is shown that control requirements are less stringent for stereotemplet triangulation than for stereotriangulation.

Part III

SELECTED PUBLICATIONS RELATING TO RECENT DEVELOPMENTS IN PHOTOGRAMMETRIC PLOTTING INSTRUMENTS IN THE UNITED STATES

BEAN, R. K., "Use of the ER-55 Projector", *Photogrammetric Engineering*, March 1954

BEAN, R. K., "Instrumentation for the Integrated Photogrammetric System of the U.S Geological Survey", *Photogrammetric Engineering*, April 1956

BEAN, R. K., and THOMPSON, M. M., "Use of the Orthophotoscope", *Photogrammetric Engineering*, March 1957

BURNS, J. P., "A Comparison of the Kelsh and Balplex Plotters for Large-scale Mapping", *Photogrammetric Engineering*, March 1958

CRAIG, D. R., "Log Etronics", *Photogrammetric Engineering*, September 1955

CROUCH, L. W., "Performance of Air Force Mapping Cameras", *Photogrammetric Engineering*, September 1955

NORTON, C. L., "The 'Multi': Fairchild's Vertical Reconnaissance Camera Test Equipment", *Photogrammetric Engineering*, June 1955

PENNINGTON, J. T., "Aerotriangulation with Convergent Photography", *Photogrammetric Engineering*, March 1954

RADLINSKI, W. A., "Convergent Low-oblique Photography and its Application to the Twinplex", *Photogrammetric Engineering*, June 1952

RADLINSKI, W. A., "A Reappraisal of Photogrammetric Research", *Photogrammetric Engineering*, June 1957

SOUTHARD, R. B., Jr, Orthophotography—Its Techniques and Application", *Photogrammetric Engineering*, June 1958

WHITMORE, G. D., "Economic Factors in the Integrated Photogrammetric System of the U. S. Geological Survey", *Photogrammetric Engineering*, April 1956

BEAN, R. K., "Use of the ER-55 Projector", *Photogrammetric Engineering*, March 1954

Abstract: This paper discusses the use of the ER-55 projector in the over-all photogrammetric mapping programme of the United States Geological Survey. The principal distinctive feature of the instrument is that the light for projecting the image is condensed by means of an ellipsoidal reflector instead of a condensing lens system as in the Multiplex. The results of a test of a stereoscopic model made with ER-55 projectors using convergent photography flown at 8,000 feet is given: 569 ground control points were measured in the model; all but one point checked within 2 feet; 96 per cent of all points were within one foot. The mean-square-error for all points was 0 77 feet The United States Geological Survey plans to use the ER-55 projector for compilation and stereotriangulation of both vertical and twin low-oblique photography.

BEAN, R. K., "Instrumentation for the Integrated Photogrammetric System of the U.S. Geological Survey", *Photogrammetric Engineering*, April 1956

Abstract: After the Second World War a research photogrammetry section was organized in the Topographic Division of the United States Geological Survey with the objective of exploiting photogrammetry to the fullest. Advances in three major fields in photogrammetry were made: aerial photography, photogrammetric instruments and techniques and standards. The concept of a system was evolved in which all of the elements required for compiling topographic maps more efficiently were considered as part of a unit. It has been possible to exploit the advantages of twin low-oblique photography by developing suitable plotting instruments for compilation and aero-triangulation; these were the ER-55 projector and the twinplex plotter. Simultaneously, the development of new cameras with greatly improved high-resolution low-distortion lenses opened the way for improvement in the photographic and geometric quality of the basic materials of aerial photography. The Survey installed a multi-collimator calibrator for controlling the characteristics of cameras used on Survey projects. A twin low-oblique camera mount, which incorporates a centre-of-gravity suspension, provides for maximum resolution in photographic details. Other recent developments, such as the aspheric plate diapositive printer, the variable-ratio pantograph, the orthophotoscope and stereotemplets, are discussed, among the major results of the research programme, which has led to better photogrammetric instrumentation. The cost of research in this field—less than one per cent of the total for topographic mapping—appears to have been an excellent investment.

BEAN, R. K., and THOMPSON, M. M., "Use of the Orthophotoscope", *Photogrammetric Engineering*, March 1957

Abstract: The orthophotoscope is an instrument for converting perspective photographs to the equivalent of orthographic photographs. Operational research experience with a crude experimental model showed that the system is practical and gives orthophotographs for which the scale is uniform within an acceptable tolerance. An "engineered prototype" orthophotoscope has been constructed and is operating on a production basis. The new instrument and its operation are described and illustrated in detail. Some applications, all having the common requirement of photography on which correct distances can be measured directly, are discussed.

BURNS, J. P., "A Comparison of the Kelsh and Balplex Plotters for Large-scale Mapping", *Photogrammetric Engineering*, March 1958

Abstract: This paper outlines the motivation behind the purchase of the Balplex plotter, discusses whether anticipated benefits were realized and compares the Kelsh and Balplex plotters with respect to ease of operation, maintenance and accuracy of final results.

In conclusion, it is felt that these plotters tend to supplement, rather than compete with, one another. An organization equipped with both types is well prepared to take advantage of the strong points of each, using either vertical or oblique photography, using stereotemplets or stereotriangulation in areas of low or high relief, with a fairly wide range of direct plotter scales

CRAIG, D. R., " Log Etronics ", *Photogrammetric Engineering*, September 1955

Abstract: Log etronics, the application of well-known electronic concepts and components to the exposure of photosensitive materials, now makes possible a photographic printer with provisions for completely automatic " dodging " and control of over-all exposure level. Basic principles and system parameters of the log etronic CP1OS contact printer are described, accompanied by examples of comparative prints. The photographic effect of " dodging " is discussed to establish its role as the sole means for transferring maximum information from negative to print. A preliminary test of plotting precision with log etronic diapositive plates is reported. The importance of log etronics to both the user and producer of aerial photographs is stressed.

CROUCH, L. W., " Performance of Air Force Mapping Cameras ", *Photogrammetric Engineering*, September 1955

Abstract: The paper presents a review of past mapping cameras which have been used operationally by the Air Force for mapping purposes. The relative merits and deficiencies of the cameras are presented. Other components of the photo mapping system are discussed relative to their deficiencies when compared to the mapping cameras. These components consist of the aerial film and the aircraft camera window. It is concluded that, in order to utilize the mapping camera effectively, extreme care must be used in selecting and installing the windows and in the handling of the aerial film.

NORTON, C. L., " The ' Multi ': Fairchild's Vertical Reconnaissance Camera Test Equipment ", *Photogrammetric Engineering*, June 1955

Abstract: The vertical reconnaissance camera test equipment described provides a means of determining with one photographic exposure the optical quality of a functioning reconnaissance camera when that camera is mounted vertically with its weight supported on its trunnions. The main features of this equipment are the high optical quality of the collimators, the vibration-isolation mount, the vertical-camera mounting, and its versatility which allows a high-production inspection schedule to be met while various research projects are being investigated concurrently. The equipment and its facility are described and some of the special projects are discussed.

PENNINGTON, J. T., " Aerotriangulation with Convergent Photography ", *Photogrammetric Engineering*, March 1954

Abstract: A method of aerotriangulation with convergent (twin camera) photography is described. This method is applicable to double projection stereoscopic plotting instruments like the multiplex as well as to the stereoplanigraph C8 and Wild autograph A7. The stereopontometer, an auxiliary device designed for use with the multiplex and similar instruments for convergent photo aerotriangulation, is also described and the results of some tests with the multiplex and stereopontometer are given. It is noted that the accuracy of aerotriangulation with convergent photography is of a higher level than with vertical photography under similar conditions.

RADLINSKI, W. A., " Convergent Low-oblique Photography and its Application to the Twinplex ", *Photogrammetric Engineering*, June 1952

Abstract : An excellent and elementary presentation of the significant principles of convergent low-oblique photography and its application to the twinplex. The principles outlined are pertinent to the fields of governmental, military and commercial mapping.

The following is a summary of comparable data between vertical and 20° convergent low-oblique photography:

Characteristic	*Vertical*	*Convergent*
Flight line overlap	60 per cent	100 per cent
Base-height ratio	0.63	1.23
Width-height ratio	1.15	1.27

The ground area covered by convergent photography is six times greater than by vertical photography when the flying height is adjusted on the basis of a 1,000 C-factor for the convergent system and a 600 C-factor for the vertical system.

The advantages and disadvantages of convergent photography are presented in a simple straightforward manner.

The present multiplex projectors have been adopted to compile convergent photography by the addition of a simple inexpensive bracket.

RADLINSKI, W. A., " A Reappraisal of Photogrammetric Research ", *Photogrammetric Engineering*, June 1957

Abstract: Progress in any scientific field is the direct result of research—whether it be basic or practical. Progressive-minded photogrammetrists should therefore be concerned with the status of research in their profession, particularly in view of the fact that a recent survey revealed that three out of four mapping organizations believe the current research effort in photogrammetry to be inadequate. The author presents various data compiled from a research survey and analyses the results. Included in the presentation is a list of research items that the mapping industry feels require the greatest attention, and also some opinions as to what steps should be taken to improve our research activity. As a matter of further interest to all, the three outstanding developments in photogrammetry in the past ten years, based on a consensus of opinion, are named.

SOUTHARD, R. B., Jr., " Orthophotography—Its Techniques and Applications ", *Photogrammetric Engineering*, June 1958

Abstract: A system for producing orthophotographs—photographs which are the equivalent of orthographic photographs—has been developed by the United States Geological Survey, compatible with its integrated photogrammetric system. These orthophotographs, made on the orthophotoscope, have been furnished to field geologists and field topographic mapping personnel for operational testing under varying conditions of terrain, vegetation and field control. Valuable experience is being gained in the proper and economical use of orthophotographs under field conditions. Experimental projects are planned utilizing orthophotographs with superimposed contours and others with spot elevations in areas of interest. A different system of accomplishing the same objective has been developed commercially and reports indicate that it is also very successful. The Geological Survey recently completed the design of a new model orthophotoscope which will allow more efficient and comfortable operation and will yield a much improved product.

WHITMORE, G. D., " Economic Factors in the Integrated Photogrammetric System of the U S. Geological Survey ", *Photogrammetric Engineering*, April 1956

Abstract: This paper describes some of the important changes taking place in the United States Geological Survey map-making procedures. The integrated changes and improvements affect virtually all the major aspects of the topographic mapping operations: aerial photography, photogrammetric instruments, plotting techniques, field operations, cartographic work and map reproduction processes. A review is given of the economic background of the Survey's mapping operations together with a description of some advantages of the new system from the point of view of economic savings. As an indication of the trend, savings of about 30 per cent have been reported in the supplemental ground control phase on projects where convergent photography has been available. Also, savings of approximately one-third have been reported in one regional office in colour-separation preparation by the use of scribing techniques in place of drafting.

AERIAL PHOTOGRAMMETRY IN CHINA[1]

Background paper by Wei-Shu Hwang,
Chief Director, Chinese Society of Survey Engineering

Mapping Methods and Instruments

The aerial cameras first used in China were Zeiss normal-angle ones with focal lengths of 13.5 and 21 centimetres. Later, the Zeiss wide-angle camera with a focal length of 10 centimetres was adopted. After the Second World War, China began to use the American Fairchild K-17 wide-angle camera with a 6-inch focal length.

The mapping methods adopted in the past can be divided into two kinds, namely, stereoplotting and rectification. The former was used in areas with great differences of elevation, while the latter was used in a flat terrain. The instruments first used for stereoplotting were the Wild autograph A2 and the Zeiss stereoplanigraph C4; the Zeiss multiplex was adopted later. Rectifying instruments were the Hugershoff rectifier and the Zeiss SEG C4 and SEG I automatic rectifiers. Rectification was based on four control points for each photograph. After rectification, the photographs were mounted together as a photomap and reproduction was made on blue prints which were used in the field for classification surveying and contouring. The first control points for rectification were located by ground surveying methods and some others were determined by radial triangulation (Zeiss radial triangulator) and stereotriangulation (Zeiss stereoplanigraph and multiplex).

The mapping methods now used in Taiwan are mostly the same as those used in the past, except that stereoplotting is limited to multiplex. In addition to the old German Zeiss multiplex, the American Bausch and Lomb multiplex units are also available. It should be pointed out that simple graphical methods and simple instruments, seldom used in the past, have become standard. Since 1949, the grid method, the vertical sketchmaster and the stereocomparagraph have been used to revise existing maps. As for mapping work in the fields of agriculture and forestry, only the KEK plotter and the Kail radial planimetric plotter are used. The data obtained from both field investigation and photographic interpretation are transferred to the map by means of these two plotters.

Review of Previous Work

Since the adoption of aerial photogrammetry in China, the maps compiled by this method have been very satisfactory to users. Most of such maps have conformed to specifications, except for a few sheets which were less accurate for reasons of economy and other factors.

This compromise has to be made when conditions are such that all the three factors affecting surveying—accuracy, economy and speed—cannot be strictly observed.

For many years aerial photogrammetric work, except for hydraulic, railway, cadastral and engineering surveys, was mostly applied to the making of topographic maps. These were: from 1931 to 1936, mainly 1 : 10,000 fortress maps; in 1937 and 1938, 1 : 25,000 topographic maps; from 1938 to 1948, 1 : 50,000 topographic maps; and, after 1949, they consisted of the revision of existing maps.

The works carried out are set out in tables 12, 13 and 14.

Table 12. China: Aerial photogrammetric work carried out during the period 1931-1942

Type and scale of map	*Number of sheets*
Military	
1 : 10,000	651
1 : 25,000	
Maps	128
Mosaics	68
1 : 50,000	228
Cadastral	
1 : 1,000	121,022
1 : 2,000	1,550
1 : 5,000	153
Railway	
1 : 5,000	302
1 : 10,000	
Mosaics	[a]
Hydraulic	
1 : 10,000	
Maps	19
Mosaics	60 [b]
1 : 20,000	
Mosaics	197
1 : 25,000	20

[a] For 600 kilometres, strips of varying width.
[b] Plus, for 600 kilometres, strips of varying width.

Table 13. China: Aerial photogrammetric work carried out during the period 1943-1948

Type and scale of map	*Region*
Military	
1 : 10,000	
Mosaics	Sixteen cities in north-east China
1 : 1,000,000	China proper
Railway	
1 : 5,000	Szechwan – Hupehi
	Kiangsi – Fukien
Hydraulic	
1 : 10,000	
Mosaics	Yangtze Valley
Maps	Han River
1 : 25,000	
Mosaics	Wei River
	Yellow River
Maps	Yangtze Valley and Wei River

[1] The original text of this paper, submitted by China, appeared as document E/CONF 25/L.28.

Table 14. China: Aerial photogrammetric work carried out since 1949

Type and scale of map	*Region*
Military	
Map revision	
1 : 25,000	Taiwan
1 : 50,000	Taiwan and China (mainland)
Hydraulic	
1 : 10,000	Shih-men Reservoir
1 : 25,000	
Mosaics	Shih-men Reservoir
City planning	
1 : 1,200	Taipei and five towns in Yunlin district
Mining	
1 : 10,000	Miaoli district
Agriculture and forestry	
1 : 5,000	West coast of Yunlin
1 : 10,000	Big Snow Mountain
1 : 50,000	Taiwan

Future Programme

Today a tremendous mapping problem faces China. The 1 : 50,000 topographic maps planned for the whole country have not been completed. In order to dispose more efficiently of manpower, materials and financial resources, China intends to establish a unified organization to undertake the surveying works of the whole country to meet all of its requirements.

With regard to mapping procedures, it is hoped that electronic methods and new instruments will be available to speed up first-order and second-order triangulation. Controls of third-order and fourth-order can be accomplished by the stereotriangulation method with first-order stereoplotting instruments or by analytical methods with stereocomparators. Plotting of details will be carried out by simpler instruments, such as multiplex or even stereotope.

In the past aerial photographs were primarily used for mapping purposes. It is planned to establish an aerial photograph library which will make all available materials accessible to all departments, in order to improve working efficiency by permitting more personnel to analyse and interpret aerial photographs for studies in their respective fields.

THE PRODUCTION OF TOPOGRAPHIC MAPS BY PHOTOGRAMMETRIC METHODS[1]

Technical paper by Dr. W. Brucklacher

Introduction

For topographic purposes especially, complete maps of large areas are required. In general, production of such maps is entrusted only to state survey offices, so that the requisite organization and the considerable amount of highly efficient equipment can be acquired and set up with greater facility than would be the case with private firms, which are often hampered by financial problems. A government surveying office will usually be able to count on the help of various other government institutions; thus, for instance, defence aircraft may frequently be used for photographic flying missions.

From a technical point of view, the compilation of topographic maps of large areas is as much a matter of geodesy, which supplies the skeleton of control points, as of photogrammetry, whose task consists of filling in the control network. In this paper I want to discuss the share of geodesy only to such extent as is absolutely necessary, since others, more competent, will discuss this aspect in greater detail. In particular, I shall try to point out those considerations that are important for photogrammetric mapping.

Definition and Requirements of Topographic Maps

The term " topographic maps " is used to designate maps on such scales as are normally used for the original plotting. Such scales are: 1 : 25,000; 1 : 50,000; 1 : 100,000. Maps on smaller scales are mostly derived from these scales by graphical methods and simultaneous generalization.

Map sheets not materially exceeding 50 by 50 centimetres have proved to be the most convenient and handy size.

Map contents

Topographic maps contain the natural configuration of the terrain—coasts, rivers, lakes, forest boundaries and the like—as well as the ground relief in the form of contour lines. In addition, artificial, man-made objects, such as roads, railways, bridges, settlements, canals, industrial facilities and mines, are reproduced. Only property boundaries are not included in topographic maps.

Depending on the scale of the maps, a choice must be made from the multitude of terrain details. Too many details will make a map confusing and unreadable. On the other hand, appropriate symbols and the use of coloured surfaces, for instance for woods, will considerably simplify the resulting map.

Also, with regard to the selection of appropriate contour intervals, certain limits will be indicated. As is known, topographic maps as used for economic, scientific or military purposes will serve only for general planning. The following contour intervals should be adequate for these purposes:

Map scale	*Contour interval*
1 : 25,000	20 – 25 metres
1 : 50,000	25 – 50 metres
1 : 100,000	50 metres; in mountainous terrain, 100 metres

[1] The original text of this paper, submitted by the Federal Republic of Germany, appeared as document E/CONF.25/L.42.

In flat terrain intermediate contours should be avoided, if possible, since they create a wrong impression of relief. Switzerland, for instance, which is known for its excellent maps, has recently abandoned the inclusion of intermediate contours in topographic maps.

For detailed studies of technical installations, such as dikes and dams, irrigation projects and the construction of roads and railway lines, special large-scale maps may always be made after preliminary studies on the basis of topographic maps. Consequently, it is not necesary to cram topographic maps with details required only for special planning purposes. The reproduction of too many details and the selection of very short contour intervals will only delay the production of the maps and increase their cost. On the basis of these considerations it is not easy to find a limit which will still fulfil the various requirements. However, contrary to classical methods, the photogrammetric technique has a specific advantage which may satisfy the majority of requirements as regards the completeness of the map, which is that the aerial photograph itself contains—up to the limits imposed by the photo-scale—all details actually existing on the surface of the earth, both important ones and less important ones. For this reason, the following solution is suggested.

1. Only the most important details should be reproduced in the map, so that the compilation work can be accomplished quickly and without difficulty, while at the same time excellent readability is achieved;

2. Every map sheet should be supplied with a transparent cover sheet—or at least such a sheet should be made available upon request—containing the photograph centres of all those aerial photos from which the map sheet was plotted.

In case of a special interest in details not contained in the final map, there will then always exist the possibility of calling for the respective aerial photographs and extracting such details by monocular or stereoscopic interpretation. Transferring these details to the existing map will always be possible with the aid of simple graphic methods. In that case, the respective topographic survey need only take the required steps to make such photographs readily available for general use. Such a procedure would considerably accelerate the compilation of topographic maps, while at the same time expensive aerial photographs, with their mass of information, would be made accessible to all interested circles in the fields of economics and science.

Accuracy

The accuracy of a map should correspond to its purpose. Topographic maps are used:

1. For general planning purposes in various fields, such as city planning, traffic planning, economic geography, forestry and the like;

2. For tourist traffic;

3. For defence purposes.

For all these purposes, topographic maps provide certain distance measurements with an accuracy not exceeding approximately one millimetre. A higher order of accuracy is made impossible by such factors as shrinkage of the photographic paper, map symbols greatly exaggerating the actual size of objects, as compared to the map scale, and distortions resulting from the map projection.

It must always be borne in mind that any unrealistic demand for map contents and accuracy will make the final map more expensive, at the same time slowing down production. Therefore, the following accuracy values are suggested: ± 1 millimetre at the map scale over the entire map sheet, and ± 0.3 millimetre as internal accuracy in smaller portions. As compared to areas with a high land value, these accuracy tolerances can be doubled for less densely populated areas, such as woodland and deserts.

For the accuracy of contour lines, half the contour interval should suffice as a limit.

The Compilation of Topographic Maps

The photographic flight

For financial reasons it will be impossible frequently to repeat the flying of the relatively large amount of aerial photography required for the production of a small-scale map of a country. Therefore, the original photographs should also be available for various interpretation purposes, for instance, for forestry, for geological studies, for city planning and the like. For this reason, the following photo-scales are recommended:

Map scale	*Photo-scale*
1 : 25,000	1 : 35,000
1 : 50,000	1 : 45,000
1 : 100,000	1 : 60,000

At the International Congress of Photogrammetry in Stockholm, statistics were published by Commissions I and IV on the photo-scales at present used in the various countries of the world. The photo-scales indicated in these statistics are generally somewhat larger than the values given above.

As mapping camera, a film camera with a negative size of 9 by 9 inches and a calibrated focal length of 6 inches for the production of vertical photography is suggested. This camera should be equipped with a recording statoscope, so that the required photogrammetric vertical control can be determined by aerial levelling.

Both for a subsequent aerotriangulation and for the plotting work, a favourable position of the flight strips and the various models is of great importance. The photographs are best flown in the form of blocks about 50 by 50 kilometres or 100 by 100 kilometres, if possible in the east-west direction. In planning the flight routes, attention should be paid to the distribution of map sheets, so that, if at all possible, the various map sheets are covered by complete flight strips. For a map scale of 1 : 25,000 and a photo-scale of 1 : 35,000, the flight routes can be so arranged that two flight strips exactly cover the entire width of one map sheet.

If the flight strips are flown with 90 per cent end lap and 60 per cent overlap, a series of photographs can be selected for plotting in the various strips, which will give a neatly arranged pattern of models without any undue displacement. This will considerably facilitate the entire work and reduce to a minimum the number of control points required. The production of such 90 per cent overlapping photographs has already been discussed in detail at the seminar in Tehran.

Determination of control points

Terrestrial measurements

Horizontal control points

For the photogrammetric plotting process, horizontal control points are required for every photograph or photopair. In this connexion, photogrammetric procedures have been developed which permit the determination of such points over certain distances with the aid of aerotriangulation. However, geodetic control points on the ground in intervals of about 30-50-100 kilometres are required for the adjustment of such an aerotriangulation. The density of these points corresponds more or less to a first-order geodetic network which would have to be established in the areas to be surveyed. For this purpose, the following methods are available:

1. Classical triangulation with the aid of angular measurements, possibly by means of theodolites with automatic recording of the respective readings;

2. Triangulation with electrical or optical distance measurement, for instance with geodimeter, tellurometer or the like;

3. Astronomical determination of points;

4. Establishment of triangulation chains with the aid of Hiran or Shoran, comparable to Canadian procedures.

As compared with the angular or distance triangulation, the astronomical method has the disadvantage that the full influence of deviations of the vertical is felt. Deviations of 5 to 10 seconds have to be expected. This corresponds to horizontal-position errors of approximately 200 metres. On the other hand, the establishment of networks with the aid of Hiran or Shoran is rather costly as compared with other methods which, in inaccessible terrain, can be considerably accelerated by the use of modern means of transportation and, especially, by helicopters. For geodetic triangulation with the use of angular or distance measurements, one point should be especially emphasized: for the compilation of topographic maps it is not necessary to wait for the rigorous and time-consuming total adjustment of the nets. A first preliminary computation of the results with an adjustment made only in partial networks will be entirely sufficient. As a consequence, the results of a triangulation will be available for the plotting very shortly upon completion of the observations in the field.

Vertical control points

For vertical adjustment of aerotriangulations and especially aerial levelling, vertical control points are required at intervals of approximately 100 kilometres. For this reason it is recommended that lines of levels be placed at such intervals along roads or, in mountainous terrain, along valleys. Whether, in this case, preference is given to trigonometric levelling or levelling with spirit levels will depend on the relief of the terrain. For smaller areas good results can also be achieved with the aid of barometric levelling, if fluctuations in temperature and atmospheric pressure are taken into consideration. For any subsequent engineering project, such as improvements of river channels, construction of irrigation facilities and storage dams, vertical tie-in points are needed. With the aid of automatic levels, such lines of levels can be carried out quickly and accurately.

Aerotriangulation

Aerotriangulation to determine the control points for the photogrammetric plotting process can be carried out according to slotted templet triangulation or spatial aerotriangulation. Whether the first or second method is used will depend on the accuracy required and on the kind of terrain involved.

In flat terrain which will be mapped only by planimetry, the respective ground control points may be determined by the slotted templet method. This will be used exclusively in less densely populated areas, woodland and desert. The slotted templet method is so popular that I need not go into more detail. In the case of blocks 50 by 50 kilometres in size, the following values are applicable:

Photo-scale	*Size of layout (metres)*	*Number of strips*	*Number of photos per strip*	*Total number of photos*
1 : 35,000	1.4 by 1.4	9	16	144
1 : 40,000	1.1 by 1.1	7	12	84
1 : 60,000	0.8 by 0.8	5	9	45

At a separation between control points of " e " metres (at the scale of triangulation and a distance of " e' " metres between any group of points and the nearest control point), the following accuracy will be obtained:

External accuracy: $m_p = \pm (0.4 + 0.6 \cdot e)$ (mm)

Internal accuracy: $m_p = \pm (0.4 + 0.1 \cdot e')$ (mm).

If still higher requirements have to be fulfilled, the stereotemplet method can be employed. The stereotemplets will be obtained automatically in the aerial levelling. The combined method of aerial levelling plus stereotemplet triangulation can be considered as very economical. In this case, the accuracy will be about 100 per cent higher than in the case of the ordinary slotted templet method.

In mountainous terrain requiring the reproduction of relief, a spatial aerotriangulation will be indispensable. Such a triangulation is made with first-order plotting instruments, such as the C8 stereoplanigraph with its co-ordinate recording unit. Complete formulae of second and third power, which for the first time make accurate provision for the required topographic correction in high mountains, have now been set up for the rational adjustment of such aerotriangulations in automatic computers. As was shown in a larger number of experiments, mean horizontal point errors of $\pm 0.75\ ^{0}/_{00}$ of the flight height will be obtained in the case of strips 85 kilometres long and an adjustment of the second power—one control point in the centre of the strip, that is, at a distance of 50 kilometres. The adjustment of a strip of 100 kilometres including the transformation into the system of state co-ordinates takes about two to three hours in a relatively slow relay-type automatic computer. In this case, the accuracy achieved in the various strips is so high that for topographic work the block adjustment can be limited to the determination of mean values of the co-ordinates of common points. As a matter of fact, in cases of special lack of ground control, the method very thoroughly developed by Dr. Jerie for the block adjustment with the aid of an analogue computer can be used to advantage.

For the aerial levelling, that is, the use of statoscope records, vertical control points are required for a vertical adjustment only at the beginning and at the end of the strip, or at distances

of approximately 100 kilometres. For strips of 85 kilometres in extremely high mountains, experiments made in Germany produced mean vertical errors of $\pm 0.6\ ^{o}/_{oo}$ of the flying height when a linear adjustment of the heights was made. If we adapt this value to the conditions encountered in the compilation of topographic maps, the following absolute errors will be obtained:

Flying height	*Mean vertical error (metres)*	*Mean point error (metres)* $m_p = \sqrt{m_x^2 + m_y^2}$
5,200	± 3.2	± 4.0
6,800	± 4.1	± 5.0
9,200	± 5.6	± 7.0

Plotting process

The characteristics of the terrain will largely determine the kind of plotting to be employed.

In flat terrain

In flat terrain aerial photographs may be rectified at the map scale according to the control points determined by triangulation. After that, all the topographic details to be reproduced in the final map are traced with Chinese ink on the rectified prints. Image details may be identified under stereoscopic observation. Once this has been achieved, the map contents thus emphasized in the photographs are transferred to transparent foils containing the control points and the respective values of the corners of the sheets. While the selection and tracing of details in the aerial photographs themselves may be made by topographic personnel, the subsequent transfer to transparent foils can be carried out by draughtsmen. In principle it is also possible to use the scribing method for the fair drawing. This method will produce especially good fair drawings which can be copied directly.

Production of rectified mosaics

Production of rectified mosaics according to the various map sheets is recommended only for map scales up to about 1 : 25,000. With smaller scales, the readability of the mosaics with the naked eye is very limited.

In contrast, mosaic maps can also be produced for smaller scales up to 1 : 100,000. In mosaic maps all important topographic details, such as roads, railways, settlements and the like, are emphasized by map symbols, and woods by imprinting surface colours. An example of such a mosaic map—a combination of mosaic and traced map—shows that this type of map, which can be produced relatively quickly, is very clear and pleasing at the same time.

In hilly and mountainous terrain

In hilly and mountainous terrain the use of third-order stereo plotters is required. If plotters of the stereotope type are employed, the manuscript can be traced directly at the scale of the final map. Rapid progress of the work, from the preparation to the manuscript and the final fair drawing, is achieved by appropriate organization of the various working phases. Each model is plotted on an individual tracing sheet; these are then passed to the compilation section which makes the final maps on transparent foils. Thus, the fair drawing is completed at practically the same time as the manuscript. Furthermore, this procedure makes it possible directly to obtain the colour separations required for the subsequent impression of the map—such as black planimetry, brown contour lines, blue rivers and green woods.

For the revision of the planimetry of obsolete maps in mountainous terrain the stereotope can be used to advantage, since this equipment does not require vertical control points for the respective horizontal orientation.

As regards the plotting of high mountains, it should be stated that in most countries such areas cover only a fraction of the total surface; furthermore, such areas practically always play an inferior role in the economic development of a country. Therefore, they should be left unplotted until the rest of the country has been sufficiently covered. Moreover, the purchase of photographic aircraft should not be obstructed by requirements for an extreme ceiling only on account of these relatively unimportant areas.

CARRYING OUT OF LARGE-SCALE SURVEYS BY AERIAL PHOTOGRAMMETRY [1]

Information paper by the Institut géographique national, France

Introduction

As part of its normal functions the French National Geographical Institute (Institut géographique national) is responsible for the production of the basic topographical map of France and the Overseas Territories, the scale being selected in accordance with the economic development of the area to be mapped. The Institute is therefore mainly concerned with the production of maps on a scale of 1 : 20,000 for France and 1 : 50,000 or 1 : 100,000 for the Overseas Territories.

In response to external demand, however, the Institute has undertaken the preparation of an increasing number of large-scale maps, on scales of 1 : 2,000 to 1 : 5,000. This development is the result of economic, industrial and technical factors.

(*a*) Economic: the higher a country's level of development, the larger the scale that must be used for the basic map. In some parts of France, a comprehensive map on a scale of 1 : 5,000 is now needed and, since partial, unco-ordinated or poorly co-ordinated surveys are not sufficient, such a map can only be made by a state agency.

(*b*) Industrial: users are coming increasingly to realize that modern photogrammetry techniques provide the only consistent, rational and economic solution when major works are to be undertaken; however, these techniques entail the use of expensive equipment and specialized staff that are only available to major state agencies or large private companies.

[1] The original text of this paper, submitted by France, under the title, " L'exécution de levés à grande échelle par photogrammétrie aérienne ", appeared in French as document E/CONF.25/L.48.

(c) Technical: the Institute for its part had no objections to the use of photogrammetry for the production of large-scale maps as no major difficulties were involved. There should in principle be no reduction in the quality or precision of the instruments or the strictness of the methods used in taking the photographs and in preparation and plotting when a small scale is employed; the scale of operations is merely varied in accordance with the degree of precision desired in the final results. Other things being equal, therefore, work on a larger scale has not required the Institute to undertake special research or use special instruments, but has merely demonstrated the general applicability of its equipment and methods.

The trend appears to be both general and irreversible, and, in view of the considerations mentioned, it may be of interest to offer some tentative conclusions regarding possible or probable development. They will indicate to surveyors the important part they have to play in this connexion.

Although it is impossible in photogrammetry to deal with a problem without offering a full conspectus of the different phases of the work, it was felt that the simplest course would be to consider first the adaptation of photography, preparation, plotting and completion techniques to the construction of large-scale maps.

PHOTOGRAPHY

From the photographic point of view, the only problems are the selection of the scale of the negatives and of the focal length of the camera.

Choice of Scale of Photographs

If fine-grain emulsions are used and the optical aberrations of the camera and plotting instrument lenses are precisely determined, the accuracy with which the photographic co-ordinates of a point are measured with a first-order plotting instrument—about 20μ[2]—is much greater than the graphical error of a map—approximately 1/10 millimetre. If, therefore, a stable emulsion support, preferably a plate, is used, and the distortion of the *lenses employed* is accurately measured, a map/negative enlargement ratio of about 5 can be adopted—provided all that is wanted is a planimetric map, as is usually the case for cadastral survey, reapportionment of land, reconstruction and similar purposes. Thus, in the case of a trial made in the Nièvre in 1955 on the basis of coverage on the 1 : 10,000 scale, the mean horizontal accuracy at the control points was 0.12 metre—much higher than that of a map on the 1 : 2,000 scale.

If heights are to be plotted, the enlargement ratio must be between 2 and 3; for a given scale, particularly a large one, the requirements as regards spot heights are as a rule much stricter than as regards horizontal plotting. In most cases the indication of relief by contours obtained by photogrammetric plotting should be dissociated from the determination of highly accurate spot heights, for which precision ground levelling is necessary, as exact heights cannot be obtained without an accurate ground survey.

As an indication of the possible alternatives, table 15 shows the photo-scales (Ph.S.), plotting scales (P.S.) and contour intervals (Int.) in work recently carried out at the National Geographical Institute on a scale of 1 : 5,000 or greater.

Table 15. Photo-scales, plotting scales and contour intervals in recent work at French National Geographical Institute

Area	*Ph.S.*	*P.S.*	*Int. (metres)*	*Ph.S./P.S.*
Territory of the Saar	1 : 12,500	1 : 5,000	5	2.5
Route of the southern motor expressway	1 : 8,000	1 : 2,000	2	4
Donzy town plan [a]	1 : 6,000	1 : 2,000	1	3
Alpine valleys	1 : 15,000	1 : 5,000	2.50	3
Motty reservoir [b]	1 : 15,000	1 : 5,000	2.50	3
French Guiana [c]				
Cayenne	1 : 8,000	1 : 2,000	1	4
St.-Laurent du Maroni:				
Town	1 : 5,000	1 : 2,000	1	2.5
Environs	1 : 10,000	1 : 2,000	1	5
Gabon				
Libreville [d]	1 : 10,000	1 : 2,000	1	5

[a] *See* figure 29.
[b] *See* figure 30.
[c] Undertaken for the Ministry of Reconstruction.
[d] Undertaken for the Cadastral Survey Service.

The variety of the types of work undertaken is noteworthy: a Basic topographic map on a scale of 1 : 5,000; a survey of the route of a motor expressway; town plans; maps of flood-damaged valleys; a map for the construction of a dam, and a cadastral type survey. This variety of purpose explains the different contour intervals chosen and the different ratios of photo-scales to plotting scales.

Choice of Camera

The choice of camera focal length depends mainly upon which of two opposing considerations is given the more weight. When wide-angle cameras of short focal length are used, the precision of plotting is greater both horizontally (since the model can be made on a larger scale) and vertically (since the base/flight altitude ratio is greater for a given format); on the other hand, it may be difficult to take photographs at low altitudes (difficulties of navigation and maintaining straight and level flight). This is why the National Geographical Institute has selected cameras with a focal length of 210 millimetres and 300 millimetres instead of the usual 125 millimetres for some projects; the format of the negative remains 19 by 19 centimetres (as in the photographs for the cadastral survey).

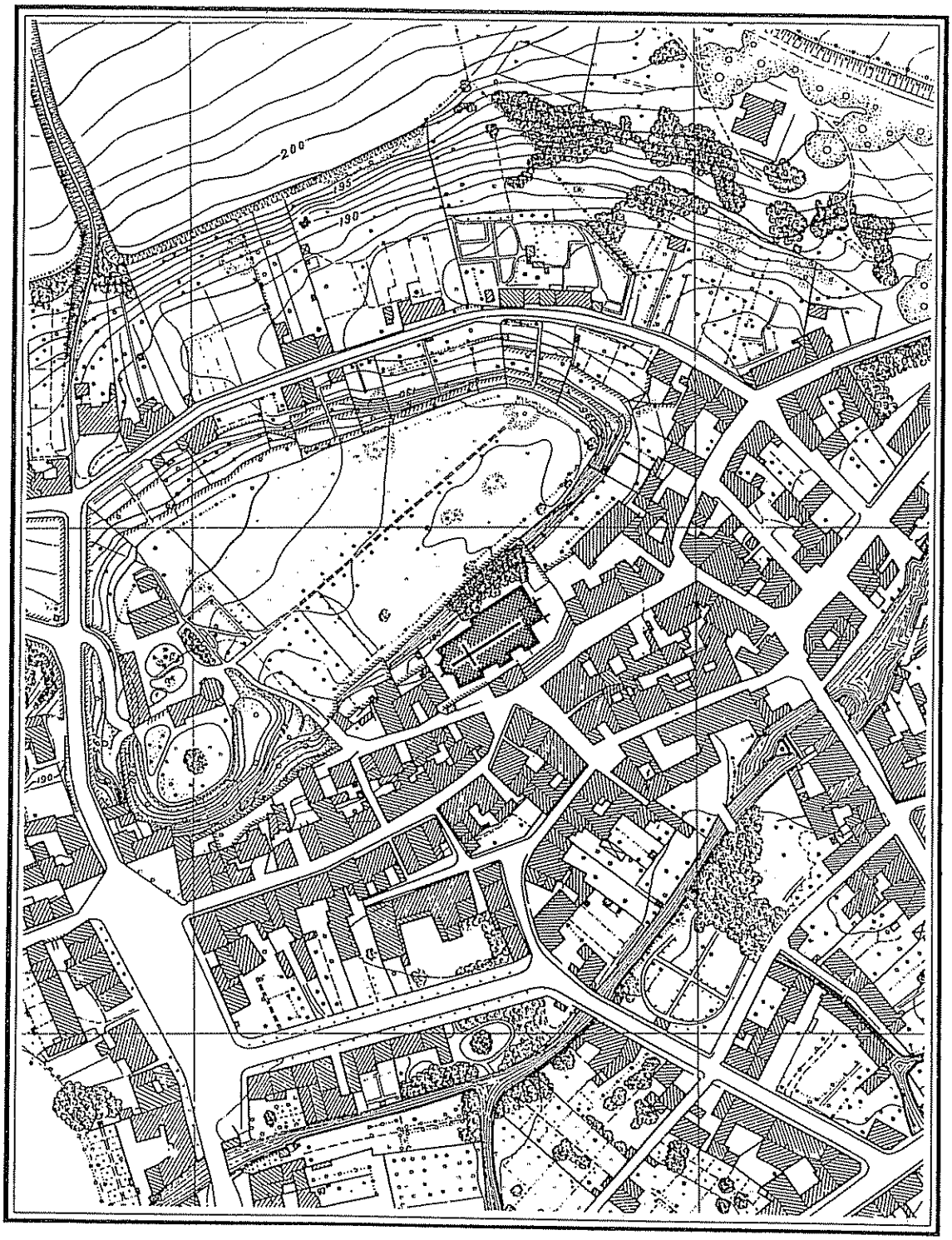
However, in taking photographs for large-scale maps, certain technical problems which have not yet been completely solved assume great importance, such as the fidelity of reconstitution of the perspective rays. High definition in the photographic image of a point, minimum deformation of the emulsion support and thorough knowledge of the distortion under working conditions are therefore required.

PREPARATION

General Observations

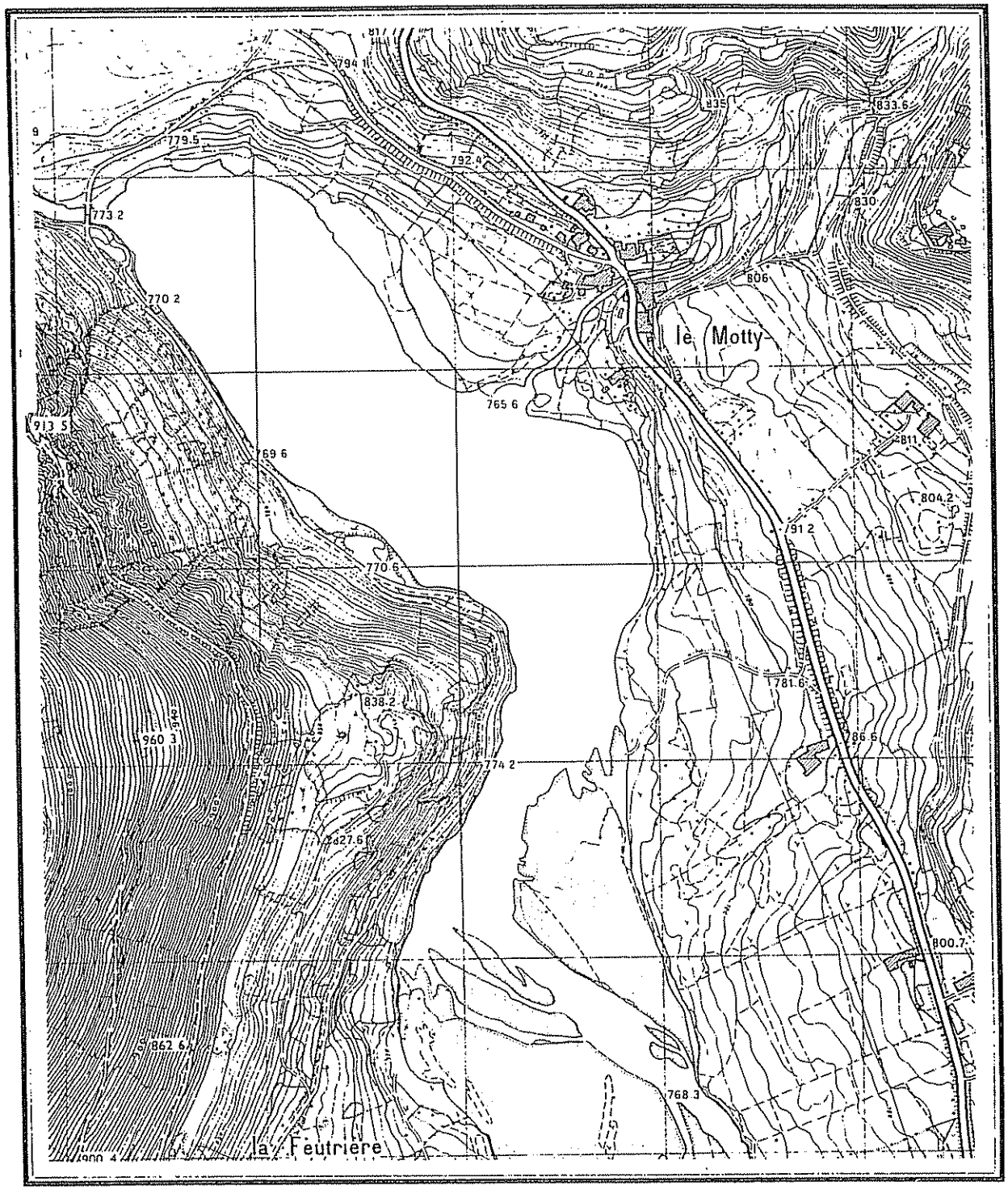
Are photogrammetric preparation techniques generally applicable to the construction of large-scale maps? Here again, since the only difference is that the graphic error on the

[2] This estimate takes into account all sources of possible error in plotting a point with a first-order instrument (definition of the picture, interior and exterior orientation of the perspective rays, and optical and mechanical adjustment of the instrument).



DONZY - EXTRACT FROM THE 1:2,000 STEREO-TRACING
(Plotting without completion)
Photographic reduction: approximately 1/5

Figure 29



MOTTY RESERVOIR - EXTRACT FROM THE 1:5,000 STEREO-TRACING

(Plotting without completion)

Photographic reduction: approximately 1/5

Figure 30

ground is smaller, it is sufficient to determine the network of control points with greater absolute precision. Before taking the photographs, therefore, it is expedient to fix a number of points—reference points, end-points, corners of walls, and so on. This, however, presents no particular difficulty.

A more significant factor is the comparative cost of maps made under different conditions. Let us take as an example the following comparison of the total time required to map one hectare by two different methods for a 1 : 2,000 town plan.

First method (rectification of photographs and plotting with a simplified instrument):

	Hours
Office work	1,886
Field work	2,397
TOTAL	4,283

Second method (plotting from photographs with a first-order instrument) :

	Hours
Office work	1,860
Field work	1,185
TOTAL	3,045

Thus, when a first-order photogrammetric instrument is used, the total time, in other words the cost, is substantially less and, more important, the proportion of field work—the more expensive of the two—is reduced considerably.

New Techniques

Every effort should be made, therefore, to cut down field work to a minimum. This can be done in two ways, both of which have been tried out by the National Geographical Institute.

Double photography technique

The procedure is to take two photographs, one on a small scale and the other on the scale used for plotting; to prepare only the small-scale pairs, especially in the horizontal; to orient these pairs in the instrument in order to obtain the points needed for plotting (and, in particular, for reducing to scale) the large-scale pairs; then the co-ordinates of these new points will be read off on the instrument (instead of being surveyed graphically), after which the adjustment to the plotting scale will be calculated from all the reference points.

The town plan survey of Donzy was compiled by this method in the following way:

Preparation on negatives on a scale of 1 : 10,000;

Plotting on negatives on a scale of 1 : 6,000;

Formation of model on a scale of 1 : 4,000;

Plotting on a scale of 1 : 2,000;

Mean horizontal error : 0.12 metre at control points;

Mean vertical error: 0.15 metre at control points.

The preparation/map scale is thus 5 and the errors remain well within the permissible limits of the map to be carried out. In addition to its financial advantages, this technique gives the preparer more latitude in choosing natural points and deciding on the density of the points picked out on the ground beforehand.

Aerotriangulation technique

The aim is to use an aerotriangulation technique to determine the control framework required for map-making from photographs, regardless of whether the next process is rectification or plotting.

An experiment in the use of this technique was carried out in the Yonne in 1955 under the following conditions:

Area: 5,500 hectares;

Photographs taken on a scale of 1 : 10,000 after reference points had been fixed;

Normal preparation of one pair in ten (horizontal accuracy: 0.20 metre, vertical accuracy: 0.30 metre);

Transfer to the instrument and calculation of compensated co-ordinates of control points by the French aerotriangulation technique.

The following results were obtained:

Probable horizontal error: at reference points: 0.28 metre; at control points: 0.44 metre.

Probable error in distances between points (0.5 to 3 kilometres): 0.31 metre.

Probable relative error in distances between control points: 1 : 4,000.

Probable vertical error : at reference points: 0.30 metre; at control points: 0.48 metre.

The aerotriangulation technique has the disadvantage of requiring a first-order plotting instrument, but it also has the following advantages:

The cost of preparation is halved;

The results are independent of the relief and of the regularity of the coverage;

The co-ordinates of any point are determined with constant and essentially uniform precision;

The height of any point needed for subsequent map-making from the photographs or for the establishment of a control point network is determined directly.

In some cases, especially when the three last-mentioned properties of aerotriangulation are not required, the technique can be simplified and reduced to, for example, a radial-line graphical triangulation. Output and economy are further increased, at the expense of uniformity and vertical measurement. The technical problem then is to find an inexpensive and sufficiently precise method of determining the elements needed for rectifying the photographs.

Conclusion

It would appear that, for the compilation of large-scale maps, preparation will increasingly be confined, for reasons of economy and output, to the establishment of a very limited horizontal and vertical reference network and the establishment of precision levelling meshes as a separate operation.

PLOTTING

Selection of Plotting Instrument

The cost of first-order plotting instruments is high and many attempts have been made to reduce equipment costs.

With this aim in view, several simplified instruments have been devised and built.

In practice the use of such methods or instruments entails such extensive checking that the cost is ultimately greater. The plotting problem is solved only very roughly, with the result, first, that the specifications for the photography and preparation are much more stringent; secondly, that it is difficult to dispense with rectification of the photographs—in other words, with the use of an equally expensive instrument; and thirdly, that the lack of uniformity in the map compiled, which has several causes (neglect of the effect of relief on planimetry, mapping from the negatives without use of stereoscopic methods and so on), necessitates additional controls—and the harder the errors are to detect, the greater is the expense involved.

In the experience of the National Geographical Institute, confirmed by the results of the experimental compilation of town plans organized by the International Society of Photogrammetry,[3] the greater the scale of the map the more necessary it is to use a first-order plotting instrument. This will be increasingly the case with the improvement of modern techniques of aerotriangulation; it is equally valid whatever the purpose of the operation—a continuous traverse with a view to the establishment of the map, or numerical plotting to determine co-ordinates for the cadastral survey.

Plotting of Height

Altimetric data have been omitted in some operations because in direct map-making their inclusion would have had a major effect on over-all cost. One of the great advantages of photogrammetry is that it provides contouring and a skeleton map of spot heights without additional difficulty. Apart from cadastral surveys confined to delimiting parcels of land, there are few operations in which altimetry is not at least as significant as planimetry: reconstruction projects, layout of roads and railways, civil or military engineering works and the like.

Adaptation of the Plotting Instrument

However, it was found necessary to make the following modifications to the Poivilliers S.O.M. stereotopograph type B P for use in the compilation of large-scale maps:

Extension of travel on the z axis (extensions) to permit formation of the model on the largest possible scale;

Modification in the form of the floating mark, which is now adapted for taking both precise planimetric sights (the centre of the mark is free) and altimetric sights.

Completion

General Observations

In the compilation of some maps—for example, town maps—a good deal is left to the completion stage: overhanging roofs, the interpretation of details and the like. Although somewhat inexperienced in this field, the National Geographical Institute normally finds post-completion preferable to pre-completion since the ground operator knows what adjustments to make and is not obliged to invent them. This does not preclude some special checking before the photographs are taken, during the preliminary process of fixing the bench-marks or cadastral boundaries.

On the other hand, completion can be dispensed with in some projects where the scale of the photographs permits.

Function of Interpretation

Mention should be made at this point of the function of photo-interpretation; this, however, is feasible only if organized on a national or regional scale. Such interpretation will, for example, make the best use of photographic coverages taken at the same time under different conditions, for instance, when using different scales or emulsions. The cost of such additional coverage is low if several cameras can be operated simultaneously from the aircraft used.

Conclusion

The use of aerial photogrammetry for the construction of large-scale maps appears to be an incontestable advance and the trials made by the National Geographical Institute seem to confirm this. However, before the technique can be taken into general use two basic problems must be solved: first, the practical problem of organization, and secondly, the technical problem of adaptation.

The need to organize operations will be plainly seen on merely listing the advantages of photogrammetry over direct technique (uniformity, speed of execution, output, altimetry chart) and its disadvantage (investment required for the purchase of expensive equipment). As the penalty of modern mechanization, it entails, from the standpoint of the profession as a whole, the thorough revision and recasting of the old organization. It is wholly conceivable and logical that the strictly photogrammetrical part of the operation (photography and plotting) and the field work (preliminary bench-marking, preparation, completion and fair drawing) should now be separated, that is, entrusted to different units. This could bring together, in harmonious co-operation, what must of necessity be large organizations—national authorities or private corporations—and local surveyors' offices. This development would be facilitated by the institution of programmes on a large scale at the national or regional level and in the Overseas Territories.

While photogrammetric methods can be adapted to large-scale map-making, as is demonstrated by the examples described in this report, several technical problems remain to be solved: definition of the photographic image of a point; adaptation of aerotriangulation techniques; use of bench-marking before the photographs are taken for plotting; interpretation of the photographs, and so on. These problems can be solved only with the co-operation of the authorities concerned and of specialists in large-scale map-making. It is consequently incumbent upon surveyors—using the term in its widest sense—to realize the full extent of the resources which photogrammetry puts at their command and to make more and more use of them, adapting them to their own special problems.

[3] *Cf.* experimental town map on a scale of 1 : 2,000 (communication from the National Geographical Institute to the International Congress of Photogrammetry, Stockholm, 1956).

USE OF ASTRONOMICAL CONTROL NETS FOR PREPARING MAPS BY PHOTOGRAMMETRY[1]

Information paper by the Institut géographique national, France

The horizontal control network for map-making by photogrammetry must have a minimum density of two points per photographic pair; these points are needed to reduce the pair to scale. In the case of a 1 : 100,000 map, to obtain the co-ordinates of these points by making measurements on the ground is out of the question, and the network is obtained by a technique of photographic triangulation based on the measurements made on the photographs, by carrying the scale and orientation forward from one end of each strip to the other. The strips are then adjusted to one another. This operation can be performed by calculation or by mechanical assembly. Since the accuracy of measurements made on photographs is limited, the carrying forward of scale and orientation involves some cumulative errors. It is therefore essential to limit the accumulation of these errors by fixing the position of a number of points which have been determined on the ground, and which constitute the " over-all horizontal control network ". The plotting network is adjusted by reference to the point so established. The over-all horizontal control network can be obtained by either geodetic or astronomical methods.

The characteristic of *geodetic methods* is that they involve measurements of distance. These can be taken by chain measurement (chain, tape or wire); by measuring the parallactic angle subtended by a staff of known length; by an optical process (geodimeter); or by various electromagnetic techniques. In the last-mentioned case the measurements may be made between ground stations (tellurometer) or with the aid of auxiliary air stations (Decca, Shoran). The accuracy of such measurements of distance is highly variable; it may range from 1 : 1,000 to 1 : 1,000,000.

Measurements of distance may be combined with angular measurements (geodetic triangulation, polygonation and the like). In any event the network is obtained by linking, and the errors are cumulative. However accurate the measurements, the error in the co-ordinates calculated may become substantial at a great distance from the initial point. There are always a great many measurements to be made, and compensation is necessary. Strictly speaking, this compensation cannot be applied until the measuring process is completed over the whole area to be covered. In practice, when the area is very large, this rule has to be disregarded, but only at the risk of very serious difficulties in bridging.

At the National Geographical Institute (Institut géographique national) the geodetic network is used in the preparation of small-scale maps only where the territory to be covered is small or where such a network already exists. In all other cases the *astronomical network* is used.

The Astronomical Method

This technique does not involve any measurements of distance. The points are determined completely independently of one another; consequently there is no linking and no cumulative error, but only the specific errors at each individual point.

The co-ordinates of the points are determined by observing series of stars on the basis of the true vertical at each point, which is given either by a level or by a mercury bath.

This method is based on the assumption that the verticals are normal to the reference ellipsoid, or that the geoid and the reference ellipsoid may be regarded as the same. This is only an approximation, the validity of which is inversely proportional to the ruggedness of the ground and the irregularity of the distribution of masses underground. In areas where the terrain is very rugged or the distribution of masses highly irregular, the discrepancy between the true vertical and the normal to the ellipsoid—known as the " deviation of the vertical "—has the effect of falsifying co-ordinates obtained astronomically, sometimes to a considerable extent.

There are thus two elements to consider in the absolute determination of an astronomical point:

(1) The error inherent in the determination of the point, apart from deviation of the vertical. Using modern equipment and time-signals, the average error is likely to be 30 metres;

(2) The error due to deviation of the vertical, which may be as great as several hundred metres, depending on the area.

The astronomical framework therefore inevitably lacks uniformity even under the best conditions.

Despite this theoretical disadvantage, the National Geographical Institute has adopted the astronomical method in preparing the 1 : 100,000 map for most of the Overseas Territories. The method has several very important practical advantages.

The main advantage is that each determination is made independently of the others. Errors are not cumulative, and no compensation is needed. The establishment of the astronomical network can be fitted within the scheme or priorities imposed by financial considerations. Photographic triangulation and plotting may be undertaken immediately, and there will be no major difficulties in bridging.

The method can be used in every type of country—plain, mountain, desert or forest—although it should not be used in very rugged terrain for the reasons given above. The equipment is light and can be carried on the back if necessary.

Output is very satisfactory and cost low; a team of two operators can easily fix fifty points in a six months' campaign.

The positions are fixed by the equal-heights method and entail taking sights on some fifteen stars on each of two evenings. A stone is set up to mark the point and related to a detail which can be identified on the photographs.

The *density of the astronomical network* as a whole depends on the accuracy of the photographic triangulation used. This density must be low enough for discrepancies between neighbouring astronomical points to be offset by the distances involved, and high enough to ensure that the admissible absolute errors are not exceeded in the detailed planimetric

[1] The original text of this paper, submitted by France, under the title " Utilisation du canevas astronomique pour l'établissement des cartes par voie photogrammétrique", appeared in French as document E/CONF 25/L 52.

network. In practice, in order to strike a balance between these two conflicting requirements, the mean distance between points adopted ranges from 35 to 50 kilometres in the case of central-point radial triangulation (templet) and 60 to 75 kilometres in the case of triangulation by adjustment of scale (stereotemplet). With these densities, the relative error over the distance between two adjacent points on the astronomical network is 1 : 1,000 and is of precisely the same order as the error inherent in mechanical assembly. A higher degree of consistency in the over-all framework would therefore be of little value, because it could not be preserved in the detailed framework. This is the justification of the solution adopted.

In view of the development of modern methods of calculation, mechanical triangulation processes could be discarded in favour of methods based solely on calculation and preserving all the precision of stereoscopic plotting. By this means a local consistency of 1 : 10,000 could be achieved in the detailed network. Under these circumstances, the arbitrary introduction of astronomical co-ordinates into the calculations as imposed values would obviously be out of the question, but this by no means implies that the astronomical network should be discarded. The problem is similar to that raised by the introduction into aerial triangulation calculations of data obtained with low-precision auxiliary instruments, and is solved in the same way. All that is needed is to weight the astronomical co-ordinates by a factor—in principle the same for all—which corresponds to their estimated accuracy and which is appropriately selected having regard to the weighting to be applied to the step-by-step linking operations of photographic triangulation. The idea is to apply to the astronomical co-ordinates corrections which will improve their coherence. Thereafter they will be used only in a general way, to fix the scale, orientation and positioning of a whole aerial triangulation block, and the effect of local deviations of the vertical will be, if not eliminated altogether, at any rate greatly reduced.

The astronomical method is an economical means of obtaining a control network of sufficient coherence for a 1 : 100,000 map in all areas of slight or medium ruggedness where the deviation of the vertical is slight.

This method is very economical in use compared with those involving radar-type operations, which entail elaborate and expensive ground equipment and the use of aircraft.

The National Geographical Institute currently uses the astronomical method for mapping large territories in the French Union, such as those in Africa, where for the most part the terrain is relatively even and the method thus particularly appropriate.

INTRODUCTION INTO AEROTRIANGULATION OF DATA FURNISHED BY INSTRUMENTS INSTALLED IN THE PHOTOGRAPHIC AEROPLANE [1]

Information paper by the Institut géographique national, France

Introduction

Aerial triangulation, as carried out by the French National Geographical Institute (Institut géographique national), may be regarded as a succession of three operations:

1. Reconstruction of the relative orientation of the pencils of perspective rays in relation to each other. This can be done by forming stereoscopic models (the solution so far adopted by the Institute) or by carrying out computations based on measurements made from the photographs (a solution which involves the use of electronic equipment and which is now being considered by the Institute);

2. The computation, strip by strip, of a system of approximate values for the co-ordinates of each of the control points to be determined. The principle underlying the methods which are used by the Institute and which vary according to the data available was explained in the communications submitted to the Stockholm Congress of Photogrammetry held in 1956. Because of their simplicity and accuracy, these methods have been used in many surveys carried out by the Institute in North Africa and the Overseas Territories of the French Union. The Institute's efforts have thus been directed towards improving the accuracy of the external data supplied by certain instruments carried in the mapping aircraft. The use of such instruments would not only reduce the amount of ground control but would also make it possible to eliminate the distortions which inevitably result from the linking-up of the pencils of perspective rays;

3. Over-all adjustment of a block of strips and the simultaneous introduction of ground data. This adjustment makes use of a mechanical analogy, the principle of which was explained at the Stockholm Congress.

The present paper is a report on the experiments carried out by the Institute in 1957 with a view to utilizing the information provided by the two instruments—namely, the gyroscope and the statoscope—carried by the mapping aircraft.

Utilization of Symmetrical External Data for Purposes of Aerotriangulation

The expression " symmetrical external data " refers to the information which is furnished by certain instruments carried by the mapping aircraft and which relates to each pencil of perspective rays in identically the same way (absolute orientation, height of camera station and the like).

These data are distinguished, on the one hand, from " internal data " (which are derived from measurements or other operations carried out on the photographs) and, on the other hand, from " topometric external data " (which result from direct measurements on the ground and are not symmetrical because they do not affect all the pencils of perspective rays in identically the same way).

[1] The original text of this paper, submitted by France, under the title " L'introduction en aérotriangulation des données fournies par certains instruments situés à bord de l'avion qui effectue la prise de vues ", appeared in French as document E/CONF.25/L.54.

What matters, of course, in the recording of the data in flight is not so much the accuracy of each observation as the accidental character of the residual errors. Even if, for each pair considered separately, these errors are actually greater than the errors deriving from the step-by-step calculation of the traverse, their accidental character should make it possible to avoid the accumulation of systematic errors which inevitably arise in the linking-up of the pencils of perspective rays. The correction of such systematic errors is in most cases a delicate and somewhat arbitrary process.

The efforts of the Photogrammetric Research Section of the Institute have accordingly been directed towards eliminating any systematic error from the recorded data. The two instruments to which the greatest attention has been given are the gyroscope and the statoscope.

The gyroscope

One of the principal unknowns in aerial photography, apart from the position of the aircraft, is the direction of the camera axis at the time the photographs are taken. The determination, for each photograph, of the two components—the lateral and the longitudinal—of the inclination of this axis is important not only for aerotriangulation, but also in other respects. It serves, for example, to facilitate the placing and adjustment of the photographs in the plotting instruments, to reduce the amount of ground control and to assist rectification and mosaic-assembly operations.

Two solutions which suggest themselves are to record the inclination for each photograph or to stabilize the camera. At the present time, the degree of accuracy in the two cases is approximately the same, since, in the case of stabilization, the supplementary error of the servo-mechanism is clearly less than the error of the tilt-detecting instrument which is, moreover, in both cases the same instrument. On the other hand, stabilization has the disadvantage of requiring bulky equipment that must be adapted to each type of camera.

Several more or less satisfactory methods of solving the problem of how to record the perpendicular during the photographing operation have been proposed and tested. A circular level, a set of two cross-levels or a pendulum does not give an instantaneous tilt-value. This is true because the momentary position of balance is achieved by the effect of all the various types of acceleration to which the instrument is subject and not merely by that of the acceleration of gravity. Acceleration due to variations of aircraft speed or to a momentary rotation of the datum system must also be considered. Such disturbing forces prevent the instrument from detecting instantaneously the position of the true perpendicular. Apart, however, from the systematic error resulting from variations in heading and drift during flight, which is in any case easy to determine, it is considered that, because of the purely accidental character of these disturbing forces, the mean value of the data furnished by the detecting instrument will, over a sufficiently long period of time, give the mean value of the true inclination of the camera. The period of time selected for this purpose may be equal to one or several of the intervals between two consecutive photographs.

Similarly, a vertically constrained gyroscope does not give either the apparent or the true perpendicular, but rather a direction, which is a complex function of the successive directions of the apparent perpendicular in the previous periods, this function being further determined by the characteristics of the constraining mechanism. Thus, where the accelerations referred to above are computed, the result shows that a change in course of 5 degrees within two minutes results in a difference of more than a half degree between the mean direction of the apparent perpendicular indicated by the gyroscope and the mean direction of the true perpendicular. Such variations in course are by no means unusual in a photographic flight where it is necessary to ensure the side lap of adjacent strips. This example shows how little importance, from the point of view of judging the accuracy of the instruments, can be attached to the fact that the indications of several gyroscopes used simultaneously in the same aircraft tally.

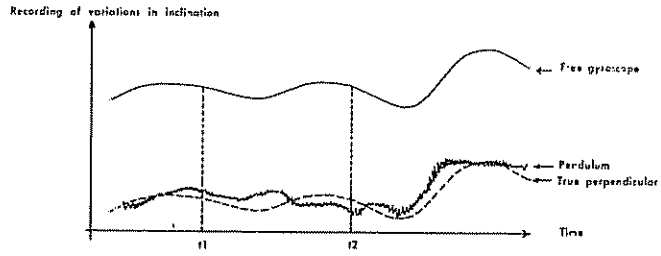


Figure 31. Recording the true perpendicular through simultaneous data of a free gyroscope and a pendulum

The Institute's experiments were designed to record the true perpendicular through the expedient of recording the simultaneous data of a free gyroscope and a pendulum (see figure 31). Since the gyroscope attached to the camera is free, its axis of rotation will indicate any direction in space. This will, however, be a fixed direction, and the values recorded in relation to it will thus be the momentary values of the (lateral or longitudinal) inclination of the camera axis at the time each photograph is taken. These values of the angle between the fixed direction and the true perpendicular are corrected by calculating the mean value, for the interval between two photographs, of the difference between the gyroscope data and the pendulum data. In other words, the gyroscope gives a momentary value of the inclination except for one constant, and the mean position of the pendulum helps to determine this constant.

The gyroscope readings must, of course, be corrected for the effect of diurnal motion, the curvature of the earth and accidental precession. In the same way, the pendulum readings are corrected for the heading and drift angles, which are determined from the operations by which the pencils of perspective rays are linked together.

Experiments based on this method were carried out on 30 March 1958. Several photographic strips were flown, at a scale of 1 : 25,000, over a distance of fifty kilometres. Two strips were processed: one had been flown with a free gyroscope, and the other with a vertically constrained gyroscope. These were then placed in the plotting instrument, and thus, on the basis of known points on the ground, the true inclination of the camera axis was accurately determined. In the two experiments, twenty-eight pairs were examined. The results obtained with the free gyroscope were found to be

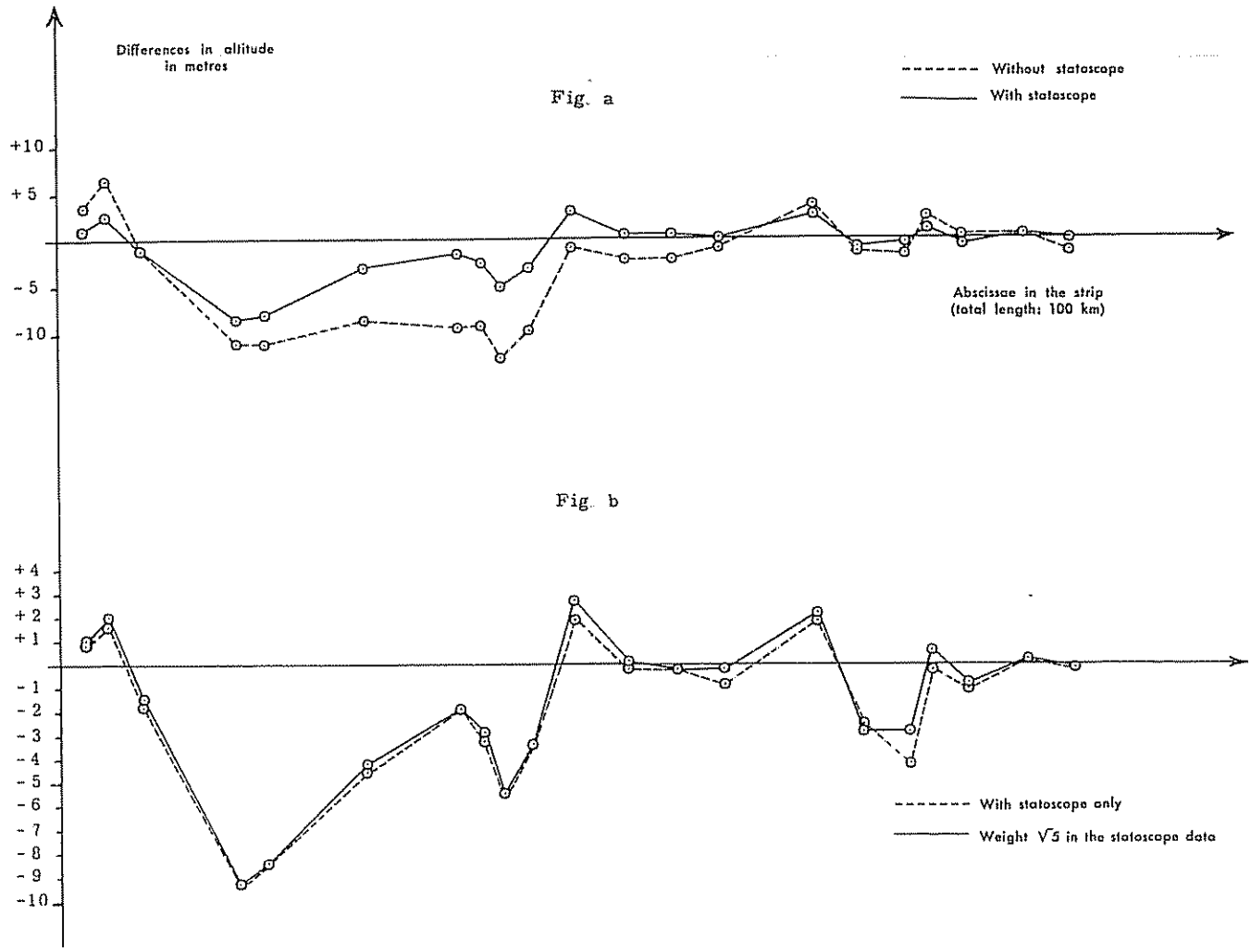


Figure 32. Conclusions of experiments with and without statoscope in relation to terrain having a number of known reference points

more uniform, and thus substantiated the arguments set out above.

Research is being carried out to improve the present sensitivity of the detecting instrument, but the parasitic accelerations to which the gyroscope is subject make it unlikely that under the conditions normal to aerial photography the gyroscope can give real (and not apparent) indications accurate beyond ten centesimal minutes.

Such indications would, however, be valuable, for they would make it possible to avoid errors that might lead to " breaks " in the computations relating to the photographic strips, but research would have to be directed towards an instrument in which the parasitic accelerations affecting the mount would be corrected.

The differential statoscope

While it seems difficult at the present time to make use of the gyroscope data in forming a model, the results obtained with the differential statoscope have been much more encouraging. The statoscope, after correction of the pressure readings, makes it possible to determine the variation in the altitude of the aircraft from one photograph to the next and thus gives a value for the longitudinal inclination of each base line. In processing these data, the following two problems arise:

1. Transformation of the pressure readings into the inclination angle of each base line;

2. Introduction of the results into the strip computations.

If dl represents the difference in readings between two successive peaks of the aerotriangulation, and if B is the mean value, regarded as constant, of the base line, then the ratio dl/B must be multiplied by a certain coefficient K in order to obtain the longitudinal inclination of the base line expressed in milliradians. This coefficient K is determined in the first place through an approximate calculation, and its definitive value is then obtained by regarding it as a free parameter to be introduced into the conditional equations in which the corrections to the approximate values are linked with the accidental reading errors. A consideration here is the weight to be given to the values for the longitudinal inclination of

the base line as obtained through the linking-up of the pencils of perspective rays, on the one hand, and through the statoscope data, on the other.

The experiments were carried out on several strips and were intended to compare the results when the statoscope was used with those when it was not used, in relation to terrain in which a certain number of reference points were known.

The conclusions arrived at are shown in graphic form in figure 32, *a* and *b*. In figure *a*, the dotted line represents the differences in altitude as determined solely by the linking-up of the pairs with each other; the solid line represents the combination, that is, the linking-up of the statoscope pairs, the weight in the latter case being 7. In figure *b*, the dotted line represents the differences with the statoscope alone; the solid line, drawn on a scale different from that in figure *a*, represents the combination, that is, the linking-up of the statoscope pairs, the weight in the latter case being 7, as in figure *a* but on a different scale.

The conclusions are as follows:

1. The results are very much better with the statoscope (errors with regard to the heights of known points reduced by half); in particular, breaks and wide discrepancies in closing are avoided;

2. There is even a possibility that the statoscope data alone would be sufficient for the purpose of the computations, the inclinations furnished by the linking-up of the pencils of perspective rays being used only for calculating the mean calibration coefficient K of the statoscope for a given strip.

The use of a differential statoscope is thus very valuable for aerial traversing. It is particularly useful when lateral strips are flown, for these provide a more solid control and facilitate the adjustment of the blocks of strips. Such lateral strips flown with the statoscope have already been resorted to on various occasions for the surveying of large areas in Africa. What has been said above concerning this apparatus is not, therefore, something for the future only, but is rather the outline of a method that has already been applied in practice to large-scale cartographic projects.

RECENT DEVELOPMENTS IN ADJUSTMENT TECHNIQUES IN AERIAL PHOTOGRAMMETRIC MAPPING WITH MINIMUM GROUND CONTROL [1]

Background paper by Rear Admiral H. Arnold Karo,
Director, United States Coast and Geodetic Survey

Abstract

Instrumental and computational details are shown which facilitate aerotriangulation, or the utilization of a minimum number of ground control points in a strip of aerial photographs. Not only do the methods reduce the number of hours of labour required both in the office and in the field, but also the results are more accurate than formerly, few control points are needed, and the specific location of the control is less critical. The methods may be particularly useful in hitherto unmapped and remote areas as well as in large-scale cadastral surveys.

Introduction

The production of an accurate detailed plan which has (1) a definite scale, (2) a correct geographic location and (3) a correct geographic orientation comprises a fundamental problem in mapping from aerial photographs as well as in conventional mapping. A single aerial photograph, or a trace from one, does not satisfy these requirements because it is a perspective projection which is not geometrically compatible with the idea that a map is an orthogonal projection. However, an overlapping pair of aerial photographs set in a stereoscopic plotting instrument to fit control can be traced orthogonally to comply with the conditions of an accurate map.

The number of control points required for an overlapping pair may seem to be unreasonably large for small-scale mapping: the minimum theoretical number includes two horizontal control points (triangulation or traverse stations) and three vertical control points (which may, but need not, coincide with the horizontal control stations) although more points are nearly always used in practice. It is pointed out that seven numerical quantities, or parameters, are supplied by the minimum theoretical control data—namely, two X-co-ordinates, two Y-co-ordinates and three Z-co-ordinates.

Needless to say, the cost and difficulty of establishing such control for small-scale mapping may be prohibitive. This is where aerotriangulation is applicable.

A few photogrammetric principles seem to be important at this stage of the discussion. (*a*) First-order stereoscopic plotting instruments (Swanson [2]) have the facility which allows one to adjust accurately two overlapping photographs relative of each other through the analysis of common images without any knowledge of control or datums. (*b*) After an operator has oriented one pair of photographs he can remove the first one, replace it with the third photograph of the flight strip without disturbing the second, and step along in this manner until the end of the flight is reached. (*c*) Each new photograph can be adjusted to fit the previous one with a high degree of accuracy without any reference to ground control. (*d*) The instrument registers a set of three miniature rectangular co-ordinates for any desired photographic image, and continues the same co-ordinate system throughout the flight strip. (*e*) Six image points are so registered and recorded for each photopair, as well as for all the points for which

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.35.

[2] Swanson, L. W., "Topographic Manual", Special Publication No. 249, United States Government Printing Office, 1949, page 466.

control information is available, but no attempt is made to adjust the instrument to fit the control. (f) The result of such an instrument aerotriangulation consists of a list of the three instrument co-ordinate values for all the images selected. This list of numbers defines a surface in space, but the relation of this surface to the earth is unspecified at the moment.

Inasmuch as it is therefore possible to connect the photographs in a continuous chain or surface, it may seem reasonable that the amount of required control is reduced accordingly. Theoretically, the seven parameters mentioned earlier can now serve an entire flight strip instead of only one pair of photographs. In practice, however, the number of control points must be greater than the theoretical minimum to guard against gross mistakes and to enable one to analyse the solution for systematic instrument errors.

Progress at the Army Map Service

by Carl J. Born

With the acquisition of the first model C5 stereoplanigraphs at the Army Map Service and their subsequent use for aerotriangulation, the investigation of adjustment methods was a necessary consequence. The development of practical methods was pioneered by R. S. Brandt, following the theoretical analysis described by O. von Gruber.[3] The graphical adjustments,[4] both horizontal and vertical, are the same as those described in subsequent portions of the present paper.

The graphical recording of stereotriangulated passpoints on a plotting medium soon gave way to the digital recording of this data in Cartesian co-ordinates in an effort to increase accuracy of the photogrammetric extension. However, the complete numerical adjustment of a stereotriangulated strip is time-consuming when computed on a desk calculator. It is further burdened by the frequent inclusion of erroneous control data, which necessitates a second or third solution for the coefficients of the horizontal adjustment equations. For this reason, a combination numerical-graphical method was adopted. The numerical portion consisted of computing a co-ordinate transformation and scale change for transforming the instrument co-ordinate system into the system of the geodetic control. The graphical adjustment eliminated the non-linear error of the photogrammetric extension. Needless to say, the vertical adjustment was accomplished graphically.

The purchase of the UNIVAC by the Army Map Service provided the means for rapid numerical adjustment. The horizontal adjustment [5] was first programmed for the UNIVAC in 1953 and the vertical adjustment [6] in 1955. About 90 per cent of the horizontal adjustment and 50 per cent of the vertical adjustment for stereotriangulated strips are at present processed through the UNIVAC with an appreciable saving in time and cost. Studies are under way to improve the vertical adjustment. Satisfactory results are obtainable on short extensions of ten to fifteen models. However, on longer extensions, the random errors exceed the allowable tolerance within which the mathematically defined correction surface must fit the vertical control. A better solution is obtainable by increasing the degree of the adjustment polynomial or by separating the extension into shorter segments which can be satisfied with the present equation as programmed. The relative merits of these methods are being tested. Regardless of the method finally selected, the electronic computer will be used extensively in place of the graphical adjustment.

Consideration is being given to the feasibility of horizontal area adjustment through automatic computation. With the capacity of such computers as the UNIVAC, the simultaneous solution of large number of equations presents no unusual problem.

Instrumental Procedure

Let us review for a moment the general procedure in the operation of a first-order plotting instrument doing aerotriangulation. First, all the counting dials are reset to zero or to the centres of their runs. Glass transparencies of the first two photographs are set in place and one is oriented by a prescribed routine relative to the other so that all common images in the overlap area seem to be in perfect alignment (relative orientation). Next, the operator records the three co-ordinates for each of at least six points in the overlap area, and also plots their positions on a map sheet if he wishes (the graphic record may or may not be needed). If geodetic control points appear, their co-ordinates are recorded also, but no effort is made to fit them at this time. The three instrument co-ordinates are usually designated as x, y and z, with x referring to the longitudinal horizontal flight axis of the strip, y to the transverse horizontal direction and z to the vertical, or elevation.

Next, the third photograph is put in place of the first, as mentioned earlier, and the procedure is repeated. The instrument is so arranged that the three co-ordinate directions continue to accumulate in their proper directions of progress. The result of an instrument aerotriangulation for a strip consists of four columns of numbers, one of which identifies the image points, the others being the three co-ordinates. The next step is a numerical one of converting this list of instrument co-ordinates (in millimetres) into more useful units, such as metres on the ground referred to a standard geodetic system. This numerical conversion constitutes the major topic of this paper.

Any mechanical or optical procedure of this nature is subject to errors of various types. They may be segregated into three different categories: (1) those which are linear and can be compensated by transformations through the application of standard analytic geometry formulae involving scale change, rotation of the axes and translation of the origin; (2) those which are non-linear and are due to systematic errors propagated by the operator and instrument during the aerotriangulation procedure, and (3) those which are random accidental errors of operation and observation. It is emphasized that the problem is one of three dimensions.

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[3] O. von Gruber, "Beitrag zu Theorie und Praxis von Aeropolygonierung und Aeronivellement", *Bildmessung und Luftbildmessen*, for the year 1935.

[4] Robert S. Brandt, "Résumé of Aerial Triangulation Adjustment at the Army Map Service", *Photogrammetric Engineering*, vol. 17, No. 5, 1951, page 806.

[5] Charles W. Price, "Some Analysis and Adjustment Methods in Planimetric Aerial Triangulation", *Photogrammetric Engineering*, vol. 19, No. 4, 1953, page 627.

[6] C. J. Born, "Vertical Aerotriangulation Adjustment Utilizing Electronic Computers", *Photogrammetric Engineering*, vol. 22, No. 4, September 1956.

The Linear Transformation

The equations for the linear transformation (appendix I) constitute a set of computational instructions for converting instrument co-ordinates into corresponding ground or geodetic co-ordinates. The equations include a scale change, an axis rotation and a shift of the origin which can be stated briefly by the vector equation

$$aAx + b = X$$

in which a is the scalar factor, A is the rotation matrix, x represents the instrument co-ordinates, b represents the translation of the origin and X represents the desired co-ordinates in the geodetic system. In the earlier stages of development, this computation was done by desk calculator. Later it was programmed for an electronic computer. Recently it has been combined with a more comprehensive programme which is discussed later. By desk calculator this transformation required about twelve hours for a strip of forty photographs; the electronic computer completed it in one or two minutes!

It is noteworthy that this transformation is based only on the minimum number of seven conditions or parameters mentioned before, namely, the X and Y horizontal co-ordinates of two horizontal (triangulation; traverse) stations and the Z elevations of three vertical stations, wherein it is permissible but not necessary for a single point on the ground to serve as both a horizontal and a vertical station. It may seem logical that the two horizontal stations lie at opposite ends of the strip, similarly for two of the vertical stations, and that the third vertical station should be on the side of the strip opposite from one of the other vertical stations. This idea of considering exactly seven parameters is comparable to kinematic design of mechanics wherein no redundant information overconstrains the three-dimensional photogrammetric strip.

Consider the presence of a larger number of control points than the minimum of seven parameters which we have specified. If the instrument co-ordinates of such a superfluous point are transformed numerically like any other photographic image, one might expect the resulting co-ordinates to be identical with the known (but withheld) co-ordinates. On the other hand, those familiar with this type of work are not surprised that the transformed co-ordinates will be in error owing to the two remaining sources—namely, (1) the systematic instrumental discrepancies and (2) random observational variations.

The Systematic Instrumental Discrepancies

Those who are familiar with conventional surveying and mapping operations appreciate that small systematic errors gradually grow through repeated instrumental procedures into large discrepancies which cannot be ignored. The rate of growth of this type of error is considered to be quadratic (second degree) in which the total deviation is related to the square of some parameter such as the distance from the starting point. This is also true in photogrammetric aerotriangulation, wherein errors too small to be detected in a single pair of photographs appear as measurable quantities several photographs later as the work progresses. Brandt [7] and Price [8] stated some of the basic principles. Directed by Captain L. W. Swanson, several technicians of the Coast and Geodetic Survey studied and worked under those of the Army Map Service who were already employing these methods.

If linear transformation of appendix I is applied to a set of instrument co-ordinates at points near the ends of the strip, it is expected that ground control data in excess of the required seven quantities will indicate erroneous positions for all other geodetic points within the strip. The errors can be expressed in each of the three dimensions x, y and z. A separate graph drawn for each of the three dimensional discrepancies and having the line of flight (usually x) as its abscissa and independent variable shows that the discrepancies form smooth curves if they are reckoned with respect to the centre of the flight strip. These curves have been shown to be quadratic for the y and z dimensions and slightly cubic for the x.

The three deviations might be visualized in more familiar terms, as follows. The y-deviation is essentially a horizontal bow in the flight strip to the right or left and is often called "azimuth". The z-deviation is a vertical bow usually bent downward, figuratively, and is often referred to as the "BZ-curve". The x-deviation represents a growth in scale which may be either increasing or decreasing, and is called "x-scale".

It is probably obvious that if sufficient intermediate control existed along a strip, then the graphs of the three deviations could be drawn from which corrections could be determined for various image points between the control points. This is essentially what is actually done in practice.

Another item, however, needs to be considered: what effect is caused if a point does not lie on the flight line? This question was also treated by Brandt and Price and is solved by the addition of three more curves, making six in all, of which two are in each dimension. The curves are not independent: at least the horizontal ones depend on one another. It seems logical that all the curves should be interdependent, but this has not yet been established with regard to the vertical z, although study continues in an effort to discover the complete relationship.

Until recently a graphic solution of the systematic errors was used in the Coast and Geodetic Survey. The graphic solution has now been replaced by an equivalent numerical solution using an electronic computer. The latter solution is described by Harris [9] in detail and is reviewed here presently. The graphic method may be of more interest, however, if an electronic computer is not available. Consequently both methods are discussed.

The Graphic Solution

The instrumental procedure as described heretofore is the same for the two methods. Control consists of at least three and preferably five horizontal points about evenly distributed throughout the strip. The ratio of the number of control points to the number of photographs is related to the accuracy specifications established for the map, but should not be more sparse than about one horizontal control point in each tenth photograph. For more accurate work the spacing

[7] Robert S. Brandt, op. cit.

[8] Charles W. Price, op. cit.

[9] William D. Harris, "Aerotriangulation Adjustment of Instrument Data by Computational Methods", *Technical Bulletin No. 1*, Coast and Geodetic Survey, 1958.

should be reduced to four or five photographs. In most accurate (cadastral) applications two to four horizontal and vertical control points in every fourth or fifth photograph would be helpful.

Vertical control should occur in pairs on opposite sides of the flight strip not more sparse than one pair in each eighth photograph. Again, for greater accuracy, one needs to have the control closer together, but perhaps not more frequent than one pair in every third model.

This paper is concerned chiefly with sparse control and moderate accuracy. Consequently it is assumed that the absolute orientation of any model is not possible and that "free" aerotriangulation is accomplished through careful relative orientation. The operation might be compared to flying through space in an undetermined direction, slope, altitude and speed. The instrument co-ordinates of images are related to the adopted instrumental system and the relationship of instrument to ground co-ordinates is not considered until after the instrument work is complete. Auxiliary aerial instruments—such as statoscope, gyroscope, solar camera, horizon cameras, oblique cameras, or radar profile recorders—are not employed although they could possibly be utilized with an undoubtedly significant increase in accuracy. Instead it has been found preferable to obtain the required accuracy through the judicious selection of the flight altitude relative to the density of the control.

The result of the instrumental procedure is then a four-column list of the instrument co-ordinates in millimetres at an unknown scale and with the direction of the x-axis only generally known. The next step is a linear transformation which may be regarded as a strange one indeed: the control data are transformed into the instrument co-ordinate system through the use of the *inverse* transformation (appendix II):

$$(1/a)A^{-1}(X-b) = x.$$

It is not a very long computation, because only the control points themselves are operated on. As shown in appendix II, the numerical constants are related in a simple way to the elements of the direct transformation, which needs to be computed for a later use.

The reason for transforming the control data into instrument data is that the systematic instrument errors are related to the directions of the instrument axes along which each of the three-dimensional errors is propagated. This is all the more necessary because in our application the aerial photography is flown parallel to the shore line, or to connect systems of geodetic control points. Inasmuch as the instrument axis is essentially parallel to the flight axis, the instrument axes do not resemble the cardinal ground geodetic axes.

Once the inverse transformation of the control is complete, the corrections ${}^{c}x$ to the instrument co-ordinates needed at the control points can be obtained by subtraction :

$${}^{c}x = x' - x, \text{ etc.},$$

where x' is the inversely transformed control co-ordinate and x is the observed instrument value. After the corrections are determined for all the control points, the next step is to construct the graphs, which is described in appendix III.

In addition to printing a set of instrument co-ordinates for each image observed, the instrument is also used to plot the position of the image on a continuous roll of tracing paper at any designated scale. This tracing paper showing only about three image points per photograph plus all the control points becomes the basis for the graphic adjustment. The paper is laid on a long table (ten to twenty feet in length) which has been covered with cross-section paper. The position of an image in the strip serves as the abscissa and the ${}^{c}x$-value is the ordinate for a point on a curve.

The six curves are called:

Primary curves
- 1.1 x-scale
- 1.2 Azimuth (y-bow)
- 1.3 BZ (z-bow)

Secondary curves
- 2.1 y-scale
- 2.2 Swing (x-effect of azimuth)
- 2.3 Twist (z-cross tilt)

The primary curves are nearly quadratic whereas the secondary curves are nearly linear or straight. The y-scale curve is derived from the x-scale curve: it is a graph of the slope of the x-scale curve. In the sense pertaining to calculus, the y-scale curve is the first derivative of the x-scale curve. Likewise, the swing curve is the first derivative of the azimuth curve. The derivative curves are easily obtained from the primary curves by means of a simple graphic construction.

The twist curve is *not* derived from the primary BZ-curve, but instead is obtained from the corrections at vertical control points lying on opposite sides of the strip.

The total correction ${}^{c}x$ at any image point can be derived from the curves opposite the position of the point:

${}^{c}x$ = total x-correction = ordinate of the x-scale curve ± (ordinate of the swing curve times the distance by which the image is off axis)

${}^{c}y$ = total y-correction = ordinate of azimuth curve ± (ordinate of the y-scale curve times the distance by which the image is off axis)

${}^{c}z$ = total z-correction = ordinate of the BZ-curve ± (ordinate of the twist curve times the distance by which the image is off axis).

A corrected instrument co-ordinate is then simply the sum of the observed instrument co-ordinate and the total correction, taking the algebraic sign into proper account.

The final adjusted ground co-ordinate in the geodetic system for an image can then be obtained by substituting the corrected co-ordinates in the transformation equations 1, 2, and 3 of appendix I. This completes the adjustment.

The Computational Solution

The graphic solution discussed in the preceding section was sufficiently successful so that it was decided to programme the complete operation on an electronic computer to reduce the amount of hand labour, the number of unavoidable human mistakes and the lapse of time required to get a finished product and to increase the accuracy of the operation and the volume of work produced by the instruments. The last-named item was possible because the instrument operators were usually also involved in the graphic operations. Consequently, one can now supply the automatic computer with the control and instrument co-ordinates, and five minutes later print out the completely adjusted set of geodetic co-ordinates. These co-ordinates are then plotted on map

sheets with a co-ordinatograph at appropriate scales and used as control for map compilation using Kelsh plotters.

The computational solution is treated in detail by Harris.[10] He indicates several features which were not necessarily included in the graphic adjustment, but were relatively easy to incorporate in the programme.

(1) Both the instrument and the geodetic co-ordinates are transformed into an auxiliary flight-axis co-ordinate system which often deviates materially from the instrumental system. The centre of this adopted flight axis is considered as the origin of co-ordinates, thus effectively "scaling" down the large numbers which ordinarily occur in the x-dimension.

(2) The programme computes and applies its transformation coefficients (appendices I and II) without any human intervention.

(3) The x-scale curve is considered to be cubic as noted in the literature[11] as well as through our graphic experience. One is cautioned about using curves of too high a degree for these purposes; otherwise even higher degree curves might have been used.

(4) The same interrelationship between the horizontal corrections was imposed as was done in the graphic solution. For example, the total x-correction includes a function of the first derivative of the primary y-curve (azimuth).

(5) The coefficients $A \ldots G$ in the correction equations, such as

$$^{c}x = Ax^3 + Bx^2 + Cx - 2Dxy - Ey + F,$$

are determined so that the sum of the squares of the differences between the value of ^{c}x as given by the equation and as given by the control data is minimum. Thus, any number of control points can be used and adjusted according to the least squares law. The formation of the condition equations, the normal equations, their solution and application is coded as part of the one continuous programme.

(6) A list of residual discrepancies is printed out allowing one to detect gross errors, and thereafter perhaps repeating the solution with the erroneous point deleted.

(7) A minimum number of three control points can be used, in which case both of the horizontal primary curves are only quadratic, and the least squares solution is not significant.

* * *

The programme includes only the horizontal phase at this writing, while the vertical phase is under consideration.

The programme has satisfied all expectations. It has increased the output of the instrument unit by about 40 per cent. At least two other government agencies have made use of the programme.

Tests and Results

The general solution has been tested extensively by both the graphic and computational methods (reported by Tewinkel[12]). A test strip was flown in a well-controlled area near Miami, Florida. The strip included fifty photographs covering a distance of 100 miles. Fifteen horizontal control points are included in the area, which is very nearly flat, and for which contour maps exist. The strip was processed, using the stereoplanigraph C8, a total of seven times.

Four triangulation stations were regarded as control points (purposely distributed non-ideally), and the others served as test points. The standard error of all the strips was 32 feet after adjustment (the maximum error was 68 feet; and 90 per cent of the errors were less than 56 feet). Inasmuch as the total distance between the terminal stations was 89·4 miles, and the four control points divided the distance into three sections, the standard error was one part in 4,900 of the average spanned distance between adjacent control stations.

Further tests using improved instrumental techniques have indicated a possible reduction of the 32-feet figure to 21 feet, or 34 per cent.

As a consequence of these tests, further and more comprehensive tests have been initiated. A new test area having thirty-five control stations in eighty miles has been selected. These stations are to be marked before aerial photography to eliminate errors due to faulty control identification from the study.

The computational method did not show a decided increase in accuracy as compared with the graphic solution. This is because the computational method restrains the error curves to standard algebraic formulae, whereas the graphic method allows the operator to bend the spline a little here and there to fit the control as best he can. The computational method is preferred, however, not only because of its time-saving feature, but also because of its distribution of errors according to accepted least squares principles, and its exhibiting of errors to inform one of the relative quality of the instrument operation and the validity of the control point identification. The economy of the system has made it practicable to fly special strips of aerial photographs for the sole purpose of determining the position of a *single point* in the strip.

Tests and studies are continuing for the purpose of further improving the accuracy of the system. For example, rather large errors in X are sometimes caused where large elevation differences occur in models. The errors are due to the slope of the BZ-curve. Consequently, if the curve can be reduced, this source of error will also be lessened. It was apparent that the principal cause of the curve is earth curvature and atmospheric refraction. In accordance with several references to the subject in the literature, a small divergent tip correction is now being applied to the fixed photograph before each relative orientation. One test indicated, as expected, that the maximum BZ-correction was reduced to only 20 per cent of its former value. This will reduce the corresponding X-discrepancies to a value which can be neglected.

Another idea being investigated is the use of alternate corners of the model for the phi and omega adjustments in relative orientation for the reduction of the magnitude of swing and twist.

APPENDIX I

The Linear Transformation Equations

The given control consists of the solid rectangular co-ordinates X_1, Y_1; X_2, Y_2; Z_3; Z_4; Z_5. The subscripts denote arbitrary point numbers. Points 1 and 2 are horizontal control points considered

[10] William D. Harris, op. cit.

[11] J. M. Zarzycki, "Some Theoretical and Practical Problems in Photogrammetric Bridging", *Photogrammetric Engineering*, vol. 20, No. 3, 1954, page 567.

[12] G. C. Tewinkel, "Aerotriangulation Tests", paper presented at annual meeting of American Society of Photogrammetry in March 1958.

to lie near opposite ends of a strip of photographs. Point 3 is a vertical control point considered to be near one end of the strip, and points 4 and 5 are vertical control points lying on opposite sides of the strip near the other end.

The needed observed instrument quantities are in a miniature solid rectangular co-ordinate system: $x_1, y_1; x_2, y_2; x_3, y_3, z_3; x_4, y_4, z_4; x_5, y_5, z_5$.

The linear transformations are represented by the equations:

$$X = ax - by + c \tag{1}$$

$$Y = bx + ay + d \tag{2}$$

$$Z = e(x-x_3) + f(y-y_3) + gz + h \tag{3}$$

The values of the constant terms a, b, c, d for the horizontal co-ordinates are given by the formulae:

$$a = \frac{(X_1 - X_2)(x_1 - x_2) + (Y_1 - Y_2)(y_1 - y_2)}{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{4}$$

$$b = \frac{(Y_1 - Y_2)(x_1 - x_2) - (X_1 - X_2)(y_1 - y_2)}{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{5}$$

$$c = X_1 - ax_1 + by_1 \tag{6}$$

$$d = Y_1 - bx_1 - ay_1 \tag{7}$$

The values of the constant terms e, f, g, h for the vertical equation 3 can be computed from the following formulae based on the three vertical control points:

$$e = \frac{k_4(y_5 - y_3) - k_5(y_4 - y_3)}{(x_4 - x_3)(y_5 - y_3) - (x_5 - x_3)(y_4 - y_3)} \tag{8}$$

$$f = \frac{k_5(x_4 - x_3) - k_4(x_5 - x_3)}{(x_4 - x_3)(y_5 - y_3) - (x_5 - x_3)(y_4 - y_3)} \tag{9}$$

$$g = (a^2 + b^2)^{1/2} \tag{10}$$

$$h = Z_3 - gz_3 \tag{11}$$

$$k_4 = Z_4 - gz_4 - h \tag{12}$$

$$k_5 = Z_5 - gz_5 - h \tag{13}$$

These formulae are empirical rather than rigorous, but the lack of rigour has no significant effect on the final results. The lack of rigour results from the fact that z-terms are not included in the equations for X, Y and g, whence the rotation is not exactly rectilinear. An unreasonably large proportion of computing effort is necessary to make the system rigorous, and essentially no benefit would be derived. The use of a rigorous system becomes attractive if the elevations of the two horizontal stations are known and if they lie in geometrically strong positions in the strip. But these restrictions are considered to be unpractical, inasmuch as one of the important economic advantages of the system is the non-critical location of control points.

APPENDIX II

The Inverse Linear Transformation

The purpose of the inverse transformation is to express the co-ordinates of control points in the instrument system so that they can be compared (subtracted) to show the magnitudes of the systematic errors. The values of the constants $a \ldots h$ of the forward or direct transformation (appendix I) are considered to have been computed as they are needed later for the general transformation.

Let $a' = a/(a^2 + b^2)$ (14)

$b' = b/(a^2 + b^2)$ (15)

Then

$$x' = a'X + b'Y - a'c - b'd \tag{16}$$

$$y' = -b'X + a'Y + b'c - a'd$$

$$z' = (1/g)\,Z - e(x - x_3) - f(y - y_3) - h \tag{17}$$

APPENDIX III

Construction of the Correction Curves

Inasmuch as the horizontal and vertical adjustments are not considered to be interrelated, it is ordinarily immaterial which is performed first. Suppose one chooses to adjust the horizontal co-ordinates first.

Constructing the horizontal curves is an iterative process which usually converges upon redrawing the first curve. One begins with either the x-scale or the azimuth curve, whichever one has the largest corrections. Suppose the azimuth is plotted first. A flight axis is selected by rotating the tracing paper on the cross-section paper until the centres of the first and last models lie on a common longitudinal line, but the selection is not at all critical. The ordinates are plotted at a greatly magnified scale—such as two centimetres (or one inch) on the cross-section paper equals one millimetre of correction. Corrections which need to be added to the instrument co-ordinates are customarily plotted on the upper side of the flight axis. After all the ordinates have been plotted, the points are connected with a smooth curve by means of a fibreglass spline. Piano wire has been used where the scale of the tracing paper record is small.

The second curve to be constructed is the *swing* correction curve. The procedure for the construction is given first and an explanation is given later.

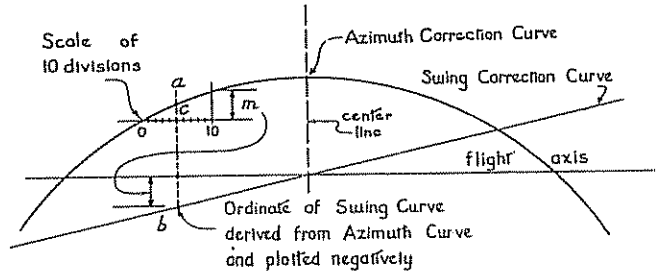


Figure 33. Construction of the swing correction curve

As was mentioned in the main text, the swing curve is the first derivative of the azimuth curve, whence it is the curve that shows the change in slope of the azimuth curve. The method of construction is shown in figure 33. A scale having ten divisions (ten inches is frequently used) is laid parallel to the flight line with its zero on the azimuth correction curve. The distance m which the 10-division mark departs from the curve is ten times the average slope of the curve at a, which is opposite the 5-division of the scale. The distance m is taken with a pair of dividers and used to locate b on the line ab below—on the minus y-side of—the flight line axis. This point b is a point on the swing correction curve. (Frequently it is preferable to enlarge the distance m ten times by measuring m and multiplying to make plotting easier.) The operation should be repeated at six to ten places along the azimuth curve, and the locus of points like b will invariably be very nearly a straight line crossing the flight axis at the centre line inasmuch as the data are considered to have been transformed so that the azimuth curve is zero near both ends.

Figure 34 illustrates the geometric basis of the swing curve inasmuch as an explanation may be helpful with regard to algebraic signs. Consider that points a, b and c are points in a model placed in its relative position on the azimuth *error* curve. The azimuth correction is designed to correct the b point by moving it to b', a to a' and c to c'. But the points a' and c' require a further secondary movement in the x-direction a' to a'' and c' to c'', which is called "swing" because of its rotational nature. It is probably evident that the angle ø (angle $c'b'c''$) is equal to the inclination of the

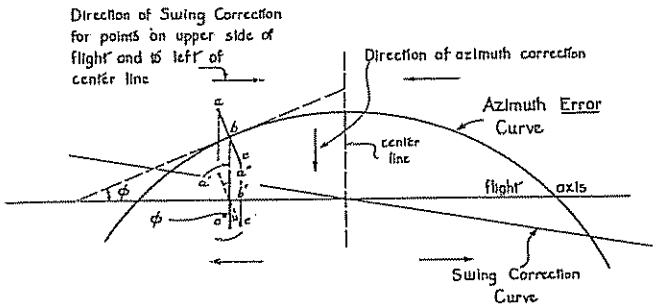


Figure 34. Geometric basis of the swing correction curve

tangent to the azimuth error curve at b. Then the x-correction (swing) at a' is equal to the distance ab multiplied by the slope of the azimuth curve:

$$\text{swing correction} = ab \tan \phi$$

where $\tan \phi$ can be obtained by measuring the ordinate of the swing correction curve opposite a.

If $bc = ab$ the swing correction at c' will be numerically equal to that at a', but it will be in the opposite direction. Moreover, the directions of the corrections are reversed on the other end of the flight strip—as well as on the other side of the flight axis—where the swing correction is zero because the slope is zero and the model does not require a rotation or " swing ".

Algebraic signs are important as well as being a source of error. As one usually draws the azimuth *correction* curve (figure 33), he should be careful to visualize the *error* curve instead to determine the algebraic signs for the swing correction.

The third curve to be drawn is the x-scale curve. From the main text, the definition is given that:

Total x-correction = ordinate of the x-scale curve + (ordinate of the swing curve times the distance the image is off axis).

Stated in different form:

Ordinate of the x-scale curve = total x-correction minus (ordinate of the swing curve times the distance the image is off axis).

Inasmuch as the total x-correction is known from the data and the second term is now available from the swing curve, it is now possible to find the value of the pure x-scale quantity. The swing component is actually obtained by reading the ordinate of the swing correction curve opposite the point under consideration, and multiplying the value—using a slide rule—by the measured distance the plotted point is off the flight axis. The units of measurement must be considered carefully as well as the position of the decimal point in the value of the slope. Thus one is able to obtain the ordinates of control points on the x-scale curve. These ordinates are plotted opposite their corresponding control point locations, and a smooth curve is constructed through them with the spline.

The y-scale curve is constructed next directly from the x-scale correction curve in much the same way as the swing curve was constructed from the azimuth curve: the difference lies in the principle that the direction of the y-scale correction is correctly indicated by the geometric slope of the x-scale curve. It may be helpful to visualize that the strip is constantly growing larger or smaller in x and also in y. If it is growing larger in x, it is too small at the beginning, it is too large near the end and has the correct size in the centre. If a model is too small, points in the model require corrections outward perpendicularly away from the flight axis (figure 35). It should be noted that the x-scale curve is a *cumulative* correction whereas the y-scale correction is an *instantaneous* one.

This completes the construction of the horizontal curves except that the azimuth curve was plotted originally with no knowledge of the effect of the y-scale correction which is now available. Consequently, the ordinates for the azimuth curve are recomputed:

Azimuth correction = total y-correction minus (the ordinate of the y-scale curve times the distance the image is off axis).

Thus, with new ordinates, a second or new azimuth curve is drawn, which is not far different from the first one. A check of the ordinates of the swing curve usually indicates that any changes in it are entirely insignificant, whence it does not require redrawing, and the construction is complete. This concludes the horizontal phase.

The two vertical curves are also iterative, but they do not " behave " so nicely as the horizontal curves. Two schools of thought exist as to which should be plotted first — the BZ-curve or the twist curve. Probably the former is preferable in practice, especially after experience is gained, whereas the latter is easier to explain in view of learning the definition of " twist " or cross tilt. So the twist curve is considered next.

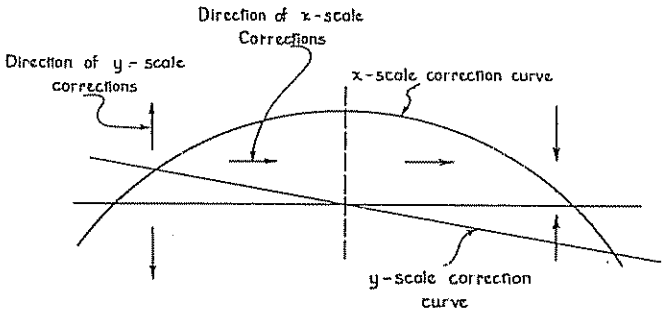


Figure 35. Direction of the scale corrections

The c_z-corrections are determined, as explained in the text, for all the vertical control points, which occur in pairs on opposite sides of the flight axis. They are never *exactly* on opposite sides because of practical considerations in the field, and this is perhaps one of the principal reasons why the system is iterative. The two correction values for such a pair of plotted points furnish the data for finding both the twist and BZ-value for a point at the intersection of the flight axis and a line joining the two points. The twist value (figure 36) is:

$$t = (c_{z1} - c_{z2})/d$$

where d is the distance between the pair of points measured perpendicular to the flight axis. Then if d' is the corresponding distance from, for example, the c_{z2}-point to the flight axis, the BZ-value is, by interpolation:

$$BZ = c_{z2} \pm d't$$

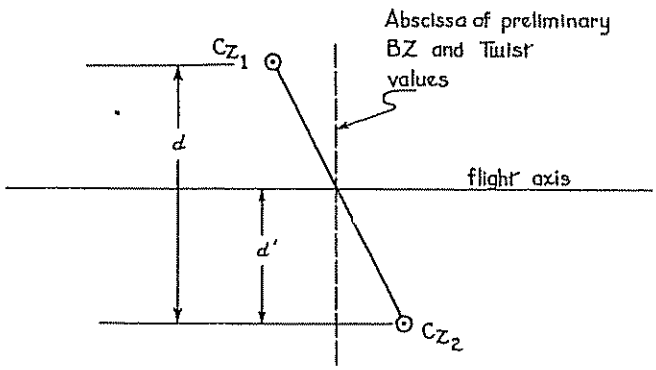


Figure 36. Elements used for determining BZ and twist ordinates

where algebraic signs apply. Slide-rule accuracy is sufficient. Thus values of ordinates are available to plot the *BZ* and twist curves opposite the intersection point on the flight line, and the curves can then be plotted. The *BZ*-curve is truly curvilinear and the twist curve approaches a straight line, sometimes bending slightly to and fro. After drawing the curves, it is necessary to check at each vertical control point:

Total vertical correction = *BZ*-correction plus (the ordinate of the twist curve times the distance the image is off axis).

Usually the check indicates a need for improvement, whence one analyses at each pair of control points what changes in the two curves are needed to produce a more agreeable solution. Frequently, one changes both curves slightly.

The alternate or practical method consists of (*a*) drawing a " raw " *BZ*-curve directly from the ^{c}z-data, (*b*) constructing a twist curve by inspection and (*c*) redrawing the *BZ*-curve, whereupon it may not be necessary to redraw the twist curve because of its secondary and smaller influence.

Thus, all six curves are drawn on the one sheet of tracing paper which was produced by the plotter during the instrument work. Liberty is taken to draw some curves intentionally in their wrong directions to avoid confusion in drafting, taking precautions to apply nevertheless the proper algebraic signs. Different colours of pencils are freely used to distinguish the different curves, and frequent bold arrows are used to remind one of the signs. The corrections are all tabulated in a standard arrangement stamped beside each plotted image point, allowing them to be entered and added algebraically. To avoid mistakes in algebraic signs, it is a good practice to affix all the signs in the tabulation before any slide rule computing is done. For example, one can take advantage of the fact that all the swing corrections above the flight axis and to the right of the centre line have the same sign.

The next step is to add these corrections indicated by the sums of the tabulations to the list of instrument co-ordinates for all the images observed. The corrected instrument co-ordinates are then transformed directly into the wanted ground co-ordinates using equations 1, 2 and 3 of appendix I.

TWO NEW FRENCH PLOTTING INSTRUMENTS: STEREOPHOTO AND STEREOFLEX [1]

Information paper by the Institut géographique national, France

The use of equipment and techniques for aerial photogrammetric plotting was originally conditioned by the problems arising in the economically most developed countries: those of Europe, and the United States. In order to solve these problems, universal plotting instruments were developed which made it possible to perfect methods of compiling large-scale and medium-scale maps (over 1 : 25,000) with a degree of accuracy and speed that represented a considerable advance over earlier methods and which were perfectly suited to their purpose.

Despite some experiments of an essentially local nature, it was not until 1945 that the use of aerial photogrammetry was seriously considered as a solution to the problem of map-making in under-developed territories. In response to the urgency of the needs in this respect there has been a rapid extension of good-quality photographic coverage to increasingly large areas, and existing equipment has been used for plotting. The practical experience gained has proved beyond dispute that large first-order or second-order instruments can also be effectively used for the rapid preparation of accurate small-scale maps of very large areas.

It may, however, reasonably be asked whether this equipment is that best suited to conditions in the under-developed countries, which differ greatly from those in the European countries or the United States.

In making large-scale maps it is always desirable to use instruments providing the maximum accuracy in plotting because every increase in mechanical precision results in an increase in the over-all efficiency of all the successive operations. It means that a map of the desired degree of accuracy can be made from photographs on a smaller scale, which has the considerable advantage that a given area can be covered with fewer pictures. The capital cost of expensive instruments is thus soon offset by the increase in efficiency.

This advantage is lost in the case of small-scale maps because the photograph scale cannot be reduced below a certain point, which is determined by the capabilities of the photographic aircraft and the necessity of identifying small details for inclusion in the map.

In these circumstances the use of a high-precision plotting instrument will, other things being equal, provide an unnecessary degree of accuracy. There is therefore some advantage in using a lower-precision, less expensive instrument, *provided that the lower-precision instrument is at least as efficient and convenient in use as the other*; if this essential proviso is not satisfied there will be no real saving on the over-all cost of the operations.

A great many attempts have been made in the past to build " simplified " plotting instruments, with the avowed aim of providing users with a means of compiling plans from aerial photographs that would be both cheap and usable by operators with little knowledge of topography or photogrammetry.

In most instances, however, experience with such instruments has been very disappointing. Their productivity has as a rule been substantially lower than that of first-order or second-order instruments; the quality of the results has often been considered inadequate even for small-scale maps, especially as regards the fidelity of the representation of ground forms, an essential element in such maps. The efficiency and quality of the work often depend on the operator so that, in the main, good results can be achieved only by highly skilled personnel.

The unsatisfactory results appear to be attributable to the design of the instruments. To keep size to a minimum, the makers have discarded the traditional principle of stereoscopic plotting, that is, the reconstitution of the perspective rays in space and the formation of a " model ", resembling

[1] The original text of this paper, submitted by France, under the title " Deux nouveaux appareils français de restitution: le Stéréophot et le Stéréoflex ", appeared in French as document E/CONF.25/L.50.

the terrain, on which the measurements are carried out. The principle of approximation on which such instruments are based requires, for accurate results, the fulfilment of certain conditions; for example, the axes of the photographs must be strictly vertical, or the ground perfectly flat. In practice these conditions are never fulfilled, hence the inadequacy of the results obtained.

In order to overcome this inadequacy, the most advanced instruments of this type include devices permitting the partial correction of deformations found at a small number of points, whose co-ordinates must be assumed to be known. The disadvantage of this arrangement is that the orientation of a pair takes considerably longer than it does in conventional instruments; further, it often involves a fairly exacting process of trial and error and procedures must vary to a greater or less degree in each case. For this reason it is difficult to lay down standardized instructions and the procedure is difficult for an inexperienced operator to carry out. Moreover, deformations of level surfaces can be corrected only at the control points; away from those points, where the simplifying hypotheses on which the instrument is based are less well respected, the deformations are considerable. The results are therefore inevitably uneven and will vary with, in particular, the relief of the ground, the quality of the photographic coverage and the skill of the operator.

Lastly, the fact that the operator sees a deformed image—which he must re-touch in places to offset transverse parallax— hampers and delays plotting which is therefore normally slower than with first-order or second-order instruments.

The use of simplified instruments based on the principle of approximation therefore leads almost automatically to the following results:

The instrument, despite its apparent simplicity, is awkward to use, especially for operators with little training;

Productivity is lower than that of first-order instruments because both orientation and mapping take longer in almost all cases;

The quality of the work is uncertain and variable, being largely dependent on the relief of the ground, the quality of the photographic coverage and the skill of the operator;

A very dense network of ground control points is required;

It is difficult to lay down standardized operating procedures applicable in all cases, which means that staff without technical training cannot be used.

The only advantage of such instruments is therefore their relatively low cost, and this is soon cancelled out in the case of instruments for use by specialized mapping services which are likely to be operated at full capacity throughout the year.

Simplified instruments do not therefore provide a sound solution to the problem of rapidly producing medium-scale or small-scale maps of large areas.

From the foregoing it is clear that the type of instrument best suited to these conditions would satisfy the following requirements:

1. Provision to ensure accuracy of plotting, regardless of relief or slight tilt, for example, under 5 degrees, a requirement normally met by specialized air survey organizations. This condition is vital; where it is met, the perspective rays in space can be reconstituted and a model can be formed which is similar to the terrain, or at any rate one whose deformations are negligible having regard to the specifications of the map to be made.

2. Mechanical construction simplified by eliminating all features of conventional instruments which serve no purpose in actual plotting. Since the precision required of the plotting machine is sharply reduced by the fact that the instrument will normally be using photographs on a larger scale than the map, solutions can be adopted which would be unsuited to high-precision instruments but which make it possible to simplify construction, reduce the cost and produce a much more compact instrument.

It is essential, however, that the instrument should be simple and easy to operate so that operators with little technical training can be employed. This condition is almost automatically satisfied: since the instrument is on the same principle as conventional instruments, the conventional methods of operation can be used.

3. Clear viewing system with a broad field so that full advantage can be taken of the definition of the photographic image, which rules out the projection of real images on to a screen. It is also most important to be able to see a large portion, if not all, of the model at once; in a great many cases this will make it possible to orient the model very quickly by eye, without ground control, on the basis of simple topographical considerations (for example, direction of flow of rivers in flat country). If this requirement is met, it may be possible to cut down the ground control network considerably; this is a great gain, because in the case of general maps on a scale of, say, 1 : 200,000 or less it may be feasible to dispense with preliminary aerial triangulation and to use only a low-density network which can easily be established in various ways according to circumstances. If this procedure is to be followed, it is obviously essential that the model should be free of any appreciable deformation.

These were the guiding principles underlying the design and construction of the two plotting instruments described below: the SOM Baboz Stereophoto and the SOM Masson D'Autume Stereoflex.

The Stereophoto

Principle

The principle of the Stereophoto is as strict as those adopted for conventional first-order and second-order instruments, but it permits major mechanical simplifications. These simplifications are made possible by an optical device whereby the photographs can be viewed in a fixed plane regardless of their orientation on exposure; as a result all the articulated supports usually used to recover that orientation can be dispensed with, and a completely independent viewing device, consisting of a simple stereoscope, is used.

The principle of the instrument is illustrated in figure 37.

Two arms, S_1M and S_2M, representing the homologous perspective rays in space, pivot about points S_1 and S_2 and meet at the reconstituted ground point M.

Two collimators, C_1 and C_2, pivot about two fixed points, I_1 and I_2, and are kept permanently parallel to the arms by

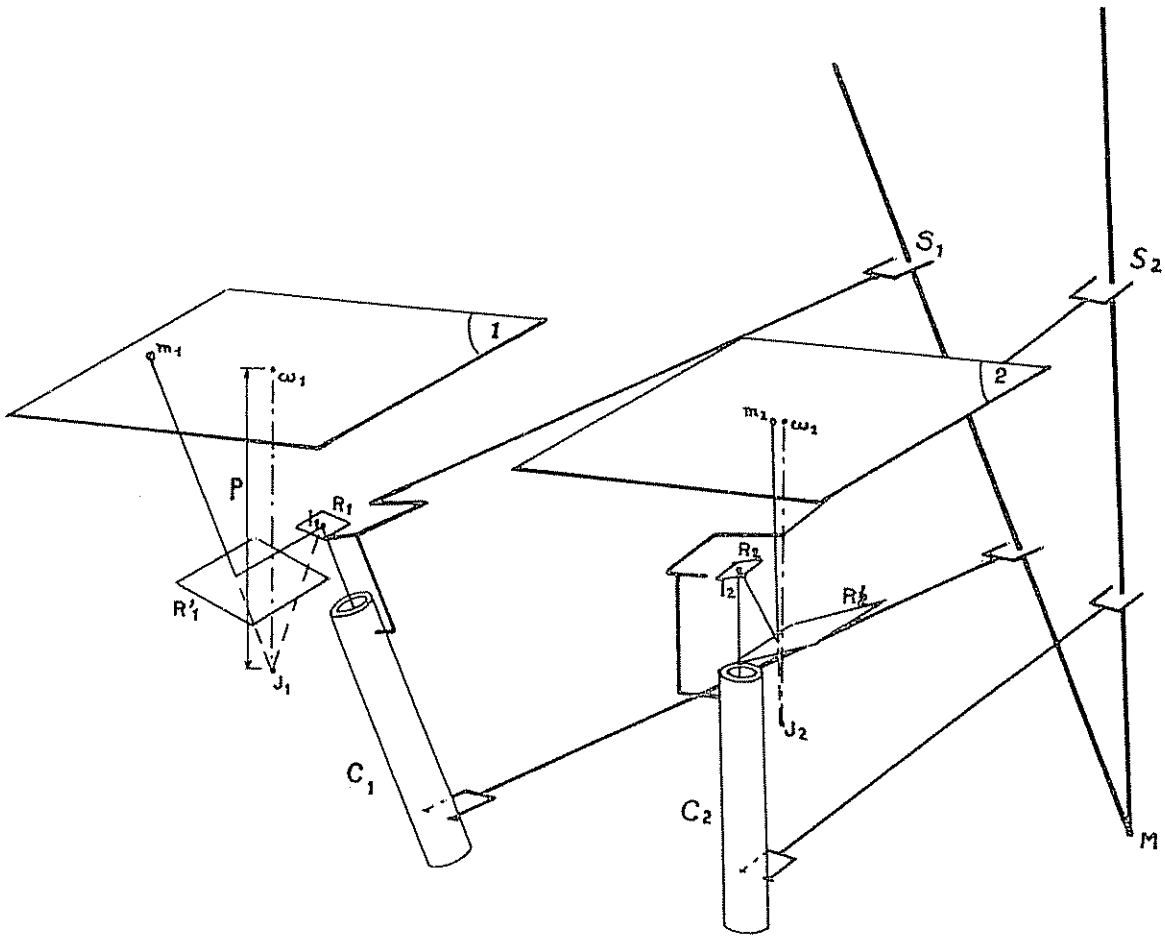


Figure 37. Diagram showing the principle of the Stereophoto

articulated parallelograms. The axis of the pencil of light which they project parallel to the corresponding arm meets a small mirror R at I and then, after reflection, a second mirror R', and finally intersects, in the plane of the photograph, a small luminous mark m, which constitutes the stereoscopic index in the observation of the photographic pair. Each photograph is placed at the principal distance p from the point J, the image of I through the mirror R'.

If the axes of photography are not tilted from the vertical at all, the two mirrors R and R' are parallel and the direction $J\,m$ is parallel to the axis of the collimator and thus to the arm. The components of the tilt of the axes of photography are introduced by rotating the small mirrors R, mounted on universal joints, about the points I, so as to impart the desired direction to the conjugate (in the collimator-arm medium) of the principal axis $J\omega$ in relation to the two mirrors R and R'.

Rotation of the mirrors R does not affect the position of the points J or, consequently, the interior orientation elements. Hence the photographs, regardless of their orientation on exposure, are observed in a fixed plane and the binocular microscope, which no longer incorporates the viewing mark, is used in the measurements only to check the stereoscopic contact between the mark and the ground.

Mechanical construction

The essential features of the instrument are:

A fixed lower table to hold the horizontal planes which act as guides to the guide-block of the arms and to the horizontal control device, whose movements are transmitted to the conducting-block by the double parallelogram, and the map-board; the movements of the guide-block are transmitted to the tracing-stylo by an adjustable-ratio (1/5 to 1/1) pantograph;

An upper frame, movable in the Z direction by means of three pedal-operated threaded rods, and bearing two base carriages which, in turn, carry the photograph holders, the guide-sleeves of the arms, and the observation stereoscope.

A photograph of the instrument is shown as figure 38.

Operation

Orientation of the pairs is effected in the same way and according to the same rules as in conventional instruments. The model is formed by setting the three orientation elements relating to each perspective ray: site and convergence by rotating the small mirrors R, swing by rotating the photographs in their own plane.

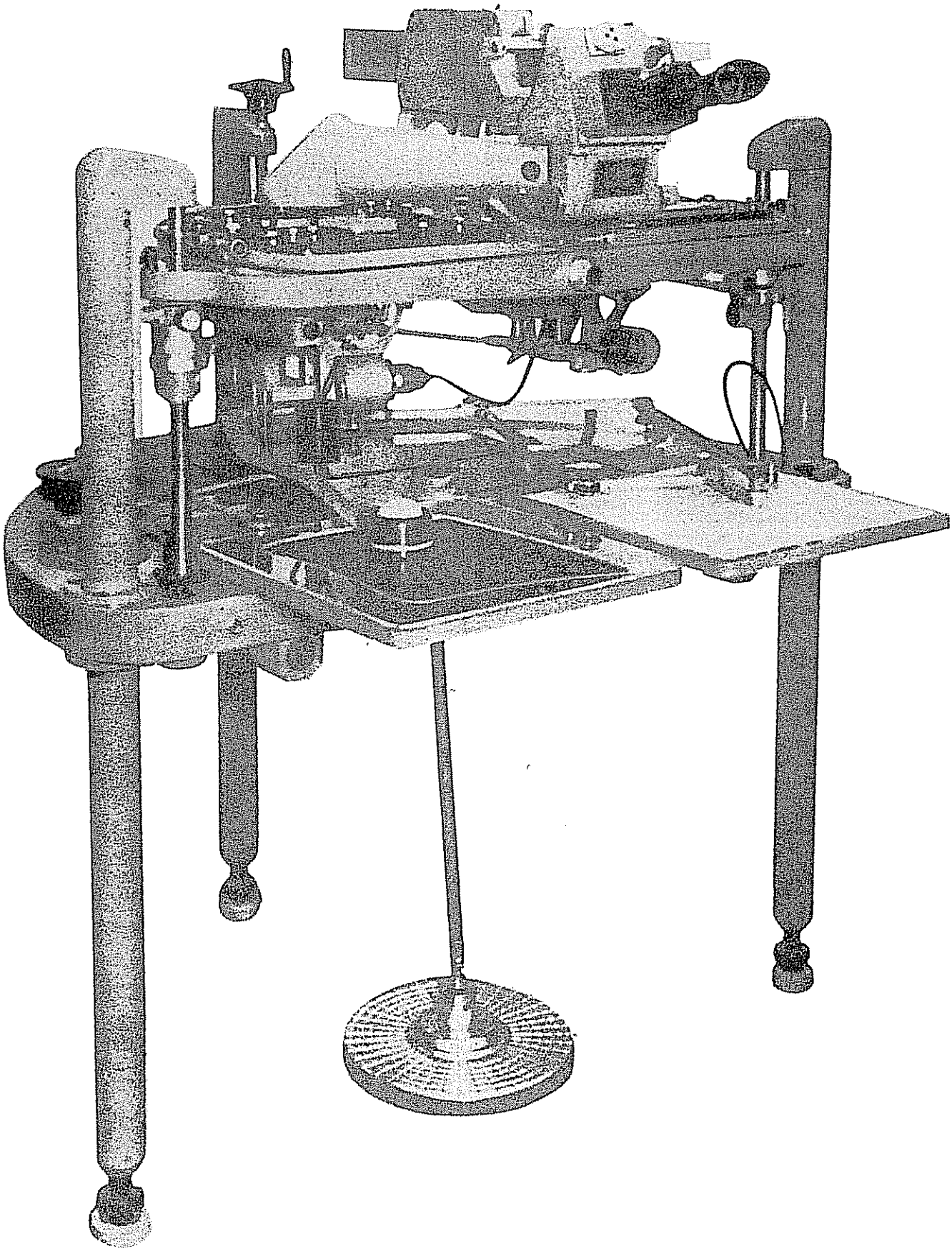


Figure 38. The Stereophoto

The model is then reduced to scale rapidly and precisely by moving the base carriages parallel to the x-axes (there is no by or bz).

Lastly, the absolute orientation of the image is obtained through the rotation of the upper frame by means of three screws with which longitudinal and transverse tilting motion can be controlled separately.

The Stereophoto can plot negatives or paper prints of any format up to 24 by 24 centimetres; the principal distances may range between 110 and 155 millimetres. No device to correct distortion has been included because the effect of distortion is negligible with most modern photographic lenses; it would be possible, however, to produce a pressure plate in a suitable form to take into account any appreciable distortion.

The tilt of the photograph axes may range up to $\pm$ 6° from the vertical, and base tilt up to $\pm$ 5°.

The magnification of the binocular microscope is 2.5 and its field 90 millimetres in the plane of the photographs; this has the great advantage that the operator can view a large portion of the model at once, at a magnification which enables him to make full use of the definition of the photographic image.

Practical trials

The National Geographical Institute conducted some brief trials with the first production model of the Stereophoto in July 1958 (the prototype appeared in 1956 and has since been greatly improved).

These trials involved:

1. The orientation of a dummy pair consisting of two identical photographs. In this case the model should be strictly plane, the effect of distortion being entirely eliminated. From the mean of plots of thirty-five details scattered all over the surface of the pair it was calculated that the accuracy of height measurements corresponded to a mean square error of 3.5 hundredths of a millimetre in the plane of the photographs, or a mean vertical error of approximately H/3,500, where H is the flight altitude.

The altimetric precision of the instrument may thus be estimated at approximately one-third that of a first-order instrument.

2. The orientation of two genuine pairs photographed with a 19 by 19 mapping camera, f = 125 mm, Aquilor lens, photograph scale approximately 1/30,000. Formation of model, reduction to scale of 1/20,000 and absolute orientation on six control points determined on the ground. Mapping of the main planimetric lines, altimetric readings on 54 control points determined in the field or by plotting in a Poivilliers type B stereotopograph.

The results were as follows:

Time taken to orient a pair, including all operations: 30 to 40 minutes;

Planimetric map exactly comparable with plotting by first-order instrument. Mapping time identical;

Mean square error in control point heights: 2.25 metres. Much of this discrepancy, however, is due to the considerable distortion of the camera lens, which systematically deforms level surfaces.

The results show that the planimetric accuracy of the Stereophoto is of the same order as that of conventional second-order instruments; the altimetric accuracy is lower but perfectly adequate for plotting on scales of 1 : 50,000 from photographs on the same scale, or for plotting on scales of 1 : 100,000 to 1 : 250,000 from photographs on the smallest possible scale.

The ease of operation, the speed of orientation and mapping which is independent of the relief and the tilt of the photograph axes, the field of the viewing system and the degree of accuracy, combined with the compactness and price, which is considerably lower than that of conventional second-order instruments, make the Stereophoto an ideal instrument for map-making on a scale of 1 : 50,000 or 1 : 100,000 from a network determined by aerial triangulation, where speed is important.

The Stereoflex

Principle

The principle of the Stereoflex, an instrument designed for very small-scale plotting (1 : 200,000), is shown in figure 39. The photographs of the stereoscopic pair are set face to face in two lateral planes and examined through two half-silvered mirrors M_1 and M_2, which are tilted at 45° and reflect the rays upwards. The images of these photographs, which they give lie at a distance P from the operator's eyes, O_1 and O_2; P is an instrumental constant equal to 300 millimetres, and the perspective rays of apices S_1 and S_2 respectively (near O_1 and O_2) are anamorphosed in the ratio $K = \frac{P}{p}$, p being the principal distance of the camera.

It is demonstrated that, within certain limits of tilt of the photograph axes and of ruggedness of terrain, a model can be formed by adjusting the normal orientation elements of these two rays: site and convergence by rotating the photograph-mirror assembly around rectangular and horizontal axes passing through the point of vision S, swing by rotating the photograph in its own plane around its centre ω; the relative orientation thus obtained is different from the relative orientation of the rays in space. This model merely undergoes a refined transformation in Z in relation to the similar image on the ground.

The model is observed simultaneously with a small light-source A, which is seen directly through the semi-reflecting surface of the mirrors and constitutes the stereoscopic index.

The horizontal movements of this source are recorded with a tracing-pencil on the drawing-board, while the vertical movements are read off a height scale.

In order to see the photographs and light index without parallax, the planimetric scale of the model must be approximately equal to that of the photographs, which means that the distance $S_1 S_2$ must conform to a certain figure. In these circumstances the observer's eyes O_1 and O_2 do not coincide exactly with points S_1 and S_2, but it can be demonstrated that the decentralization thus introduced in the position of the real perspective centres O_1 and O_2 in relation to the photographs does not destroy the model, and deforms it only by quantities which may be considered negligible provided that the ruggedness of the terrain does not exceed 1/10 of the flight altitude.

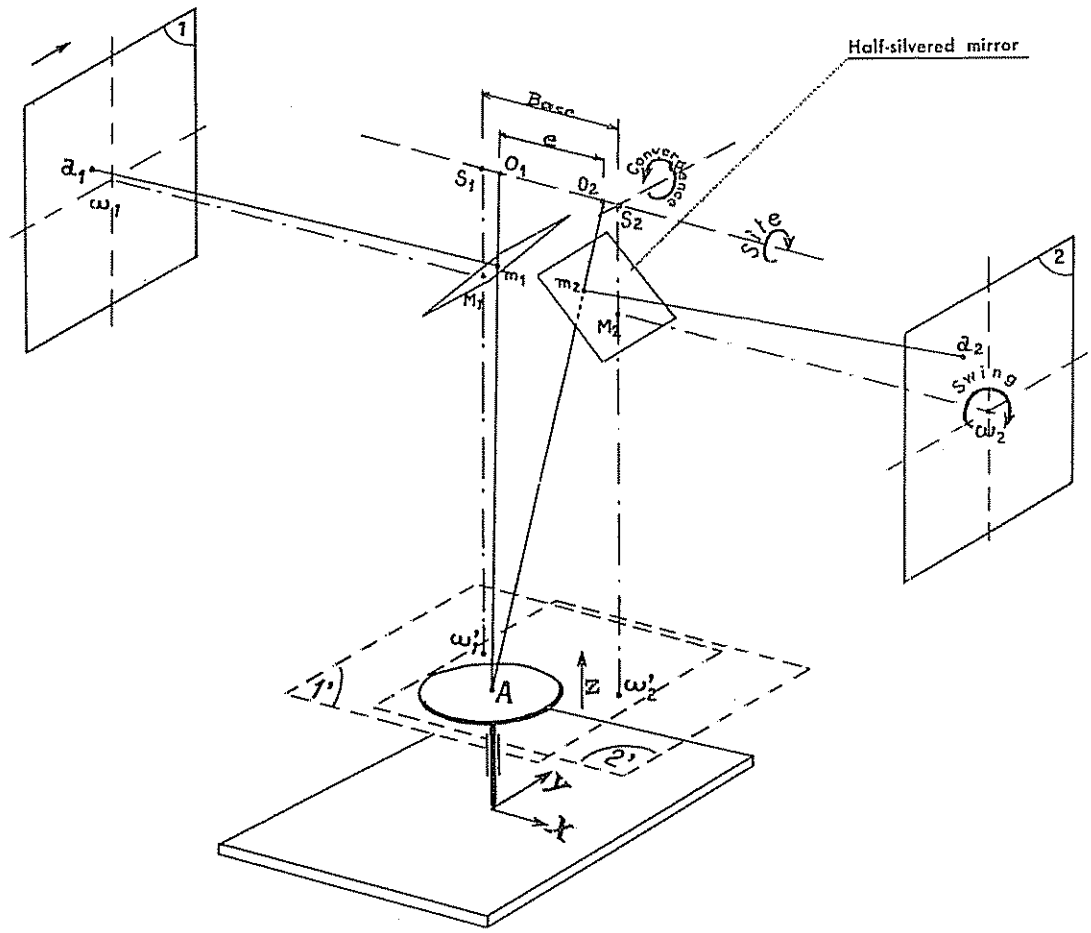


Figure 39. Diagram showing the principle of the Stereoflex

To sum up, the Stereoflex enables us to form, by the usual means, a model which, while not similar to the terrain, differs from it only as follows:

1. The scale of relief is increased in proportion to the horizontal scale in a ratio which is exactly known if the axes of the photographs are strictly vertical;

2. If the axes are tilted, there are additional deformations which may be ignored provided that the tilt is slight (under 5°), the unevenness of the terrain is less than 1/10 of the flight altitude, and the survey is on a very small scale. These conditions are almost always satisfied except in very mountainous country.

The anamorphosis of the perspective rays which brings about the related transformation of the image is essential because the eye, which is the apex of the reconstituted ray, could not adjust without excessive fatigue to a distance close to the focal length of modern wide-angle lenses; furthermore, with these lenses, the B/H ratio of air base to flight altitude is such that the effort of convergence demanded of the eyes in order to examine the model would be prohibitive.

The choice of a distance P of 30 centimetres provides the best conditions for observation and the anamorphosis, which is no problem, also increases the sensitivity of height measurements on the model.

Mechanical construction

The Stereoflex, which is simple and inexpensive to make, is under construction at SOM, and the first batch of instruments will be completed in a few months.

The instrument thus produced will be very compact (1.30 by 0.70 by 0.60 metre) and easily dismantled for shipment. The Stereoflex will be able to handle photographs of any format up to 19 by 19 centimetres, on plates, film or paper; it will be fitted with a pantograph adjustable to any ratio between 1/10 and 3/1.

Practical results

While results obtained with the final production model are not yet available, several prototypes, constructed on very simple lines to the design of the company's chief engineer, have been in use for several years at the National Geographical Institute's Brazzaville, Yaoundé and Dakar offices, and have been used to plot several sheets of the maps of French West Africa, French Equatorial Africa and the Cameroons on a scale of 1 : 200,000 from photographs on a scale of 1 : 50,000.

The orientation of a pair takes an operator of average skill about half an hour; plotting output averages three to four pairs a day, or 100 square kilometres, that is, about one

sheet of the 1 : 200,000 map (1 square degree), in four months. Plotting is almost always carried out without prior aerial triangulation; the large field of vision, which enables the operator to observe the whole model at once, facilitates the use of all the miscellaneous information available (gradients and rough profiles of rivers, topographical data, barometric points, and the like) for the absolute orientation of the pairs; the horizontal control network is obtained by radial-line slotted-templet triangulation.

In conclusion, while the potential use of the Stereoflex is limited by its very principle to the mapping, on a very small scale, of all types of country except high mountains, the characteristics described above, which have been designed expressly for such use, make it an instrument of unrivalled efficiency for the quick production of ordinary or reconnaissance maps, on a scale of 1 : 200,000, in large territories for which vertical photographs on the smallest possible scale are available.

THE RADIAL PHOTOGONIOMETER [1]

Information paper by the Institut géographique national, France

The initial and basic operation in photogrammetry is the reconstruction of the pencil of perspective rays, that is, of the cone of rays linking the camera station with each of the points of the object to be plotted. This reconstruction can be effected either by computation (analytic aerial triangulation) or by mechanical means (instrumental aerial triangulation or stereoscopic plotting). In every case, the accuracy of the result (in aerial triangulation, the co-ordinates of the points in the control network; in topographic plotting, the accurate reproduction of landforms) depends in very large measure on the accuracy achieved in reconstructing the pencils of perspective rays.

The characteristics of the pencil of perspective rays are determined by the mapping camera and by the photographic image. In order to ensure that the pencil of rays which originally entered the camera and the reconstructed pencil of rays are identical, the following conditions must be met:

1. The photographic image must be such that a given point can be defined with a high degree of precision;

2. The emulsion surface must be of the same size and shape when the photograph is taken and when the reconstruction is made;

3. The exact optical and geometric characteristics of the mapping camera must be known;

4. The method adopted for reconstructing the pencil of perspective rays must be free of error.

In recent years, remarkable advances have been made:

As regards point 1, owing to the development of high-performance lenses and to improvement of the quality of emulsions;

As regards point 4, owing to (*a*) the steady improvement in the mechanical accuracy of first-order plotting instruments; (*b*) the fact that series of uniform lenses can be produced through the application of the Porro-Koppe principle; and (*c*) the development of automatic computing methods which, in the case of aerial triangulation, make it possible to replace the former mechanical means for the solution of problems by computations that make allowance for instrument errors whose effect it was previously difficult to eliminate.

Furthermore, as regards point 2, any appreciable error can be avoided by using glass supports instead of film.

These improvements, however, will be effective only if corresponding progress is made in accurately measuring the characteristics of the mapping cameras (point 3). Up to 1940 it was generally agreed that accuracy to within one centesimal minute in the direction of a reconstructed perspective ray was sufficient. Since then, the increasingly more stringent requirements of aerial triangulation and the advances made by the optical and mechanical industry have rapidly reduced this figure to fifty centesimal seconds, and at the present time a further reduction seems desirable. This can be achieved only if some method for the calibration of mapping cameras is found which gives considerably greater accuracy and which, in particular, makes it possible to determine not only the average distorsion of the camera but also the distortion at each point on the emulsion surface. The essential consideration here is that the exact extent of irregularities of the law of distortion must be known. There must also be some way to make periodic recalibrations so that any changes in the characteristics of the camera which may occur with the passage of time can be taken into account.

With this end in view, the National Geographical Institute (Institut géographique national) asked two manufacturers to develop a new type of photogoniometer, since the old models, owing to the very conception on which they were based, could not meet modern requirements.

Description of the Radial Photogoniometer

With the aid of this apparatus, the pencil of perspective rays can be studied in each diametral plane passing through the camera axis. For this purpose the camera is placed on a circular holder which rotates about its axis and is made to coincide with the axis of the pencil of perspective rays. A network consisting of a series of concentric circles at intervals of one centimetre and of a series of diameters at intervals of twenty-five grades is placed on the focal-plane frame of the camera. In addition, intermediate diameters at intervals of 12.5 grades are drawn in the vicinity of the angles along a small portion of the radius.

Since the axis of rotation, which is identical with the axis of the camera, is vertical, the network rests against the focal-plane frame of the camera by the force of gravity and is thus

[1] The original text of this paper, submitted by France, under the title "Le photogoniomètre radial", appeared in French as document E/CONF.25/L.53.

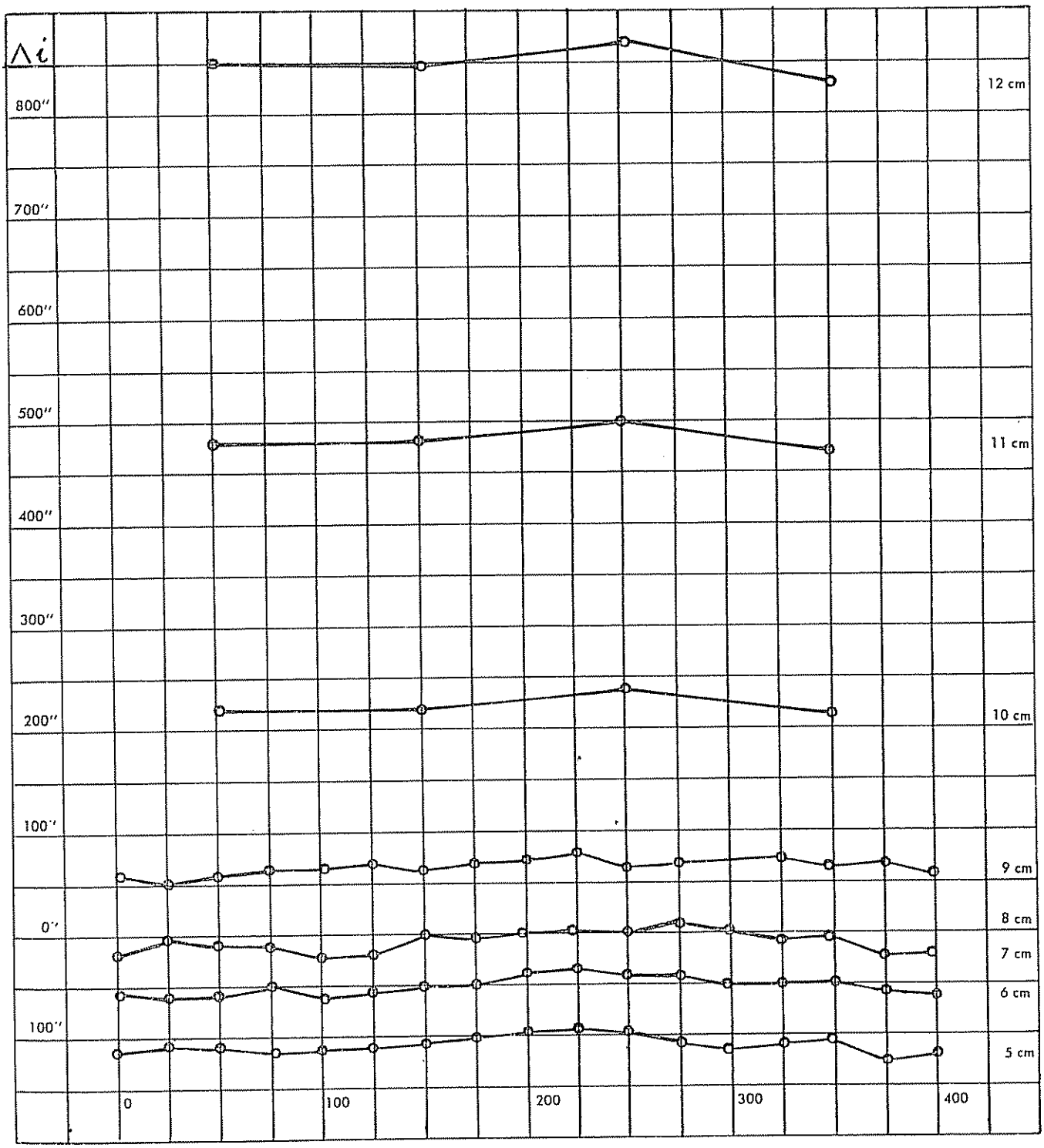


Figure 40 Distortion diagram of an Aquilor lens, f = 125 millimetres

prevented from moving even slightly while the measurements are being taken, this having been a source of error in the older types of photogoniometers. This position corresponds to that in the aircraft when the photographs are being taken.

After passing through the camera lens, the pencil of perspective rays issuing from a point on the network is received by the lens of a telescope held by an arm which pivots around a horizontal axis passing through the centre of the entry pupil of the lens. The movement along each diameter of the concentric circles is thus effected simply by pivoting the telescope arm in accordance with the settings on a finely-graduated dial that permits readings down to the centesimal second. The movement from one diameter to another is effected by rotating the camera about its axis, an operation that can be carried out with only a coarse adjustment on a graduated dial. The telescope has a twenty-power guiding eyepiece; the true accuracy of measurement of the angles of rotation of the telescope arm is ten centesimal seconds.

The apparatus comprises a number of interchangeable holders. These make it possible to switch rapidly from one type of camera to another and always to bring the centre of the entry pupil of the lens to the point of intersection of the two axes of rotation. It is thus possible to examine any of the ordinary types of mapping cameras.

Use of the Apparatus

Measurement of the principal distance and of the position of the principal point

At the National Geographical Institute, the ordinary mapping cameras are equipped with Aquilor 19 by 19 cm, $f = 125$ mm lenses. With these lenses, the distortion of which changes direction in the vicinity of the circle at radius 8 cm in the emulsion plane, a convenient procedure for characterizing the distortion of the camera is to start from the mean value of the distortion on this circle. Each diameter, at intervals of twenty-five grades, is thus successively brought into the sighting plane of the telescope, and, for each diameter, the sighting is directed towards the centre of the network and the points of the circle at radius 8 cm situated along that diameter. Let i_m be the mean value of all the angles thus measured. The compensated principal distance will then be $p = 8/tg\ i_m$. The differences $i - i_m$, which may be represented on a graph, characterize the dissymmetries of the law of distortion on the 8 cm circle.

Measurement of the distortion

The characteristics of the distortion are determined by identical measurements carried out on the other circles at as many points as are considered necessary.

If there were no distortions, the angle i measured at any point of a circle with the radius r^{cm} should be such that: $\text{tg}\ i = r/p$. If the angle measured is i', the distortion at this point is defined by:

$$\text{tg}\ i' - \text{tg}\ i = \Delta\ \text{tg}\ i$$

$$\text{or by: } i' - \text{arc tg}\ i = \Delta\ i$$

$$r/\text{tg}\ i' - p = \Delta\ p$$

$$\text{or: } p\ \text{tg}\ i' - r = \Delta\ r$$

As these definitions are all equivalent and can be represented very easily in graph form, the choice between them is determined by the procedure used for reconstructing the pencil of perspective rays at the plotting stage.

The definition adopted here for the compensated principal distance is not, of course, in any way compulsory, and the apparatus can be used equally well for measurements of distortion corresponding to some other definition of p.

Since the introduction of the radial photogoniometers at the Institute, the distortion diagrams have been given the form of a graphic representation of the quantity $\Delta\ i$. A distortion diagram is given as figure 40. The abscissae represent the azimuth, in grades, of the semi-diameter in question, and the ordinates represent the values of $\Delta\ i$ in decimilligrades. The distortion of the lens is arbitrarily designated by the $\Delta\ i$ corresponding to circle 11, which in the example given is 495″.

The radial photogoniometer represents a simple means for completely calibrating mapping cameras with speed and accuracy. In cases where the Porro-Koppe principle is used, this instrument also makes it possible to bring the distortion of the plotting lenses into agreement with a degree of accuracy better than 5 milligrades, particularly as regards the critical areas of the field, that is, those in which the distortion may be the most irregular. An instrument of this kind is indispensable to any organization carrying out aerial triangulation or photogrammetric plotting to a high degree of accuracy.

AUTOMATION IN GEODESY, PHOTOGRAMMETRY AND CARTOGRAPHY [1]

Background paper by Dr. Erwin F. Gigas

Anyone looking at an artistically drafted map sheet may be inclined to say that automation is no more feasible in map-making than in any other work of art.

But in fact this is not so because the artistic creation of a map is preceded by important calculations, for which automation has long been the desire of geodesists.

[1] The original text of this paper, submitted by the Federal Republic of Germany, under the title "Automation: Can it be realized in Geodesy, Photogrammetry and Cartography?", appeared as document E/CONF.25/L.40.

Triangulation

All mapping begins with triangulation. The exact representation of the earth's surface on a map requires a certain number of fixed points, the positions of which are determined by geodetic measurement and mathematical computation. Precise distance measurements in the field have always proved more difficult than angular measurements, because uneven ground, vegetation, buildings and the like constitute considerable obstacles. Triangulation was therefore invented at the close of the sixteenth and beginning of the seventeenth

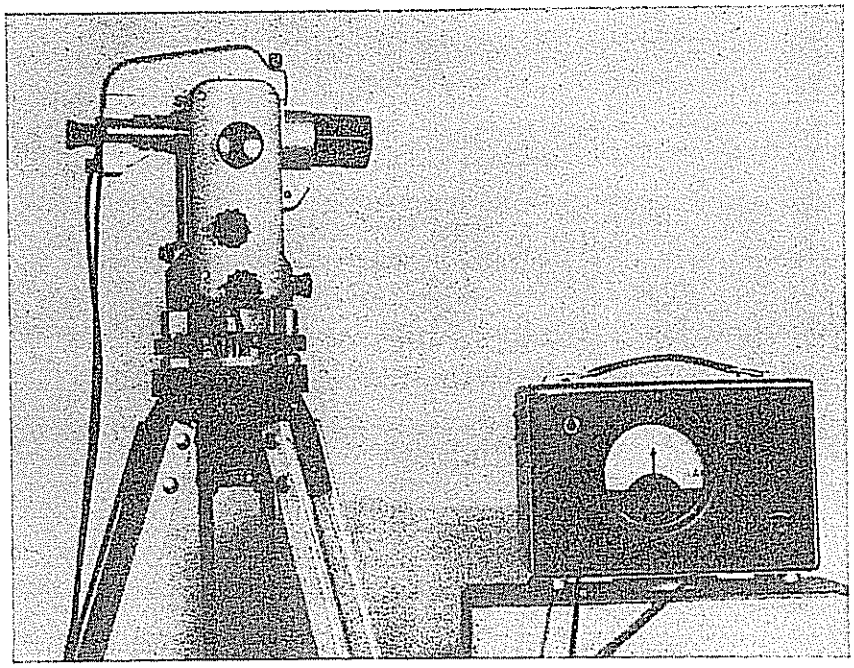


Figure 41. Electric eye in connexion with a theodolite reading directly to one cubic centimetre

century. Triangulation requires only the measurement of a comparatively short base line and, from that, it is possible to measure and compute triangles by means of pure angular measurement, mostly from elevated observation points, thus making the determination of fixed points a basis of exact cartographic representation.

Triangulation required first-class theodolites and these have been developed to perfection over the past two and a half centuries. In primary triangulation, particularly, where sides of 30 kilometres in length (and even more than 100 kilometres) were to be measured, utmost demands have been made on graduated circles. Not until recently has it been possible to manufacture graduated circles of 5 to 20 centimetres in diameter, the errors of which amount to less than one-tenth of one second.

The need for more precise graduated circles resulted from the increasing demands made on triangulation, as well as on the introduction of the " electric eye ", a device which permitted the eye of the observer to be replaced by an electronic indicator.[2]

This device was originally invented in order to substitute electronic observations for the long periods of waiting in first-order triangulation when target lights and their currently changing shape prevented the observer from measuring. These electronic observations have been connected by automatic integration for longer periods of observation (up to ten seconds). This has permitted observations to be made during periods when it was previously impossible. Moreover, increasing accuracy in reading-off has resulted, so that it has become necessary to smother by artificial damping the vibrations of the instrument, which before were imperceptible (see figure 41).

It takes more time to read the microscope of a precise theodolite[3] than to sight the target. To shorten the time of observation a photographic registration has been invented which takes only a fraction of one second. This device has increased the capacity of observation by from three to five times (see figure 42).

This instrument is designed for precise observations of primary triangulation and astrogeodetic measurements. The graduated circles have a diameter of 200 millimetres (horizontal circle) and 140 millimetres (vertical circle). The alidade bubble has a sensitivity of two seconds.

The registration device may be released by the observer as well as by wireless electric impulses emanating from a central station, that is, if in flare triangulation movable targets are continuously observed and held in cross-wires at several stations, and registration is to be made at the same moment in all stations.

Circle reading:

122° 24′	double minutes and double seconds
1′ 55.9″	
122° 25′	
0′ 55.8″	
122° 51′ 51.7″	

Figure 43 shows the microscopic image of the horizontal and vertical circles at two diametrically opposite points, as well as the position of the bubble of the alidade level. In the micro-

[2] E. Gigas, " The Electric Eye ", *Geofisica Pura e Applicata*, vol XVIII, 1950 (Milan); E Gigas and K. Ebeling, *Elektrisches Auge*, Bayer Geodetic Commission, Academy of Science, Series B-51 (Frankfurt am Main, 1957).

[3] The principle of the electric eye was described and illustrated in *United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 2, *Proceedings of the Conference and Technical Papers* (Sales No.: 56 I 23), pages 54 and 55

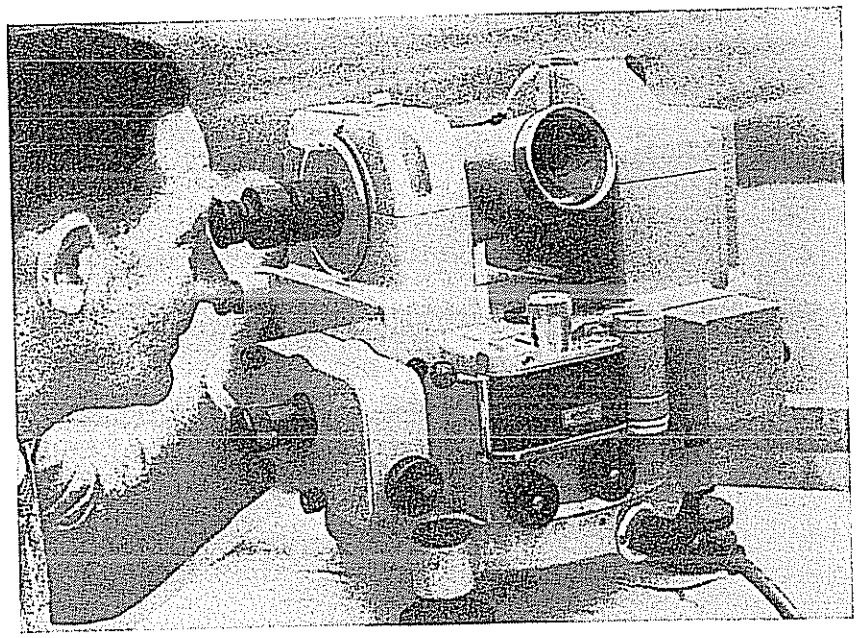


Figure 42. Theodolite with photographic registration

meter of the theodolite or in a separate special reading device the coincidence of the diametrically opposite divisions is established. The film constitutes a faultless observation document, the checking of which is possible at any time.

The photographic registration of the tedious microscope readings,[4] the electric sighting of the target, and a device to rotate the alidade following from simple mechanical laws now permit full automation of first-order triangulation.

Distance Measurements

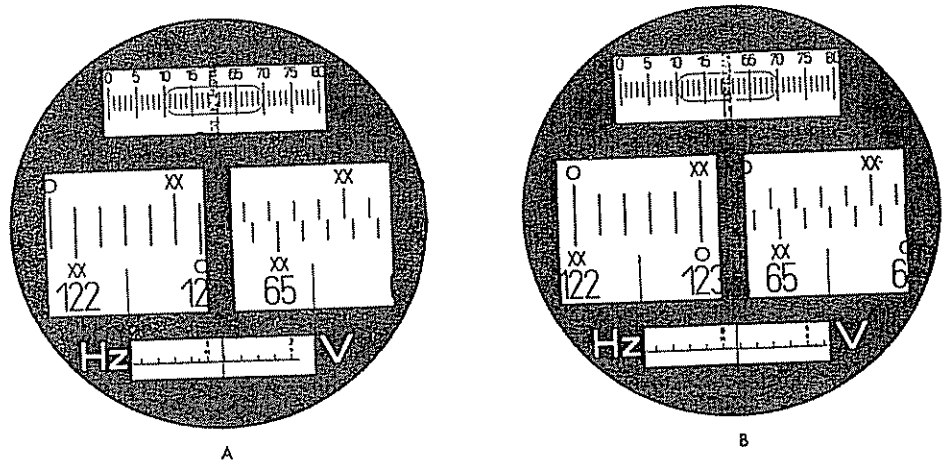
Full automation of the filling-in triangulation by small triangle nets and traversing cannot yet be realized. However, the invention of electronic distance measurement devices, such as the geodimeter,[5] the tellurometer,[6] and the electronic distance meter,[7] has, at least, increasingly simplified the measuring operation.

[4] E. Gigas, "Theodolites with Photographic Registration", *Bulletin géodésique*, Nos. 15, 16 and 17, 1950.

[5] E. Bergstrand, "Measurement of Distance by High-Frequency Light Signalling", in *Proceedings of the Baltic Geodetic Commission*, 1944-1947, and "A Determination of the Velocity of Light", *Arkiv för Fysik*, vol. 2, No. 15, 1950; E. Gigas, "Die Entwicklung des Verfahrens zur Messung von Distanzen mittels hochfrequenter modulierter Lichtwellen", a paper presented to the X General Assembly of the International Union of Geodesy and Geophysics (IUGG), Rome, 1954.

[6] L. T. Wadley, "The Tellurometer System of Distance Measurement", *Empire Survey Review*, vol. XIV.

[7] E. Gigas, "Die Entwicklung des Verfahrens zur Messung von Distanzen mittels hochfrequenter modulierter Lichtwellen", op. cit.



A B

Figure 43. Field of view of the reading microscope (one-third of actual size) when coincidence of the horizontal circle is set (A) and when neighbouring coincidence of the horizontal circle is set (B)

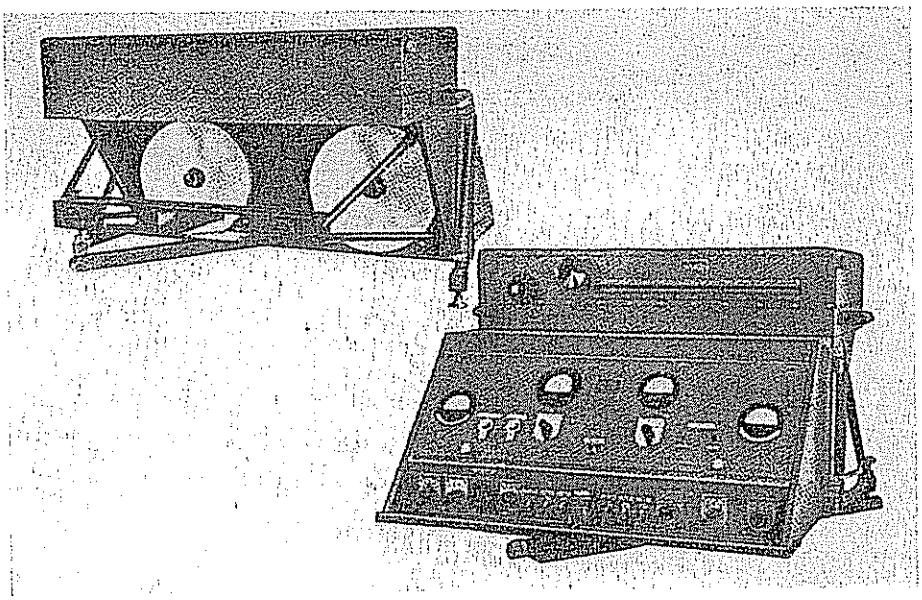


Figure 44. NASM 2 instrument

The geodimeter

Figure 44 shows the NASM 2 instrument,[8] based upon a principle used about fifty years ago for the first time by German scientists to determine the velocity of light. Bergstrand applied this method to measure distances of up to forty kilometres in length by instruments to be used in the field. The disadvantage of this procedure lies in the fact that it is applicable only during the night, and the size and weight of the instrument renders its operation difficult. Its accuracy, however, is high. Its range is up to fifty kilometres.

Figure 44 shows the instrument with switchboard, at the lower right. At the upper left is shown the reverse side, with the two reflectors which emit the modulated light waves and receive them again after they have passed over the distance, have been reflected at the end point and have returned over the distance.

Figure 45 shows the principle of this method. A light source L emits luminous rays which are collected by the lens O_1 and polarized by the Nicol prism N_1. At the focus a Kerr cell (Kz) is placed—a small glass vessel, filled with nitrobenzene, into which two electrodes are dipped and to which a high alternating voltage is applied. An alternating voltage of high frequency rotates the plane of oscillation of the polarized light with the same frequency, so that the analysator (Nicol prism N_2, at an angle of 90 degrees to N_1) placed behind the Kerr cell prevents the light from passing through the objective O_2 unless a voltage is acting on the Kerr cell. Thus, the alternating voltage of high frequency affects the high-frequency modulation of light. The wave-length of the modulated light is about forty metres; a maximum of light occurs at every half of the wave-length ($\lambda/2$), and a minimum dephased by $\lambda/4$. The modulated light passes through the distance to be measured, reaching the remote station B. There a mirror reflects the light, which is received by O_3 and the photoelectric cell (PZ). The resulting photoelectric current is amplified nearly a million times in a secondary electron multiplier and is conducted to a zero indicator.

Within the zero indicator a comparison of the emitted and returning waves takes place. In general a difference of phase will appear; for only when the distance is an integral number of halves of the wave-length will the difference of phase be zero. The double length of the distance to be measured is:

$$2E = n \cdot \frac{\lambda}{2} + R$$

where n is the unknown number of half waves and R is the remainder affecting the difference in phase. By inserting the light retarder LV, effecting a variable retardation of the emitted light with respect to the originally generated phase, the remainder R may be eliminated, that is, phase coincidence may be achieved, the indicator of the galvanometer A being in zero position. The amount of variation in LV is in proportion to R. Unless the distance E is approximately known, allowing n to be computed, the measurement has to be repeated with changed frequencies. The constancy required for the high frequency is controlled by a quartz crystal (Kr) in the oscillator (OSC). The elimination of electric retardations within the instrument is performed by an electric compensator of retardation (EV).

The tellurometer

In place of the modulated light waves used by the geodimeter, the tellurometer applies modulated electromagnetic waves. It may be operated in daylight or by night, and through mist and haze. The accuracy is about one decimetre. Its range extends up to fifty kilometres.

An electromagnetic wave with a frequency of about 2,800 Mc/sec (1 dm-wave) after modulation with 10 Mc/sec and 9,999 Mc/sec, 10 Mc/sec and 9,990 Mc/sec, and 10 Mc/sec

[8] Manufactured by the Aga Company.

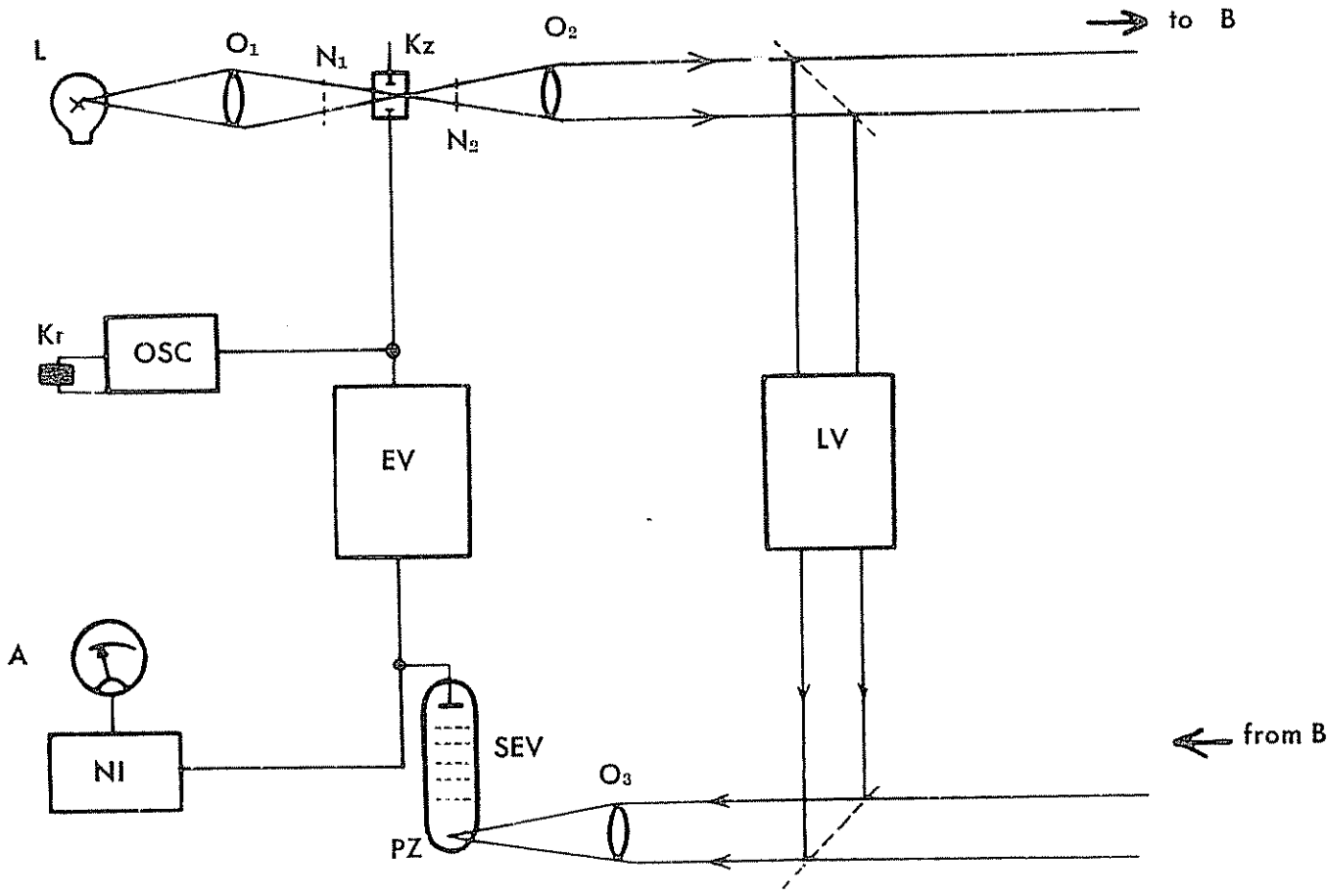


Figure 45. Diagram of the geodimeter

and 9,900 Mc/sec is emitted through the distance to be measured, received at the end point of the distance, where a remote station is set up, amplified and reflected with slightly changed frequency. At the master station the transit time is indicated on an oscilloscope and read off. The difference between the frequencies A and B (1 Kc/sec) as reading difference gives the simple distance in miles ($\sim$1.6 kilometres) if the rotation of the ray corresponds to 2,000 miles (3,200 kilometres), the scale being divided into 1/100 parts. The difference between the frequencies A and C yields 1/10 mile (0.16 kilometre), and the difference between A and D, 1/100 mile (16 metres).

The pattern frequency is 10 Mc/sec. One full rotation of the electronic ray on the oscilloscope represents $^1/_{10}$ μsec$\approx$ $^{30}/_{2}$ metres = 50 feet. Thus one minor scale division is equivalent to 6 inches or $\sim$0.15 metre up to 0.16 metre. The equipment operating with frequency modulation also permits radiotelephony between master and remote stations. The quartz crystals control the emitted frequency, indicated in the klystron of the carrier frequency of $\sim$2,800 Mc/sec generated in the oscillator. Master and remote stations are nearly alike. By changing the frequencies of the remote station by 1 Kc/sec another amplitude-modulated oscillation of 1Kc/sec may be generated in addition to the frequency-modulated oscillation. Therefore one finds links for elimination of the amplitude-modulated and frequency-modulated oscillations in the receiver unit (see figures 46 and 47).

The EDM instrument

The EDM instrument (electronic distance meter) applies the modulation of light in the same way as the geodimeter, but by a special arrangement of its elements it can also be used in daylight. Especially designed for precise traversing, its range extends from 200 to 4,000 metres in length with an accuracy of $>$2 centimetres. The EDM (formerly called EM_c) instrument was reported on at the Mussoorie Conference.[9]

The Nicol prism shown in figure 45 is removed to the reception unit, thus enabling the instrument to be used in daylight.

Furthermore, the frequency of the modulated wave is made variable. After having established phase coincidence for frequency F_1, the frequency is changed in such a way that the existing n wave cycles are now replaced by $(n + 1)$ or $(n - 1)$, and subsequently $(n + 2)$ or $(n - 2)$, wave cycles

[9] A diagram and a side view of the instrument may be found in *United Nations Regional Cartographic Conference for Asia and the Far East*, vol. 2, *Proceedings of the Conference and Technical Papers*, page 59.

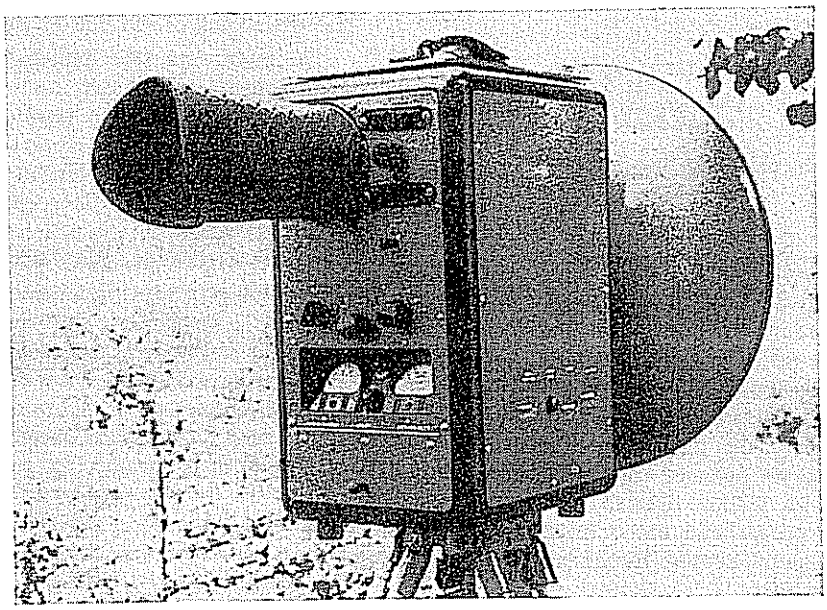


Figure 46. Side view of the tellurometer

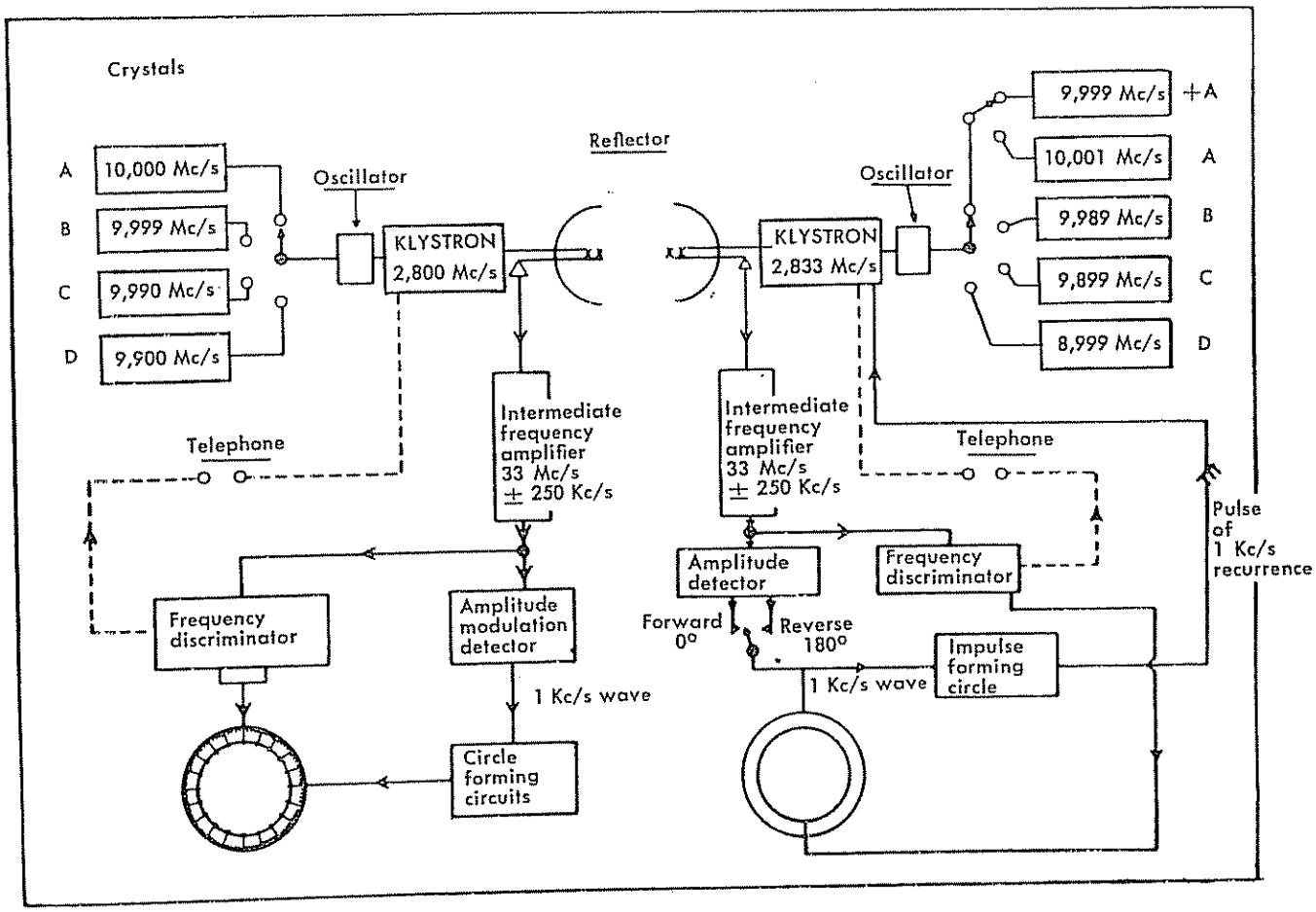


Figure 47. Diagram of tellurometer circuit

with measured frequencies F_2, F_3, and so on. From this the required value n and the distance E can be computed independently several times:

$$2E = \frac{n \cdot \lambda_1}{2} = \frac{(n+1)\,\lambda_2}{2} = \frac{(n-1)\,\lambda_3}{2} = \frac{(n-2)\,\lambda_4}{2} = \ldots$$

λ_i is computed from the measured frequency $f_i = \frac{c}{\lambda_c}$, where c is the velocity of light.

Automatic Computers

Geodetic measurements require computations. One hundred and fifty years ago arithmetical artists were employed to accomplish these extensive tasks. Later, calculating machines facilitated computing operations; but one may speak of automation only where the results of observations, after having been recorded on punched cards or magnetic tapes, are fed into machines without human aid and machined according to a fixed programme, and computed and printed for further practical use. This step has already been realized several times.

In photogrammetry the measured points are automatically recorded by their co-ordinates in the machine system, stored on punched cards or tapes, and transformed into the national system without any special assistance. The automatic computation of co-ordinates and subsequent automatic plotting may serve as another example. In this field many other suggestions might be given and nearly every day new possibilities of application arise.

Levelling

In the past, as today, extensive levellings were necessary to determine the elevation of fixed points. But in this field, too, automatic methods have been developed. At present the use of automatic levels avoids the constant control of centring the bubble. Since the Zeiss Company produced its level No. 2 (Ni 2),[10] many manufacturers of geodetic precise instruments have tried to realize the principle of automatic horizontalizing of the line of sight in different ways.

The instrument (see figures 48 and 49) requires only an approximate levelling, yet the line of sight always remains in an accurate horizontal position. The rectangular prism suspended by four wires automatically corrects the line of sight when it is temporarily deflected from the horizontal position by the sun's rays or other external influences. The mean error for double levelling has been established by different observers to be about $\leqq \pm 0.5$ millimetre per kilometre.

The Johnson elevation meter[11] developed in the United States[12] demonstrates full automation. This instrument automatically records the profile along a travelled distance. The first developments show a measuring vehicle towing a three-wheel trailer (see figure 50). Two of the three wheels are on one side, the third wheel mid-way between these on the other side of the trailer. A pendulum mounted on the left side of the trailer generates an electric current proportional to the sine of the slope. This current is conducted to a measuring device mounted in the towing vehicle where an indicator may be read off or a diagram recorded. The road distance travelled is measured by the rear wheel of the trailer. Proportional to the speed of the vehicle, impulses generated at different intervals are conducted by contacts of the rear wheel to the diagram in the towing vehicle.

The device has been in field use for six years. An innovation combining towing vehicle and trailer in one is at present undergoing field tests with the United States Geological Survey.

[10] M. Drodofsky, " Präzisionsnivellier Zeiss Ni 2 ", *Zeitschrift für Vermessungswesen*, 1957, page 430, and " Neue Niv.-Instrumente ", *Zeitschrift für Vermessungswesen*, 1951, page 225; H. Ochsenhirt, " Untersuchung des Zeiss-Niveller 2 ", *Zeitschrift für Vermessungswesen*, 1956, page 348. In addition, reference may be made to information regarding complete practical details issued by the Zeiss Company for the use of its level No. 2.

[11] Manufactured by the Sperry Sun Well Surveying Company.

[12] United States Department of the Interior, Geological Survey, Topographic Division, *Instructions for Fourth-Order Levelling with the Johnson Elevation Meter*.

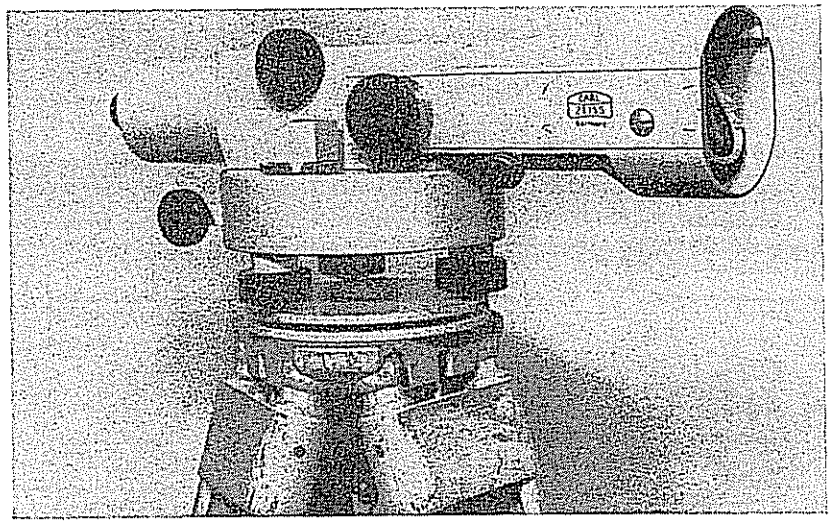


Figure 48. Zeiss automatic level, side view

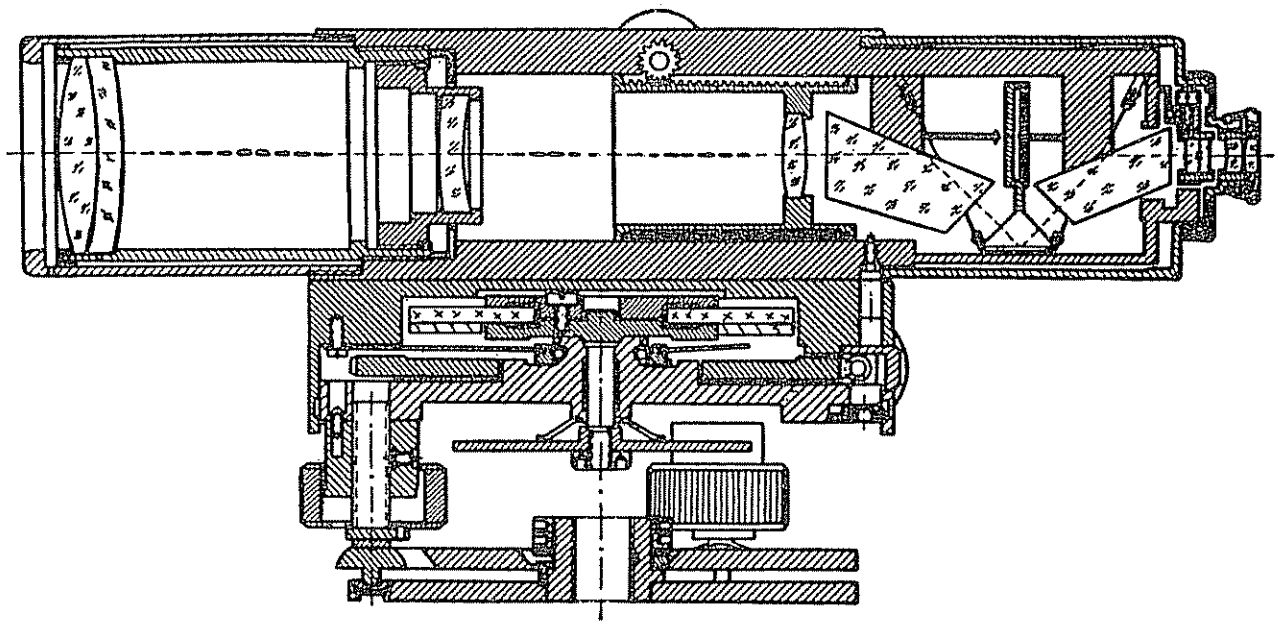


Figure 49. Diagrammatic sketch: Section through Ni 2 with graduated circle

The accuracy of the device depending on the condition of the ground seems to be satisfactory for many purposes.

In the Union of Soviet Socialist Republics,[13] too, similar automatic levelling devices have been produced. The principle of the Soviet device is shown in figure 51. Its basic idea is to measure the distance by revolutions of the wheel and to determine the appropriate slope α by means of a pendulum for each road distance travelled ΔS_i.

Figure 51 shows the pendulum (1), ending in a thin wire touching a globoidal drum (2) uniformly rotated by a motor (3). The groove (4) represents a contact line. A relay (5) is operated by every contact with the pendulum wire. This part of the diagram (1 to 5) must be imagined as perpendicular to the picture plane. The lower part of the figure is in the drawing plane and comprises electromagnetic integration sockets (6) and (7), so that the result of levelling is directly recorded or registered.

$$\Delta h = \int_A^B \sin\alpha \cdot ds.$$

The distance measurement is made by determining the revolutions of the wheel (9). The result is also conducted by the reductor (8) to the integration sockets (6) and (7), their rotation being controlled by the reductor; (10) represents the armature of the socket. Elevation is measured in counter (11), the travelled road distance in counter (12). The result of levelling is recorded on a tape of photographic paper (15). The optical system of projection is indicated in (14). The light cylinder (13) effects the transformation of the angle of rotation into a linear displacement. It consists of an opaque cylinder, the surface of which is pierced in screw-lines at two diametrically opposite places. As a result, an automatically recorded profile is obtained.

[13] W. J. Schillinger, S. M. Kusnezow and G. S. Neimann, "Nivelirowanie vysotomerom-awtomatom (WA-IM) ustanowlennym na automobile", *Geodesija i Kartografija*, vol. 5, 1957, page 30.

Long-distance levellings across wide water areas have been successfully performed by means of hydrostatic levelling.[14] As long as twenty-five years ago, full automation of these observations had been achieved. The action of the hydrostatic heads in the communicated tube system was indicated by electronic devices and automatically recorded in diagrams.

A plumb or rubber tube is first evacuated, filled with water free of air and bubbles, and then placed on the bottom of the sea. The tips of the tube are connected with glass tubes. As the water level varies with tides and atmospheric changes these variations are recorded continuously over a period of several days. Considerable accuracy is obtained. The mean error for distances of twenty kilometres amounted to only a few millimetres. However, this method necessitates special attention when changes in temperature occur in vertical sections of the tube (see figure 52).

Photogrammetry

The old topographic methods, such as tacheometric and plane-table surveying, are seldom applied today. Photogrammetry now constitutes the only quick and equivalent substitute.

Tests to realize as far as feasible the automation of photogrammetric plotting seem to be especially important undertakings in geodesy. Tedious plotting operations are to be replaced by automatic methods. When considering the historical development of automation, mention should be made

[14] N. E. Nörlund, *Hydrostatic Nivellement over Store Baelt*, 1945; G. Scheel, *Systematische Fehler des hydrostatischen Nivellements und Verfahren zu ihrer Ausschaltung*, Bayer Geodetic Commission, Academy of Science, Series B-27, 1956; H.-U. Sandig and G. Scheel, *Hydrostatische Elbübergänge im Rahmen des Nordseekünstennivellements*, Bayer Geodetic Commission, Academy of Science, Series B-33, 1957.

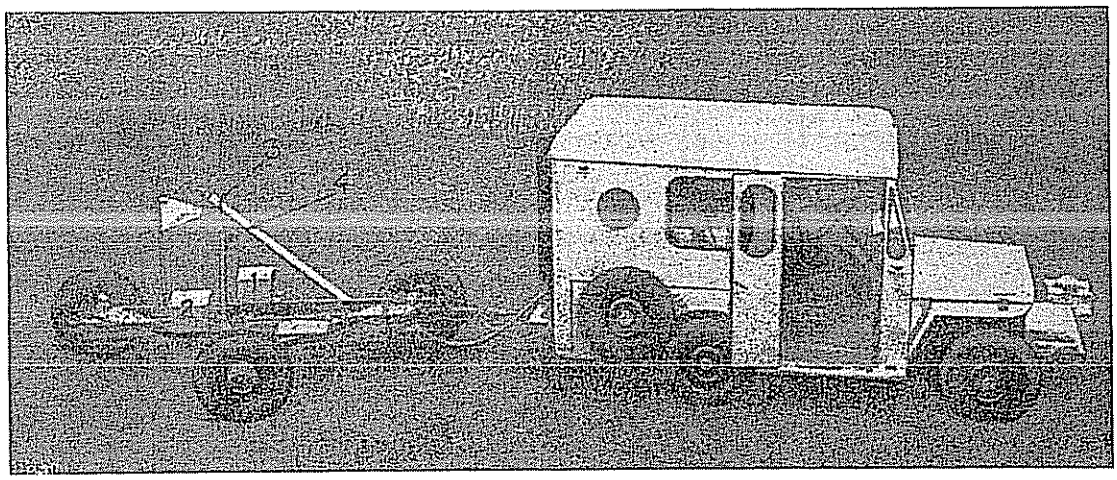


Figure 50. Johnson elevation meter with jeep tow car

1. Pendulum housing
2. Velocity—signal generator
3. Tripod bracket for telescope
4. Tube for carrying level rod

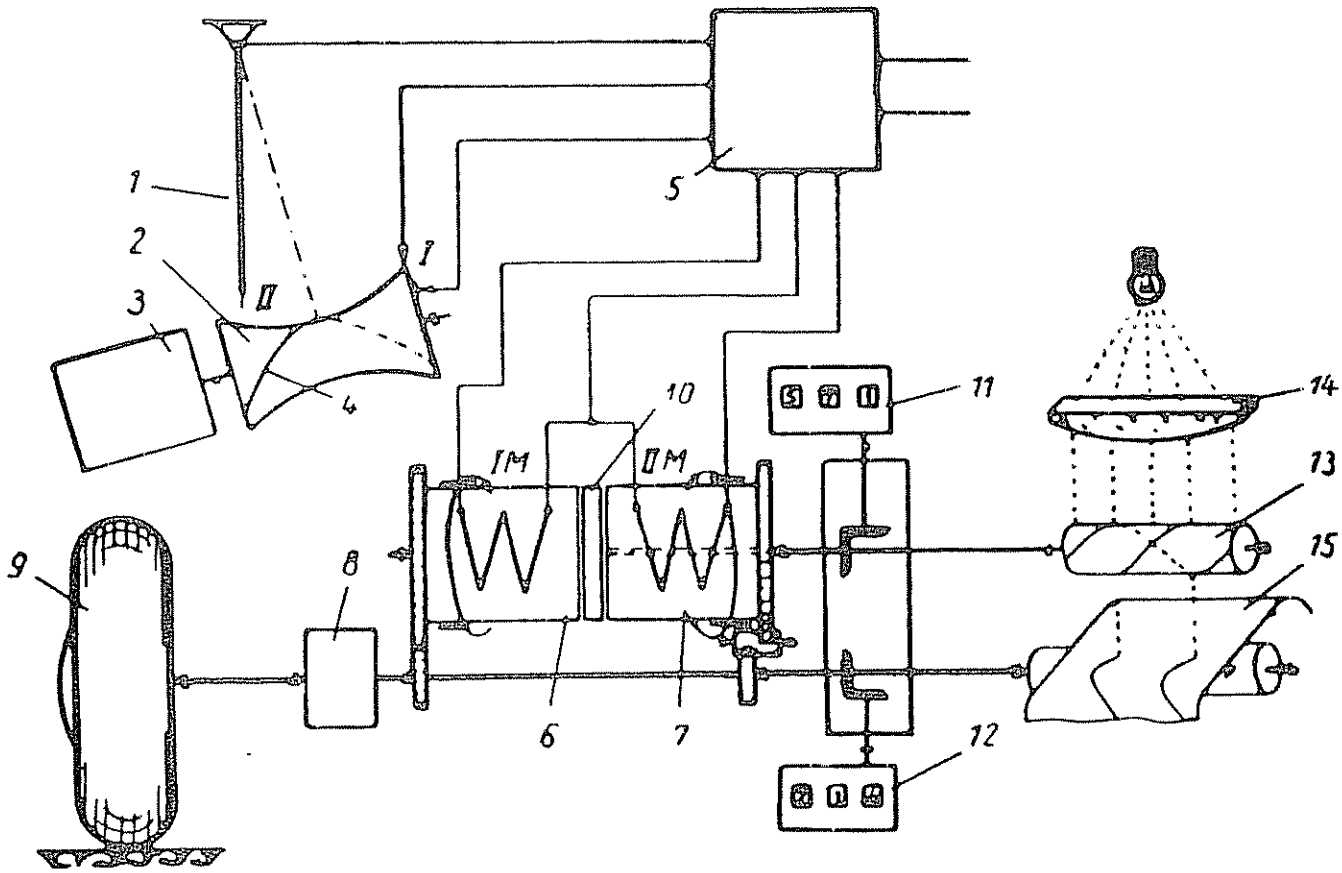


Figure 51. Soviet automatic elevation meter WA-IM

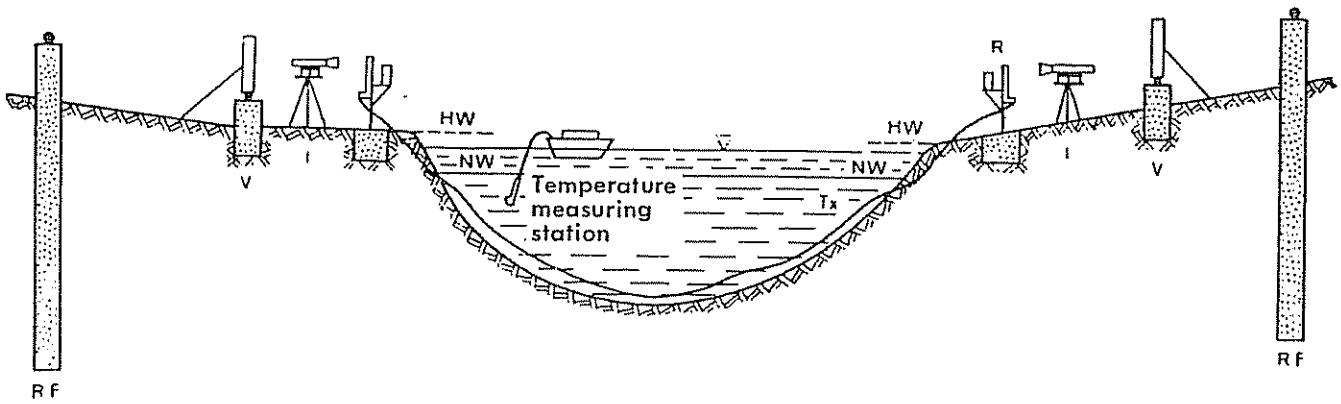


Figure 52. Hydrostatic levelling

Diagram of observation stations

L, R = Left and right observation stations
V = Control points
RF = Bench-marks
I = Instrument stations
T x = Opposite station for temperature measuring

of the orthophotoscope, developed through the fundamental work of Russel Bean (see figure 53).[15]

In a plotting instrument, such as the Kelsh plotter, the multiplex or similar equipment—the stereoscopic model, established in the customary manner and observed in the anaglyphic method, is scanned by a special additional device. In scanning, the observer has to keep the luminous spot " on the ground ". A small area surrounding the floating mark is photographed continuously along the scanned lines. Only the green or blue light is effective; the red light simultaneously impinging upon the slit remains ineffective. Thus, the central perspective is transformed into an orthogonal projection. This scanning is performed relatively quickly, since an exact setting of the elevation is not necessary. A minor error due to the scanning spot dipping " into the ground " or flying slightly " above the ground " will not visibly influence the final result.

Figure 54 shows the well-known ER-55 projector, a plotting instrument similar to the multiplex. On the table may be seen the inner frame bearing the photographic film, which may be

[15] R. K. Bean and M. Thompson, " Use of the Orthophotoscope ", *Photogrammetric Engineering*, March 1957; R. B. Southard, " Orthophotography—Its Techniques and Applications ", *Photogrammetric Engineering*, June 1958.

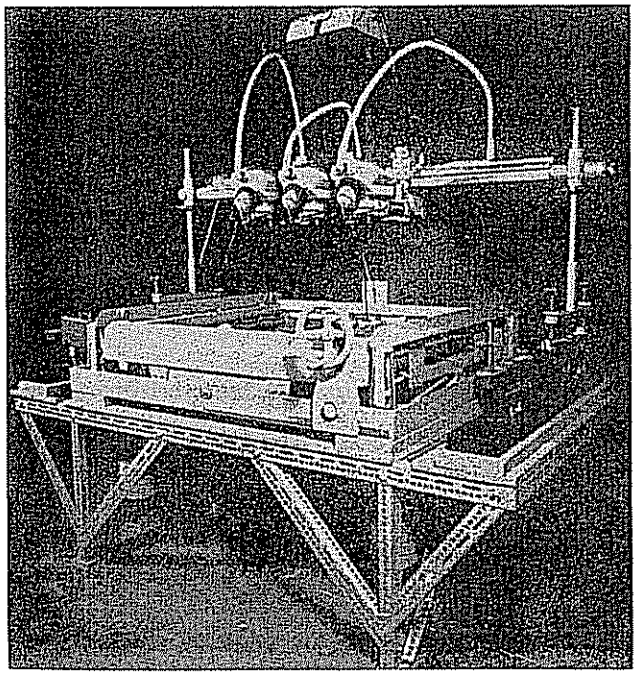


Figure 53. Side view of orthophotoscope, model 1956

Reprinting from *Photogrammetric Engineering*, June 1958, by courtesy of the American Society of Photogrammetry

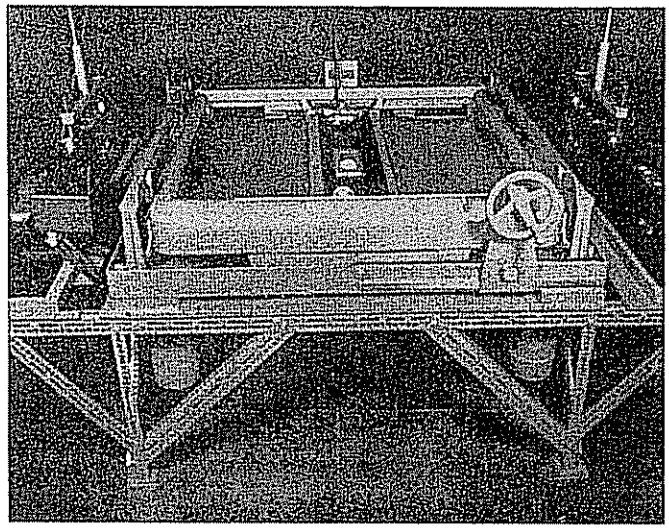


Figure 54. Plotting table of the orthophotoscope

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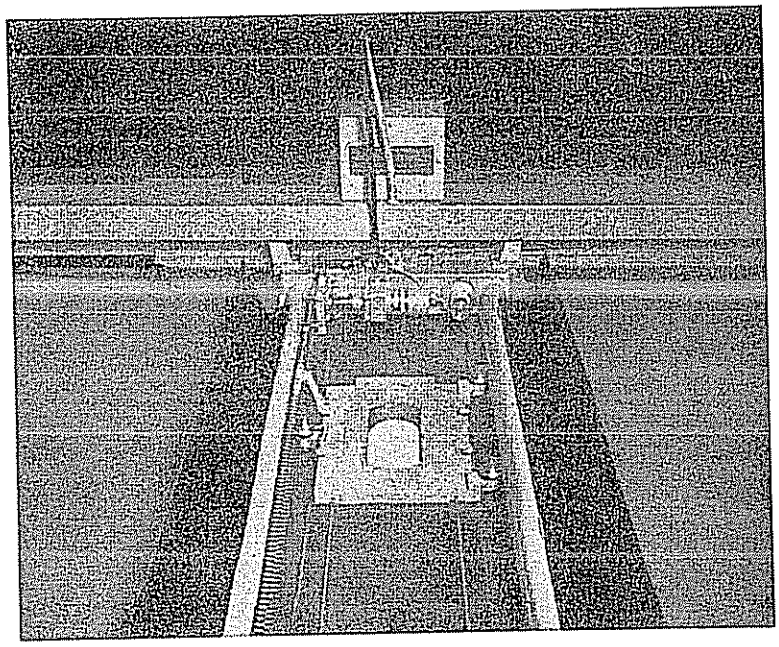

Figure 55. Scanning system

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moved vertically by manipulating the hand wheel, so that the scanning mark may be continuously kept on the ground.

Figures 54 and 55 show the equipment for linear scanning. In the middle of the slide is the white field surrounding the slit and enabling the observer to determine whether the scanning mark, which is identical with the slit aperture, is kept at the height of the ground.

In most cases three successive plates are orientated in the plotting instrument in order to enable a complete stereoscopic plotting of the middle aerial photograph. Depending on the uncertainty of the ground, the observer will choose different widths of lines. In flat areas a line width of 0.8 millimetre will be sufficient, whereas in very mountainous areas a minor line width of only a few fractions of a millimetre would be appropriate. The result of such a linear scanning is a photograph which is geometrically correct. Comparative plottings with normal plotting instruments have not shown any visible difference between these two methods.

The plotting of a complete aerial photograph takes only a few hours. However, the orthophotoscope does not give contours. Improved models of the first prototype, which proved successful in the Geological Survey, are in process of construction. Considerably facilitating the operations of the observer, they may perhaps essentially influence photogrammetric plotting operations in the future. The realization of an orthographic photograph completely free of distorsion may well serve as basic material for map preparation.

Several new ideas have been developed to overcome the disadvantage of this instrument—that is, to obtain the lacking contour plates with contour lines.

C. Spooner, Chief of the Research Division of the United States Army Map Service, and his staff have tried to produce plastic relief models by a similar scanning procedure. For this purpose, a block of laminated wax sheets of alternating colours was fastened on the plotting table of the instrument. The drawing pencil was replaced by a cutting head, cutting to a depth corresponding to the thickness of the sheet concerned when the luminous mark is moved at a constant height along the stereomodel.

As the observer, keeping at a constant " Z " setting, travelled a complete contour line on the model, the cutter carved a corresponding figure out of this wax sheet. The portions of the laminate beyond this area were removed by hand. Subsequently the observer, after changing the " Z " setting by the desired contour interval, engraved in the same manner the shape of the next lower contour line into the underlying laminate. Thus the observer produced a rough-cut relief model in wax, in a similar manner to that followed by the Wenschow Company where the shapes of the contour intervals are cut into a gypsum block. If a photograph were to be taken of this relief model by means of a camera with a very long focal length, so that, practically speaking, an orthogonal projection were obtained, it would show, because of the different colours of the laminated sheets, the different shapes of the contour lines. Furthermore, the wax model could be used for making a plastic model for relief map production.

Figure 56 shows a contour plate prepared in this way. This photograph could serve as scribe guide copy for the scribing of contour lines.

Later, the tests were modified in such a way that the connectors on the plotting table were reversed. The former " Y " direction was connected with the " Z " direction of the plotting table, so that a linear scanning of the model produced the profile drawing on the plotting table or the cutting of the profile into a laminated wax sheet. By continuous compilation of these profiles—one profile for each line—a stereoscopic

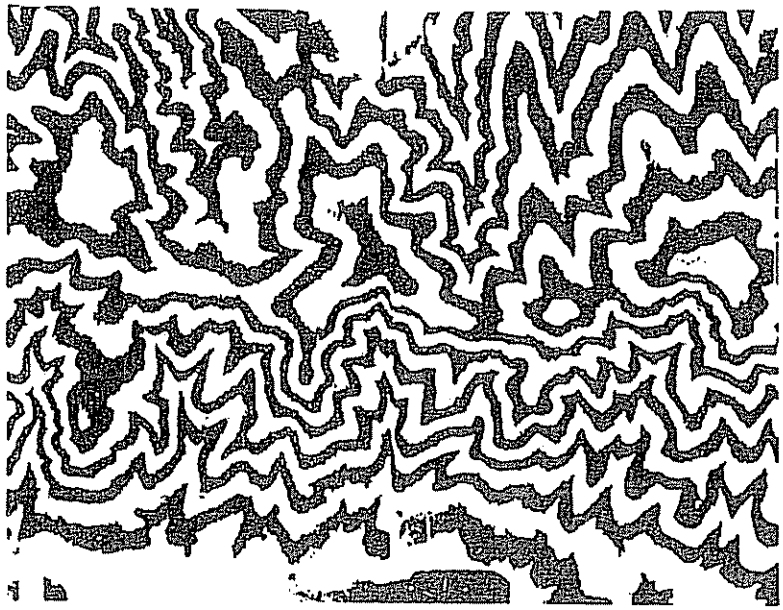

Figure 56. Orthographic photograph of a relief model composed of wax laminates of alternating colours

Reprinted from *Photogrammetric Engineering*, December 1957, by courtesy of the American Society of Photogrammetry

model could also be produced. At the same time it would be possible to determine the motions of the scanning mark by their co-ordinates and to record them on magnetic tapes. Later on it would be possible, automatically, with the orthophotoscope and without the assistance of an observer, to produce an orthogonal projection of the terrain from the magnetic tape or to prepare a contour plate of the terrain by the above-mentioned procedure.[16]

Fully Automatic Plotting Instruments

The instruments for automatic drawing of contour lines without the assistance of an observer are of particularly interesting construction.

In this field, too, American engineers and manufacturers have done excellent work. Already by 1950 Bausch and Lomb had initiated the construction of an instrument for producing contours automatically. The basic idea came from Dr. Harrison of the Massachusetts Institute of Technology. Since this instrument did not give complete satisfaction, a second model was manufactured by Pickard and Burns in the period from 1952 to 1955. But this instrument as well was not yet the final answer, so that in 1956-1957 an "automatic contour plotter", known as Hycon model 545, was constructed by the Hycon Manufacturing Company. This instrument draws contours automatically, but it has the disadvantage of requiring considerable time for automatic scanning, since the whole model has to be scanned in every contour interval.

[16] C. S. Spooner, S. W. Dossi and M. G. Misulia, "Let's Go Over the Hill", *Photogrammetric Engineering*, December 1957.

For a better understanding of this new construction, an explanation of the basic idea seems called for.

Figure 57 shows a sketch which explains the development and function of the equipment. Both diapositives are orien-

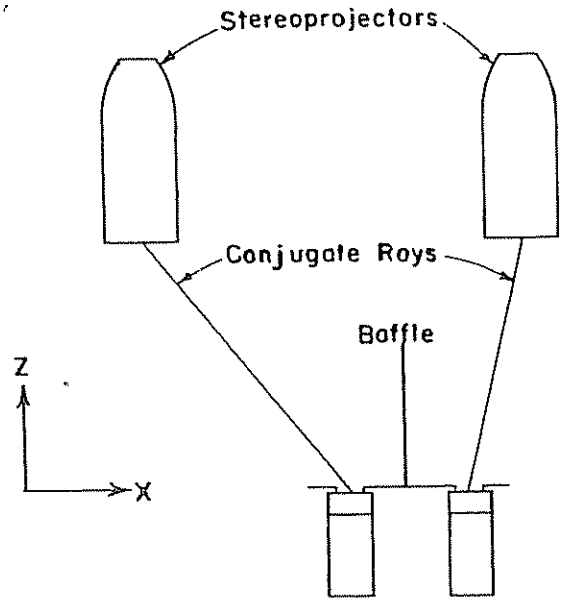

Figure 57. Principle of automatic scanning

Reprinted from *Photogrammetric Engineering*, March 1957, by courtesy of the American Society of Photogrammetry

tated in the usual way in the stereoprojectors of the plotting instrument. If the floating mark is kept in such a way that it just touches the terrain model, both conjugate rays will exactly intersect at this point For automatically comparing these two rays and the images in their immediate neighbourhood, respectively, it is necessary to lift both photoelectric cells—which replace the human eye—on which the conjugated images are projected somewhat above the height of the terrain. These two images are compared with each other by alternately opening and shutting slits (oscillating shutter). Instead of being matched optically, the absorbed optical impressions are transformed into an electric voltage by the photoelectric cells with the appropriate multipliers. It is possible to show these voltage curves, constantly changing with the motion of the slit, on the screen of an oscillograph.

For measuring one has to imagine the whole terrain as divided into small strips parallel to the " X " direction of the above-mentioned instrument, that is, parallel to the air base. The strip is opened point by point by a floating slit shutter, and the respective beam of light is received by the photoelectric cell and transformed into an electric current. The result of this operation is shown in figure 58. In the upper part of the figure the variation of the light intensity along the slit is represented by the changing density of hachures. Below, the optical impression is shown transformed into a voltage-time curve.

If two conjugated rays are focused on the appropriate photoelectric cells at the beginning of the measurement, a diagram similar to figure 59 is obtained. When the slits are proceeding in " X " direction, a similar voltage-time curve occurs for both photoelectric cells which, however, will immediately indicate a phase shifting if the slits do not remain in contact with the optical surface of the terrain. As soon as the projected point considered " dips into the ground " one curve will lie behind the other (see figure 59) and *vice versa*; one curve will precede the other if the point floats above the ground. By electronic phase comparison and automatic establishment of phase coincidence by lifting or lowering the working table, it is possible automatically to obtain the guidance of the scanning mark on the surface of the terrain.

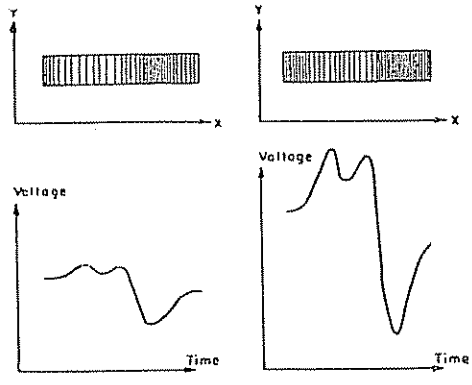

Figure 58. Voltage-time curve for automatic slit scanning with photoelectric cells

Reprinted from *Photogrammetric Engineering*, March 1957, by courtesy of the American Society of Photogrammetry

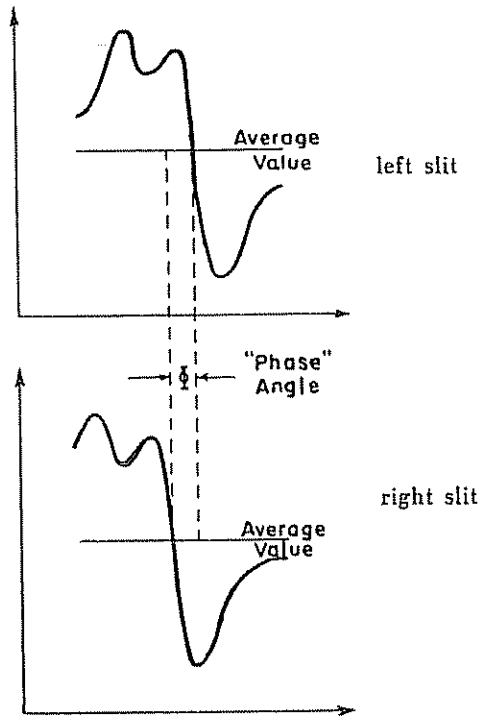

Figure 59. Method of phase comparison

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Bausch and Lomb applied this principle and, in spite of the fact that a satisfactory solution could not be realized, it was a very interesting development, worth considering in the future.

The Bausch and Lomb instrument scanned lines and cut the profile of each line into one laminated wax sheet which, when later compiled by the aid of register holes, resulted in a plastic model of the terrain.

In the Pickard and Burns instrument the principle of phase comparison of the voltage-time curves was abandoned in favour of the amplitude comparison. The elevation setting remained constant, so that the amplitude comparison resulted in equal diagrams of the voltage-time curve with scanning in the given plane only in their lines of intersection with the model (or a plane parallel with the model).

The upper portion of figure 60 shows such a moment. The right curve, however, is much more distinct than the left. Therefore, the right curve had to be reduced before the amplitude comparison could be performed.

To speed up the plotting operations a device has been installed in the Hycon model 545 which enables the contour line to be followed automatically by photoelectric cells. As soon as the curve of difference voltage as shown at the bottom of figure 60 moved up or down, an appropriate automatic control of the " X " or " Y " direction was effected.

The last step of this promising series of developments seems to be an instrument manufactured by PSC (Photographic Survey Corporation) in Toronto, which is being completed. It is called the Automatic Scanning Correlator (" Auscor ").

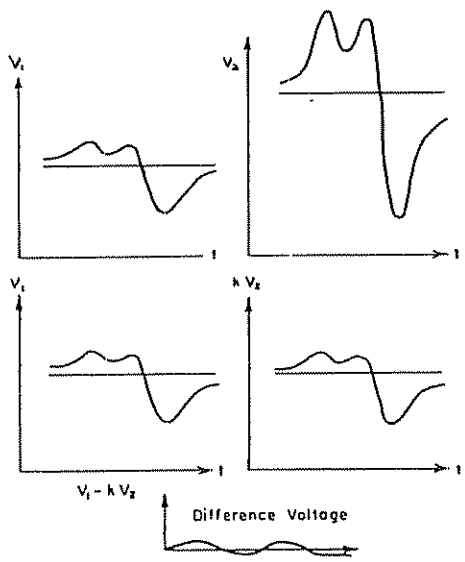

Figure 60. Method of amplitude comparison

Reprinted from *Photogrammetric Engineering*, March 1957, by courtesy of the American Society of Photogrammetry

Here a combination of photoelectric cells moves quickly up and down in scanning lines. Whenever the optical stereo-model is pierced, the appropriate X, Y, and Z co-ordinates are recorded on a magnetic tape, from which, later, an orthoscopic image, a contour plate or a plastic relief of the terrain may automatically be re-established.

Obviously these fully automatic methods are still defective to a certain extent, because the photoelectric cell will be able to indicate the accurate elevation only in a bare region; in wooded areas, however, the result of plotting shows the elevation of the tree-tops. These defects of fully automatic methods can be compensated for only by experienced observers controlling the machine's product. In the numerous unwooded areas of our earth, however, where surveys are still lacking, this method seems to be particularly promising. Full automation of mapping, nowadays aspired to in several countries, seems to be worth considering and symbolic of present trends. In these modern times it is up to the geodesist to furnish, as much for the economy as for engineering, the map material indispensable for the realization of vital plans.

Cadastre

Automation is particularly promising in cadastre. The numerous similar registering operations may be performed easily and recorded automatically by the customary office machines. But numerous technical operations may also be performed automatically to a major extent. Drawing and fixing of boundary points from punched cards, computing areas from co-ordinates, and electronically determining co-ordinates from plans are problems which have already been solved.

Let us now turn our attention to the field of map compilation. Here we find that the introduction of modern scribing methods has essentially reduced the work required for map compilation. It is said that work reductions amounting to from 10 to 80 per cent have been realized. Without exaggeration we may say that a saving of 50 per cent is a good average. Considering the few years which have elapsed since the introduction of this procedure, it may well be assumed that further improvements will essentially increase this average in the future. It must be considered that cartographers, educated and trained in the old classical methods, are often opposed to such modern and time-saving procedures. All important inventions, as for example the sewing machine, the mechanical loom and the railroad, met with stiff opposition from certain professional circles. As soon as this opposition has been overcome and people have been convinced of the obvious advantages of the new methods, a further increase in production capacity may certainly be expected. Even if a hundred per cent increase in output and complete automation of cartography cannot be realized, a great number of minor operations will be performed automatically.

In map reproduction, which is closely related to mapping technique, the realization of automation will be easier. As soon as sufficient experience has been gained, it will be simple to record automatically certain chemical processes and physical values, and the results of these operations will be realized automatically.

Automatic methods have entered the field of printing itself with relative slowness. At present completely automatic printing actually cannot be performed without an expert who must constantly supervise the machine's product. If the quality of the printing drops he must stop the machine at the right moment to correct plate holding, inking and the like and then set the machine in motion again to continue its automatic operation. To what extent this purely supervisory human activity may also be replaced by automation will be seen in the future. Attempts to substitute automation for this supervision are already under way.

The question is often asked whether or not increasing automation will cause large-scale unemployment and create a crisis in employment conditions. But if we consider that map requirements will never be satisfied if we continue to use classical procedures without automation and that triangulation and surveys to benefit the economy and assist engineering are often decades overdue, it may be understood that people released by automation may be used elsewhere to satisfy the urgent requirements of geodesy and cartography.

These requirements will continue to exist for a long time and it should not be forgotten that our rapidly-moving age causes constant changes in map depiction, requiring perpetual revision and correction.

Automation should not mean unemployment; rather it should release people from monotonous mechanical operations and afford them tasks which require thinking and individual initiative, thus giving them occupations which cannot be performed by machines and which are compatible with human dignity.

USE OF SHORAN CONTROLLED AERIAL PHOTOGRAPHY IN MEDIUM-SCALE MAPPING [1]

Background paper by the United States Army Map Service

So that the textual matter presented in this paper will be clear to those who are unfamiliar with Shoran, a brief explanation of its function follows. The system consists of three sets of specialized radio equipment: the airborne set called the interrogator and two identical ground station sets called, respectively, the rate and drift transponders. The operational principle consists of sending alternate radio signals from the airplane to the ground stations where these signals are relayed back to the airplane. Due to the speed at which the radio pulses travel (approximately 186,219 miles per second at sea level) and the rapid rate at which the signals are repeated, the distances from the aircraft to the two ground stations are known constantly. Shoran is a line-of-sight measuring system and for this reason the distances that can be measured vary with the flight altitude. Some modifications and improvements which increase the accuracy of the measured distance have been incorporated in the radio equipment. This modified equipment is called Hiran.

For the purposes of this presentation, the use of the term Shoran will also apply to Hiran, unless otherwise specified. The range limitations are shown in the following table:

Flight altitude (feet)	*Approximate maximum range, aircraft to ground stations (miles)*	*Approximate distance between ground stations (miles)*
10,000	150	130
20,000	200	175
30,000	235	205
40,000	265	230

In mapping, Shoran is used both in conjunction with the taking of aerial photography and for the establishment of ground stations by trilateration.

Trilateration is a method of geodetic triangulation in which, starting from a base line, the net is extended by measuring the length of the sides of the triangle by Shoran instead of measuring the angles by theodolite. The precision of these line measurements is shown in the table below; the results are from Hiran.

Length of line (miles)	*Probable error*	
	Miles	*Proportional part*
25	0.0011	1 : 23,000
50	0.0013	1 : 38,000
100	0.0015	1 : 67,000
200	0.0023	1 : 87,000
300	0.0032	1 : 94,000
400	0.0041	1 : 97,000
500	0.0051	1 : 98,000

When Shoran controlled photography is taken, the dials of the interrogator showing the distances from the aircraft to the ground stations must be photographed simultaneously with the exposing of the aerial film. Since the geodetic positions of the ground stations are known, the distance between them is also known; therefore, the triangle can be solved for a given set of Shoran measurements with the aircraft at the vertex of unknown position. After corrections for earth curvature, atmospheric refraction, flight altitude and velocity of wave propagation, the position of the aircraft can be related to the spheroid on which the positions of the ground stations are based. This position of the aircraft corresponds to the nadir point of the aerial photograph.

Normally each exposure of the project photography is controlled by Shoran and has a horizontal position determined for its nadir point; however, economic or meteorological considerations might necessitate varying the approach. For example, when adequate photographic coverage exists for the project area, it would be more practical to " grid " the area with Shoran controlled photography. In such a case, the Shoran controlled flights would form squares of approximately fifty miles on each side. Another method consists of establishing secondary control points with the aid of Shoran controlled photography. Areas are pre-selected on the uncontrolled project photography where horizontal control points are required for aerotriangulation. This area must contain a readily identifiable point image. Four short flights of seven exposures each are flown with the centre of each flight over this identifiable point. The first flight is flown in a predetermined direction, with the second flight at 180° to the first flight along the same path. The third flight is perpendicular to the first two flights and the fourth flight at 180° to the third flight and along the same path. The horizontal geodetic position of the point image will be determined photogrammetrically from the Shoran controlled photographs.

The photogrammetric operations will vary with the type of Shoran controlled photography being utilized. If Shoran controlled photography has been planned for a specific project for which 1 : 250,000 scale maps are to be made, the photography will be flown at an altitude of 30,000 feet above mean terrain. The ground stations will be positioned on the average of 205 miles apart and probably will have been established by trilateration. Despite the advantage of knowing the geodetic position of each nadir point, some method must be used for relatively orienting the photographs and thereby establishing the positions for the photogrammetric passpoints.

One such method employs the use of slotted templet. The templets are prepared in the conventional manner with the slots cut radially from the principal point. The Shoran positions of each photograph are plotted to the grid or projection on which the slotted templets are to be laid. The deviation from normal procedure is associated with fastening the studs to the plotted Shoran positions. Here " floating studs " are used. Each consists of a stud which is suspended in the centre of a metal ring by means of three springs. The ring is fastened securely over the plotted position in such a manner that the hole in the stud is directly over the plotted position. The " floating stud " compensates for the displacement of the nadir point from the principal point due to tilt in the photograph and also for the random errors inherent in the Shoran positions. It is not necessary to hold to each principal point; tests made show that virtually the same results are obtainable when every fourth centre is held. Although results of actual field checks are not available, results from comparable tests

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF 25/L.16.

show that 1 : 250,000 scale maps made by this method from photography at a scale of 1 : 60,000 should meet national standards of map accuracy.

A more precise method of photogrammetric adjustment can be obtained from stereoplotting instruments, such as multiplex and the first-order stereoplotting instruments. The method to be described is used primarily with " grid " photography and secondary control point photography. As was previously mentioned, the Shoran position is for the nadir point of the photograph. To recover the nadir points of the photographs in a stereoscopic model, the model must be horizontalized; then, ignoring tip convergence, which is slight for a single model, the projected vertical ray from each plotting camera will represent the nadir point for that particular photograph. As successive models are bridged in stereotriangulation, this observed vertical ray will depart from the projection of the nadir point due to earth curvature and the torsion in the spatial extension. This horizontal displacement is a function of the projection distance and the tangent of the angle of tilt, required to horizontalize the stereoscopic model. To make use of this relationship, the position of the observed vertical ray is recorded with a nadirscope, when multiplex is used, or by reference to the zero positions of the plotting cameras, when a first-order stereoplotting instrument is employed.

With a first-order stereoplotting instrument, the bx, by and bz settings must be recorded for each exposure as well as the z reading in the proximity of the principal point. The x and y co-ordinates of the vertical ray are obtained indirectly from the accumulated lengths of the base and the by settings.

$$x_i = x_o - \tfrac{1}{2}b_1$$
$$x_i = x_o + \tfrac{1}{2}b_1 + b_2 + b_i - 1 \text{ for } i > 1$$

where: x_i is the x co-ordinate for the vertical ray of the i th exposure; x_o is the x co-ordinate read from the counter at the " zero position " of the instrument, that is, plotting camera axis parallel to z track and base $= O$. This starting co-ordinate is determined for the extension before the initial model is oriented; b_i is the length of the base of the i th model.

Also, $y_i = y_o + \Delta by_i$

where: y_i is the y co-ordinate for the vertical ray of the i th exposure; y_o is the y co-ordinate read from the counter at the " zero position " of the instrument; Δby_i is the difference between the by reading at instrument " zero position " and the by value of the i th exposure. (The by_o values may vary slightly for plotting cameras A and B.)

The instrument position of the vertical rays can be corrected to the positions of the respective nadir points from data obtained in the vertical adjustment of the photogrammetric extension. When the graphic vertical adjustment [2] is used, the correction for the x component of the displacement is obtained from the tip curve (curve of correction for drop-off in line of flight). The correction is

$$x_c = PD \tan d$$

where: x_c is the x component of correction in millimetres of the position of the vertical ray; PD is the projection distance expressed in millimetres; tan d is the slope of the tip curve at the abscissa of the vertical ray to be corrected.

A tilt curve is also plotted as part of the vertical adjustment. Its purpose is to correct for any torsion which has accumulated in the photogrammetric extension. The ordinate of the correction curve at any point along its x-axis represents the slope of the datum of the photogrammetric extension in the yz plan relative to the true datum. Therefore the y component of correction for the positions of the vertical ray is

$$y_c = PD \tan b$$

where: y_c is the y component of correction in millimetres of the position of the vertical ray; tan b is the ordinate of the tilt curve at the abscissa of the vertical ray to be corrected.

When vertical control is sparse, the adjusted or unadjusted bz curves can be used for determining the nadir points.

The horizontal adjustment of the photogrammetric extension is then carried forward in the normal manner. The nadir points, which have been determined by the method just described, represent the photogrammetric extension positions for the respective Shoran positions. The extension is adjusted to the best mean fit of these positions either graphically, when multiplex is used, or mathematically and graphically, when a first-order instrument with co-ordinate data is used.

When this method is used with " grid " photography, the photogrammetric passpoints from the Shoran controlled flights are adjusted and serve as control for the mapping photography. The mapping photography is in turn stereotriangulated and adjusted to these passpoints.

With the secondary control point method, only one or two readily identifiable passpoints are adjusted. However, it should be noted that these points are established by four independent photogrammetric solutions, from which mean positions are determined. For this reason, these secondary control points should be twice as accurate as the passpoints established from " grid " photography. Again the mapping photography is stereotriangulated in the conventional way and adjusted to the secondary control points.

The stereocompilation of a project area for medium-scale mapping is usually accomplished with multiplex. The procedures at this phase of the work are unaffected by the method of establishing the photogrammetric control net work.

Considerable work has been accomplished using the slotted templet and " floating stud " method. The method is relatively simple to apply. Due to the superabundance of control, little time is wasted in isolating erroneous control; instead, such points are ignored and Shoran points for adjacent photographs are used in lieu of the erroneous ones. Difficulty in the form of a systematic shift was anticipated in tying areas controlled by different pairs of ground stations. With the slotted templet method it is sufficiently small to be absorbed; however, this is not the case with stereoplotting instruments.

The aerotriangulation and compilation phases are in the offing for several medium-scale mapping projects which will utilize grid photography and secondary control points; however, accuracy checks have been made of the photography and Shoran data using the photogrammetric methods previously described. Both the accuracy and the method have proved satisfactory for medium-scale mapping. Operational tests are presently under way to determine the usability of Hiran controlled photography for large-scale mapping. Undoubtedly the value of Shoran has been established in the field of photogrammetric mapping and its use will become increasingly important as electronic technology improves.

[2] R. S. Brandt, " Résumé of Aerial Triangulation Adjustment at Army Map Service ", *Photogrammetric Engineering*, vol. XVII, No. 5, December 1951

PHOTOGRAMMETRIC MAPPING BY ELECTRONICALLY ASSISTED SCANNING [1]

Background paper by the United States Army Map Service

Introduction

The United States Army Map Service (AMS) has been investigating a new method of photogrammetric mapping. The studies have been going on for about two years, and two reports on them have been published.[2]

Like the present method, the one being studied uses a stereoplotting instrument, in which a stereoscopic model of the ground is formed from overlapping aerial photographs and is explored by a measuring mark. In the present method, each stereoscopic model is explored a number of times: once for the drawing of contours, and repeatedly for the drawing of culture, drainage and all other planimetric features. The essence of the new method under study is that the entire stereoscopic model is to be covered just once, in a systematic manner. The mode of coverage is by profile scanning, that is, the measuring mark traverses the stereoscopic model in a series of closely spaced parallel paths, and is kept in apparent contact with the ground at all times. All of the information needed for map compilation is to be extracted from the model during these scans for further processing away from the stereoplotting instrument.

The ways in which electronic assistance is expected to facilitate the profile scanning and the extraction of information are discussed in the present paper. Also discussed are the problems and the potential benefits of this method of mapping.

Information to be extracted

The profile scanning of the stereomodel must result in these three products:

1. A plot of the ground relief, from which contour lines can be drawn;

2. An orthographic replica of the aerial photography, from which all planimetry can be drawn;

3. A stored record of the profiles. This record is not essential for the preparation of a map, but its importance will be made apparent.

Relief plot

The type of relief plot which has been most successful in experiments at AMS is illustrated in figure 61. It was drawn by the co-ordinatograph of a stereoplotting instrument during the profile scanning of the model. As the measuring mark followed each profile, the co-ordinatograph pencil was alternately lifted from the paper or lowered to the paper each time an elevation which was a multiple of the contour interval was crossed. Thus, for a contour interval of 100 feet, as in the figure, a profile rising from sea level would be represented by a solid line between 0 and 100 feet, blank between 100 and 200 feet, solid between 200 and 300 feet and so on.

The ease with which contours could be drawn on this plot by connecting the ends of the solid lines is quite apparent. If the contours were more closely spaced on the plot, that is, if a smaller contour interval had been employed, it would be desirable to colour-code the lines. With as few as three colours, all ambiguity can be removed in the drawing of closely spaced contours. Although it was sufficient for experimental purposes to assign a second person to raise and drop the co-ordinatograph pencil while the operator did the profiling, equipment to do this job could easily be designed. The equipment could also select the right one of three pens for colour-coding the plot.

One interesting property of the relief plot is that it provides an objective indication of the consistency with which an individual stereoplotter operator follows the ground. This should simplify the supervision of stereoplotting operations. When contours are drawn with a stereoplotter in the ordinary manner, the supervisor can check the work only by repeating some of the contours.

Because profile scanning requires that the operator pay more detailed attention to the stereomodel than he would in ordinary contouring, it takes him somewhat longer to cover the model. A direct comparison was made in the case of the area shown in figure 61. It took nearly eight times as long to draw the figure as it took the same operator to contour the same model with the same instrument in the conventional manner. However, it should be remembered that the contour interval in both cases was 100 feet. If a twenty-foot contour interval had been chosen, the time required to profile the model would have been unchanged, whereas the time required to contour the model directly would have increased fivefold.

When allowance is made for this invariance of profiling time with different contour intervals, and for the complete inexperience in profile scanning of the operator who performed the experiment, it seems reasonable to expect that the production of relief plots by unaided profile scanning will be slightly slower than the production of contours in the conventional manner. While profile scanning has advantages over conventional methods in various special applications, a general mapping system based on profile scanning must show a saving in total stereoplotter time if it is to gain general acceptance. The hope of achieving a significant reduction in profiling time rests on the provision of electronic assistance. The two forms of electronic assistance which are being considered are memory-assisted profiling and automatic profiling.

Memory-assisted profiling

It appears that the speed with which an operator can profile is mainly limited by the necessity for going over every hill in each scan in " low gear "; that is, he must cause the measuring mark of his instrument to make large changes in elevation while he maintains the delicate control necessary to conform to the ground surface within the normal accuracy standards. The way out of this dilemma is to cause the instrument to make the large motions by itself, with the operator making only the necessary small corrections to those motions.

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.17.

[2] C. S. Spooner, S. W. Dossi and M. G. Misulia, " Let's Go Over the Hill ", *Photogrammetric Engineering*, vol. XXIII, No. 5, December 1957; J. L. Kosofsky, " Investigation of an Integrated Mapping System ", *Photogrammetric Engineering*, vol. XXIV, No. 3, June 1958.

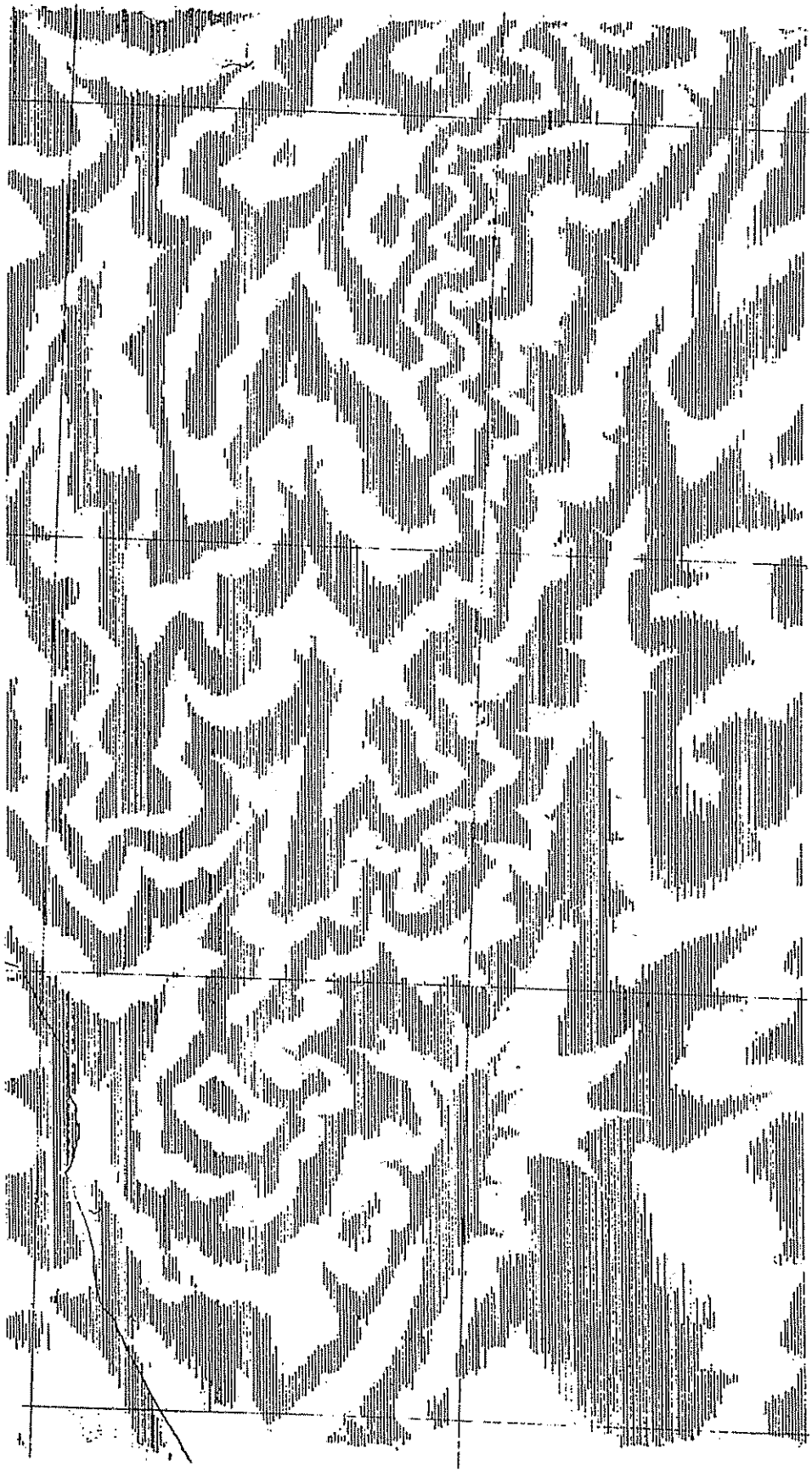

Figure 61. United States Army Map Service : Relief plot drawn during profile scanning of model

When parallel profiles are closely spaced, the terrain does not change much between profiles. If a profile is stored while it is being scanned, it can be played back while the next profile is being scanned. That is, when the measuring mark is at a given horizontal distance along the second scan, the playback mechanism causes it to come to the same elevation it had at the corresponding point in the first scan. The operator makes the slight change which brings the measuring mark to its correct elevation. When the playback and visual adjustment are done continuously, the measuring mark traces out the true second profile, which is stored for the guidance of the third profile.

The electronic elements of such a system include equipment for:

1. Sensing the position of the measuring mark during profiling;

2. Recording its positions in digital form on magnetic tape;

3. Playing back the recorded profile at a speed controlled by the operator;

4. Driving the measuring mark so that, if uncorrected, it will trace out the previous profile;

5. Effecting corrections as commanded by the operator so that the measuring mark will actually trace out the current profile.

Plans are proceeding for the design and construction, under contract, of experimental equipment using the principle of memory-assisted profiling.

Automatic profiling

Of course, the most complete help that electronic instrumentation could provide to the operator would be to do his profiling for him. Automatic profiling of a stereoscopic model by photoelectric scanning has actually been accomplished experimentally by The Photographic Survey Corporation of Toronto, Ontario. Eventually, when such equipment has been perfected, and when ways have been found to overcome the penchant of the automatic profiler for climbing trees, walls and buildings, it will be possible to perform all the operations in which the stereoplotting instrument is involved automatically. The mapping system being investigated at the Army Map Service makes the transition to such automation possible by removing nearly all the activities which must depend on reasoned judgement from the stereoplotting booth.

The orthophotograph

The key to the removal of the compilation of planimetric features (an activity that will always require human judgement) from the stereoplotter is the orthophotograph. An orthophotograph differs from both a rectified aerial photograph and a controlled mosaic in that *all* of the detail is shown in true map position. The United States Geological Survey has developed successive models of its orthophotoscope [3] for the production of orthophotographs from stereoscopic models. When an orthophotoscope is placed under any conventional projection type of stereoplotter, the exposure is made by causing a slit to cover the stereomodel by profile scanning.

Since profile scanning of the stereomodel can produce either relief plots or orthophotographs, should it not be possible to produce both without requiring the operator to cover the model twice? There are some troublesome disparities in the requirements imposed by the two products. For example orthophotographs require uniform exposure, which is best attained by uniform scanning speed, while the production of relief plots to stringent vertical accuracy requirements dictates a variable speed of scanning under the operator's control. Also, an orthophotoscope takes up all the available space under the projectors, leaving none for the equipment needed in memory-aided profiling.

These problems can be solved, however, with the aid of electronics. The space limitation can be overcome by placing a small scanning-type photosensitive tube in the position of the measuring mark and transmitting the image electrically to a cathode ray tube which exposes a film on a remote coordinatograph. The problem of constant versus variable scanning speed is solved by recourse to the memory system which was needed, in any event, for memory-aided profiling. A profile which has been stored in the memory system can be played back at a constant, rapid speed for printing, before it is played back at variable speed to aid in the forming of the next profile. The experimental equipment which is to be built under contract will incorporate both the solutions mentioned here. It is anticipated that the equipment will produce both acceptable relief plots and acceptable orthophotographs as products of one profiling exercise on the part of the stereoplotter operator.

Suitability of the orthophotograph for planimetric compilation

Questions have been raised as to the feasibility of compiling all planimetry from orthophotographs, without the support of the stereomodel. A test recently completed at the Army Map Service indicates that it is entirely feasible, at least if the orthophotographs are of good photographic quality.

For the test, a set of orthophotographs was supplied by the United States Geological Survey, covering a portion of a recently published Geological Survey quadrangle. The compiler was given only the orthophotographs, the original aerial mapping photographs and the brown (contour) color separation negative. The last was in place of the relief plate which would be available as a product of profile scanning. He was able to compile hydrography and culture color separation drawings directly from this material. Comparison with the Geological Survey's hydrography and culture color separation negatives shows that all important detail was compiled, and that the positional accuracy of the detail compiled from the orthophotographs was fully as good as that compiled in the stereoplotter. The compiler found that his need for stereoscopic examination of the photography could be satisfied by viewing the orthophotograph and some of the original aerial photographs together under any simple folding stereoscope.

Storage of profiles

When a stereoscopic model is covered by profile scanning, the sum of the profiles contains much more information about the ground relief than is needed to prepare a conventional

[3] R. K. Bean, "Development of the Orthophotoscope", *Photogrammetric Engineering*, vol. XXI, No. 4, September 1955; R. K. Bean and M. M. Thompson, "Use of the Orthophotoscope", *Photogrammetric Engineering*, vol. XXIII, No. 1, March 1957; R. B. Southard, "Orthophotography—Its Techniques and Applications", *Photogrammetric Engineering*, vol. XXIV, No. 3, June 1958.

topographic map. The purpose of preparing the relief plot is to extract the information needed to draw contours from the profiles. However, since the profiles themselves are recorded temporarily as part of the memory-assisted profiling system, it would be an easy matter, technically, to keep a permanent record of the profiles. Can we afford to throw away information which is difficult to acquire but easy to store? Not if there is a reasonable likelihood that some of it will be required in the future.

The chief future need for stored profiles is in the production of relief models. The construction of the master relief model from which plastic models can be moulded is a slow and expensive process. Experiments have shown [4] that excellent master models can be constructed much more rapidly by cutting profiles in a wax block. By storing the profiles of all stereomodels mapped by profile scanning, the Army Map Service would have the capability for rapidly producing relief models of any mapped area for which the demand arose. This capability alone should justify the retention of a record of all profiles scanned.

Other conceivable uses for stored profiles include the calculation of earth and water volumes for engineering works. There is at least the theoretical possibility of using stored profiles to produce orthophotographs from new aerial photographs of a previously mapped area. Since orthophotographs are the ideal map-revision medium, a systematic programme for bringing old maps up to date could result from the realization of this possibility.

For all these reasons, the experimental equipment will include the capability for storing a record of all profiles on magnetic tape, in a form which is intelligible to the high-speed computing facilities of the Army Map Service.

SUMMARY

The potential benefits of the profile scanning method of mapping can be summarized as follows.

Increased capacity for processing new aerial coverage

Increased capacity is a logical expectation, since the profile scanning is performed only to preserve the stereo model so that compilation can be accomplished away from the stereoplotting equipment. This frees the instrument operator to resume the scanning of new coverage. Thus, unless the time required for profile scanning should exceed that required at present for the compilation of contours and planimetry, the capacity of each stereoplotting instrument and operator is increased. In addition, it seems likely that the over-all man-hours required to go from the stereomodel to the colour separation drawings will be decreased. This can be tested only after the equipment for memory-aided profiling is available.

Savings in elapsed time to produce colour separation

These savings can be expected, since the relief colour separation drawing can be scribed directly by one compiler, using the relief plot as a guide, while another compiler is scribing colour separations of the planimetric features, using the orthophotograph as a guide. In fact, for a rush job, several compilers could scribe the different colour separations simultaneously, using duplicates of the orthophotograph.

Savings in elapsed time and man-hours for terrain model construction

The saving in elapsed time comes about because the terrain models can be constructed from the profiles at any time, without waiting for the base map to be compiled. The man-hour requirements are drastically reduced because of the efficiency with which models can be carved from profiles, and because the profiles can be supplied to the carving machine as a by-product of the map-making process.

Compatibility with automatic processes

The greatest potential benefit of the profile scanning method may prove to be in clearing the way for the introduction of automation to those portions of the mapping process which do not require human judgement.

The disadvantages of the profile scanning method cannot be readily assessed until the experimental equipment is in operation. The most obvious drawback is the cost of the equipment. Tests will be required to determine whether or not the benefits are sufficient to justify the cost of the additional equipment.

The changes in the type of work performed by the various kinds of cartographers might result in some job dissatisfaction. For instance, stereo instrument operators, who would no longer be doing any compilation, might not find the job of profile scanning as satisfying. On the other hand, people whose tasks have been changed from colour separation scribing to original compilation might find their work more stimulating.

Above all, experience with the experimental equipment is needed to determine how the quality of the maps produced compares with the products of the present methods.

[4] C. S. Spooner, S. W. Dossi, and M. G. Misulia, op. cit.

THE IMPORTANCE OF AUXILIARY INSTRUMENTS IN PHOTOGRAMMETRY [1]

Background paper by Dr. W. Schermerhorn

The auxiliary instruments referred to in the title of this paper include those used in combination with an airborne photographic camera to register data, from which can be derived the inclination of the optical axis and the flying height during each individual exposure. Theoretically speaking, they could also include the electronic systems, such as Shoran, Hiran, Decca and the like, which give planimetric

[1] The original text of this paper, submitted by the Netherlands, appeared as document E/CONF.25/L.21.

co-ordinates. It is believed, however, that this equipment is too expen ive and too extensive to be called auxiliary instruments to the camera:

We shall consider in this respect, for the determination of tilt and for tipping the gyroscope, the horizon camera and the solar periscope of Santoni. For the determination of the height of the exposure we have the statoscope which is used at present in combination with the airborne profile recorder (APR).

There are in principle two different aims behind the use of these instruments. The first is to determine the position of the nadir point of each photograph with such precision as is required for rectification of each photograph or for the execution of a radial triangulation in which the influence of the difference in position between isocentre and nadir point can be taken into account.

Several theoretical calculations regarding high precision radial triangulation have shown that the mean square error in the inclination of the optical axis of about 10^c (centesimal minute) is sufficient to keep the systematic errors, caused by the inclination of the optical axis, below the influence of the random errors of observation. In the case of a slotted templet the value of the mean square error can be even larger. The same precision can be considered sufficient for rectification.

With certain precautions, the statoscope can be used for the determination of the scale of the photographs and therefore for the enlargement in the rectifier. The precision of the statoscope is approximately independent of the flying height and, therefore, the precisions of scale pro $^0/_{00}$ will increase with the flying height. The consequence of this fact leads to the use of long principal distance cameras, which is in accordance with the general practice in the case of rectification.

The second aim in using these auxiliary instruments is to improve aerial triangulation. The precision of the inclination of the optical axis, however, is not sufficient to use as values of φ and ω in the relative and absolute orientation of a pair of photographs. The precision of the relative orientation is higher than that obtained with the auxiliary instruments. In this statement we have not taken into account rumours regarding the construction of modern gyroscopes with mean square errors in the inclination of about half a centesimal minute. This seems to apply to military constructions. If, later on, this should prove to be neither too expensive nor too complicated to be used in normal air photography for civil purposes, it would mean a revolution in photogrammetry and, in particular, in the design of plotting instruments.

This is, however, not yet the case. The normal gyroscope tends to be unreliable. The precision of the inclination in φ and ω is expressed by a mean square error from the solar periscope of from 3 to 4^c and in the horizon camera of between 2^c and 3^c. The great importance, however, is that there is, at least in the values from the solar periscope, hardly any propagation of errors in the strip and in the values from the horizon camera, unless we measure differences in φ and ω between two successive exposures. These values can be used as a check on the propagation of errors in φ and consequently on the scale in a strip.

This was demonstrated in 1939 in an article by W. Schermerhorn and K. Neumaier,[2] in which a graph was shown derived from the difference in the two series of φ-values, as obtained from the readings in the plotting machine and from the horizon pictures. It showed a strong systematic error in φ-values which, at that time, were not the same even for different operators working in shifts on the same triangulation.

The same check can be obtained by the use of gyroscope or solar periscope. The 1939 article showed clearly the importance of the use of these instruments as long as aerial triangulation of strips was applied. It is therefore strange that, although the difficulties with the propagation of errors in strips were so widely known, so little attention was paid after the Second World War to those auxiliary instruments which can keep under control an important part of the propagation of these errors.

It is different with statoscopes. Although the value of this auxiliary instrument for the check on propagation of errors in the scale of a strip became really reliable after it was combined with the airbor: e profile recorder, the statoscope found a wide field of application. Its value is that, in aerial triangulation using the method of " aero-nivellement ", the so-called φ-cracks will have only a limited value caused by the convergence of the vertical plus systematic φ-errors in convergency and the random errors in φ-orientation and in the statoscope readings. As the systematic part of these φ-cracks can be eliminated, the residual necessary rotation of each model for the computation of height remains small and does not necessitate correction to the x-co-ordinates in cases of differen heights in the model. Therefore, the statoscope makes the method of aero-nivellement applicable also to rolling and mountainous terrain.

The airborne profile recorder, in combination with the statoscope, gives not only the profile of the terrain, but, by comparison of the heights derived from this profile and from the triangulation, also a check on the scale in the strip.

The modern tendency is to lay more stress on the adjustment of blocks and less on the adjustment of strips. If, for instance, we apply a method easily accessible to all photogrammetric organizations not having available high speed computers, as described below in " Adjustment of Aerial Triangulation According to the Method of Least Squares by Means of Analogue Computer ", we come to the conclusion that the importance of the auxiliary instruments for the check on systematic and pseudo-systematic errors in x and y in the triangulation of the strip is much less than before. Only in those cases where single isolated strips are triangulated, as for instance for highway engineering or hydrographic surveys of coastal areas, are the considerations mentioned above valid. When there are blocks and a correct method of block adjustment according to least squares is applied, introducing all conditions between co-ordinates of adjacent pairs, the at least for the planimetric co-ordinates, the systematic and pseudo-systematic errors lose their importance. This is true both for a numerical-analytical treatment of this problem and for the use of the ITC-Jerie analogue computer.

The case is different for the adjustment of heights. If, for instance, a possible constant systematic error in all strips showing the same second-order curve is considered, there will be no discrepancy in height between adjacent strips. This means that no least square adjustment will eliminate such errors. Whether we deal with an entirely numerical-analytical treatment of the least square adjustment of heights or apply the ITC-Jerie analogue computer, which uses the

[2] W. Schermerhorn and K. Neumaier, " Systematische Fehler bei der Aerotriangulation ", *Photogrammetria*, 1939, page 160.

strips as such, makes no difference. For the adjustment of heights the strip remains an essential element and, therefore, the auxiliary instruments have the same importance as before, and perhaps even more, since experience has shown that the correct block adjustment gives higher precision of the planimetric co-ordinates. It is logical, therefore, to require greater precision for height than in the past. Experience has taught us that use of the auxiliary instruments mentioned above, either the combination of APR and statoscope or registration of the inclination of the optical axis by means of horizon pictures, gyroscope and solar periscope, can contribute to increased precision of height. Although this has already been proved in the 1939 article mentioned above, we believe it is still essential to draw attention to the fact.

USE OF AUXILIARY EQUIPMENT IN PHOTOGRAMMETRIC MAPPING [1]

Background paper by the United States Army Map Service

Introduction

This topic is extremely broad in scope. To attempt to do justice to the entire field would be out of the question. Therefore, for purposes of this presentation, auxiliary equipment will be defined as all office photogrammetric equipment, exclusive of stereoplotting instruments, which is currently in use at, or under active consideration by, the United States Army Map Service. The order of presentation has been selected to be in general conformity with the normal sequence of operations at this installation.

It is emphasized at the outset that the use by the Army Map Service of the specific brands of equipment mentioned in this paper should in no way be construed as implying that such apparatus is superior to that made by other concerns to perform similar functions.

Transformation Printing

The world-wide scope of operations of an agency such as the Army Map Service (AMS) necessitates the handling of photography from a variety of sources. This photography is characterized by a wide diversity of focal lengths, format sizes and distortion magnitudes and patterns. For satisfactory use in stereoplotting equipment, this photography often requires geometric transformation—enlargement or reduction of the original negative—or introduction or compensation for predetermined aerial camera distortion, or both. To satisfy the foregoing requirement, the Army Map Service has procured universal transformation printers from Wild Heerbrugg Instruments, Incorporated. These printers have a range of from a 1.6 enlargement to a 5.5 reduction of the original negative.[2] The Wild solution to this transformation problem requires the use of three separate printers, each having an adjustable projection lens. The type A produces a 230 by 230 millimetre diapositive and has a transformation range of from a 1.6 enlargement to a 2.1 reduction of the original negative. The type B produces an 82 millimetre diapositive and has a reduction range of from 1.8 to 3.2 of the original negative. The type C produces a 42 millimetre diapositive and has a reduction range of from 3.0 to 5.5 of the aerial negative. The continuously adjustable projection lenses permit the setting of predetermined adjustments to the aerial camera focal length to correct for film change and to rotate optically-mechanically the distortion curve so as to obtain maximum distortion compensation. These printers were manufactured to satisfy the performance requirements of the Army Map Service. The accuracy of each type of printer is in conformity with the accuracy potential of the specific instrument group for which transformation or compensation, or both, is desired.

One of the many sources of error in the photogrammetric chain which precludes obtaining the accuracy potential available in high precision stereoplotters is the necessity to change the focal length of the instrument. In a mapping organization such as ours, which uses photography from many aerial cameras, this operation occurs frequently. The full effect of changing the focal length on the calibration of the instrument is not known. It undoubtedly varies among the different types of instruments and even among instruments of the same type. In addition, in some instruments a change in focal length necessitates a change in the calibrated over-all model focus. Then again, there is always the possibility that the operator has set his focal length improperly. It is believed to be a much simpler task to calibrate a printer and properly make one printer setting than it is to duplicate this procedure many times on numerous plotting instruments by a large number of different operators. Therefore, with the aim of eliminating as many moving parts and necessary adjustments as possible from the AMS compilation instrument, the new Kelsh-type plotters, presently under procurement, designated M I and M II, will be equipped with distortion-free optical systems and fixed focal lengths.[3] In response to this requirement, the United States Geological Survey and the Army Map Service formulated specifications for a transformation printer entitled " The 153 : 153 Printer ". This is a misnomer as this printer actually accommodates aerial photography having focal lengths of from 150 to 156 millimetres and transforms them to a constant 153 millimetres. This printer can be equipped with compensation plates for any six-inch focal length camera. It was manufactured by the Bausch and Lomb Optical Company and the current order is completed.

Any of the transformation printers mentioned here may be modified to incorporate automatic density and exposure control equipment.

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.15.

[2] R. A. Penney, AMS, " The Wild U3 ", *Photogrammetric Engineering*, vol. XXIII, No. 5.

[3] J. B. Theis, AMS, " A Discussion of the Aerial Camera - Stereo Instrument Team ", presented at the 1958 Annual Convention of American Society of Photogrammetry, published in *Photogrammetric Engineering*, vol. XXIV, No. 4.

Automatic Contact Printing

Consider the problems in taking pictures with a stationary camera under conditions where it is possible to choose exactly the angle desired and arrange the amount and intensity of light required. Even under these ideal conditions, are not the results often disappointing? Consider then the problems of the aerial photographer. He is attempting good photographic results with a camera installed on a moving platform. This platform is moving in all possible horizontal translations and angular rotations and it is constantly vibrating. His lighting is often far from ideal. Haze usually clouds the picture. He has no choice of subject or background. He has to keep his camera properly oriented with respect to the line of flight and attempt to keep it level. It is quite a responsibility and it is no wonder that often, even in the same roll of film, the quality of the resulting photography leaves something to be desired.

One of the answers to getting the most out of less than optimum quality photography is a method of photographic processing termed automatic "dodging" (density control) and exposure control.[4] An increase in quality of the resulting photographs and diapositive plates is accomplished by using a scanning light beam from a cathode ray tube as the printing light source. Whenever the exposing spot of light from the cathode tube encounters a dense region on the negative, it automatically becomes brighter. Conversely, brightness of the scanning tube is automatically reduced for thin areas of the negative. A light-integrating switch terminates all exposures automatically. This results in a uniform, pre-set print density without adjustment for widely varying negative densities and brings out maximum possible print detail from each small portion of the film—detail which would ordinarily be lost in conventional photographic printing.

It must be pointed out that the use of such printers does not necessarily result in an increase in speed of the printing operation. However, the increase in photographic quality is incontestable and a gain in production is achieved by the proper ratio of printers to processors and more efficient employee utilization and supporting equipment. The Army Map Service is equipped with log-etronic printers embodying the principles of automatic density and exposure control.

Rectification

The minute detail of the aerial film is now faithfully recorded on paper prints or glass diapositives in the best manner that the present state of technological progress will permit. Yet, for some special purposes, the products of these electronic contact printers cannot meet the requirements. The rectifier steps in to solve some of these problems. In the special purpose category, there is the stereoplotting instrument operator's problem of analysing his convergent model with a stereoscope. His plotting instrument accommodates the convergent photography as supplied by the aerial cameras. However, in any analysis of his model, by means of a stereoscope, he must view rectified images. Although it is understood that rectifying stereoscopes will soon be on the market, it is debatable whether their use will be more efficient than the approach which supplies the operator rectified prints, with the nominal angle of convergency removed by rectification. Dispensable as the rectifier may become in this area, it is still indisputably essential in the production of rectified photographs necessary in the making of controlled mosaics. Also, it is believed by some authorities in the field of analytical aerial triangulation that rectifiers would be useful in determining close approximations of the attitudes of the aerial exposures. This is possible where a medium-scale map already exists, to which the negative to be rectified can be oriented. These approximations would be fed into the orientation and adjustment computations of electronic computers, thus minimizing the amount of iterations required for the analytical aerial triangulation procedure.

The rectifier may be displaced in some areas, but being the only instrument, other than the stereoplotter, which is capable of regaining the attitude of the aerial camera at the moment of exposure, other uses of it will definitely be found. The Army Map Service is equipped with Zeiss and Bausch and Lomb rectifying equipment.

Materials Preparation

While the photographic laboratory is preparing the most faithful pictorial duplications of the terrain that science and technical skill can provide, the materials preparation phase of operations is also under way. At this point in preparation for subsequent aerial triangulation and compilation operations, work on both the compilation sheets and the photography is initiated. Map projections are plotted on the compilation sheets and format boards by means of Haag-Streit co-ordinatographs to an accuracy of ± 0.001 inch (± 0.025 millimetre). Geodetic control is photo-identified from existing maps and from control cards or previously field-identified control photographs or both the latter. In addition, supplementary passpoint control, the co-ordinates of which will be later determined by aerial triangulation, is selected and plotted on the aerial photographs. For the selection, identification and plotting of points on the photographs, stereoscopes, from the pocket type to the "Old Delft", are utilized. Upon completion of the aerial triangulation procedure, which establishes adjusted supplementary control sufficient to orient each model independently in the compilation step, this control and the given geodetic control are plotted on the compilation sheets and format boards by the Haag-Streit co-ordinatographs. An AMS investigation, designed to determine the feasibility of automatizing these plotting operations, concluded that such automation is neither economically nor technically feasible at this time. The Army Map Service will reopen this investigation when economical changes and technical improvements in proposed equipment justify such action.

Aerial Triangulation

The nature of the AMS photogrammetric activity is such that geodetic control is generally sparse. Because of economic and political considerations it must be supplemented by auxiliary control established by photogrammetric instruments. The instruments used for this purpose are first-order Zeiss and Wild equipment. The universal plotters of both companies, in conjunction with the universal printers, are capable of accommodating all types of conventional vertical aerial photography. The Zeiss stereoplanigraphs can also accommodate 20° convergent photography, that is, 20° of conver-

[4] E. Knibiehly, AMS, "Mass Production of High Quality Contact Prints", *Photogrammetric Engineering*, vol. XXII, No. 5.

gency of a single camera. These instruments produce the co-ordinates of supplementary control to a very high degree of relative accuracy. These data are then adjusted absolutely by mathematical computation, using the UNIVAC electronic computer [5]

A considerable portion of the triangulation instrument operator's time is consumed either in manually recording the instrument co-ordinates of the supplementary control or tabulating these data in a form suitable for UNIVAC consumption. In order to eliminate or minimize these manual operations, the Army Map Service initiated an investigation in 1955 to determine the feasibility of automatizing these recording and tabulation procedures so that, by touching a button, the X, Y and Z co-ordinates of a given control point would be automatically tabulated in both a visual and a coded manner. The coded tabulation would be in such a form as to enable direct feeding into the UNIVAC. Completed in February 1957, the investigation concluded that such automation was technically, but not economically, feasible—at this time.

The Army Map Service is now engaged in an investigation to determine whether or not analytical aerial triangulation is superior to conventional aerial triangulation either in accuracy or economy. By analytical aerial triangulation is meant the process by which raw measurements are obtained by a stereocomparator and the models are adjusted both relatively and absolutely by electronic computers. The strips, measured by universal first-order stereoscopic plotters, are already being adjusted absolutely in this manner. For the present investigation, AMS is using a Cambridge stereocomparator and photography taken with cameras equipped with reseaus. It also has access to more precise stereocomparators. Should investigations prove that the completely analytical approach is superior to the semi-analytical method at present used, AMS will have a requirement for stereocomparators having a maximum error of five microns.

Compilation

The Army Map Service has developed a photographic method of obtaining edge-ties between adjacent manuscripts under compilation. The use of this method results in an increase of accuracy, completeness and efficiency.

The increase in altitude potential of photographic aircraft has made imperative the consideration of earth curvature and atmospheric refraction compensation devices in the compilation process. Consideration will be given to the question of whether a device on each instrument or compensation in a transformation printer will provide the best solution to this problem.

Conclusion

In conclusion, it is emphasized that the result of the employment of the auxiliary equipment outlined in this paper has spelt out, and will continue to spell out, a story of higher accuracy, greater economy, increased ease of operation, additional flexibility and improved integration of the many phases of making a map by photogrammetric means.

[5] C. J. Born, AMS, "Vertical Aerotriangulation Adjustment Utilizing Electronic Computers", *Photogrammetric Engineering*, vol. XXII, No. 4

ADJUSTMENT OF AERIAL TRIANGULATION ACCORDING TO THE METHOD OF LEAST SQUARES BY MEANS OF ANALOGUE COMPUTER [1]

Background paper submitted by the Netherlands

Aerial triangulation is still the bottleneck and the main scientific problem in the application of photogrammetry to map production. As a triangulation, according either to the analytical or the optical-mechanical method, is always carried out in strips, the computation and adjustment have also, so far, been carried out strip by strip. For almost twenty-five years the propagation of errors in a strip has been under discussion and a distinction has been made between random errors, and pseudo-accidental errors. Methods of computation of final co-ordinates were developed in which, in some cases, the systematic errors are assumed to be the most important while in others prominence is given to random errors. For the latter, formulae for correction were developed by several authors, based on a least square adjustment, which proved that the third-power correction formula fulfils the condition of the least squares for all three co-ordinates. Simplified methods for computing coefficients of these correction formulae have been derived and applied to many triangulations. Interpolation methods have also been derived resulting in second-power correction curves, with the assumption that the systematic errors are the most important.

All these strip adjustment methods have one feature in common: unsatisfactory results because of the unfavourable propagation of errors in each strip. It was already proved during the Second World War that the accumulation of random errors can cause irregularities in the error diagram in the distance x of a strip which look like jumps in scale. It is obvious that these jumps can never be corrected, either by a third-power or a second-power curve.

We therefore came to the conclusion that only a block adjustment which completely avoids the propagation of errors in the strip can solve the problem of aerial triangulation in accordance with the precision of the determination of the machine co-ordinates in each individual model.

A correct adjustment requires each model to have such a scale, orientation and position that all conditions of connexion by means of common points with four surrounding models (two in the same strip and two in the adjacent strip) are fulfilled as well as possible. "As well as possible" means that, throughout the block, the sum of the squares of all residual

[1] The original text of this paper appeared as document E/CONF 25/L.18

discrepancies in those common tie-points must be a minimum.

This leads to a normal problem of least square adjustment. The trouble, however, is that for large blocks, the number of resulting normal equations will be such that only the largest electronic computers can master the system.

An approximation can be obtained by treating as units, instead of individual models, combinations of two or six or more models. The propagation of random errors is then limited to what happens inside such a unit. This approximate adjustment, although having the advantage of avoiding the use of long strips, still needs the use of high-speed computers.

At the Delft International Training Centre for Aerial Survey, Dr. H. G. Jerie succeeded in solving the problem of least square block adjustment along other lines. Two successive models are combined in one section, which is represented by a stereotemplet. The four tie-points common with the surrounding sections are represented by floating studs formed by elastic springs which are placed in the slots of these stereotemplets. In the ideal position, without errors, the four studs belonging to the four adjacent sections must coincide without tension. We start with a computation of the discrepancies between the four values of the co-ordinates for each tie-point as they result from the transformation of the machine co-ordinates necessary to bring all models into one co-ordinate system. These discrepancies are introduced into a special mechanism which represents each tie-point. The whole system of discrepancies will cause certain shiftings and deformations of the sections. Since the connexion between tie-points and section templets with their tie-points is carried out by means of an elastic spring, the whole system becomes an elastic one which, after some shaking of the table, will find a position in equilibrium. In this position there remains some tension in the tie-points with a small shifting from their zero positions. These shiftings represent the residual discrepancies. Here appears the first basic principle of the system—the "Law of Castigliano"—which states that, if an elastic system is in equilibrium, the potential energy in it is at a minimum. We know, furthermore, that in such a system the shifting of a point requires an amount of energy which is proportional to the square of this shifting. The combination of these facts proves that in this elastic system the square of the residual discrepancies will be a minimum.

The residual discrepancies, however, are not measured, but by a very simple method are determined the coefficients of the linear transformation of each section, which took place under the working power of the discrepancies introduced in the floating tie-points.

New co-ordinates of the tie-points are now calculated by means of these transformation formulae and then, from these, the new discrepancies are computed. These new discrepancies are introduced again on a larger scale and the whole procedure is repeated.

A second characteristic of this method is that it is an iteration method in which, at each step, the discrepancies are introduced on a larger scale. Experience has shown that in many cases two steps are sufficient and three can, as an average, be considered a maximum. It can easily be proved that with this system the same final residual errors are obtained as with numerical treatment of the adjustment by means of an electronic computer.

The advantage of the system is, as has been shown by experiments, that in blocks of, for instance, eight strips of sixteen models each, no more ground control is necessary than along the four edges of the block. Ground control points in the interior of the blocks contribute very little, if anything, to the accuracy of the results.

In addition to this method for the adjustment of planimetric co-ordinates, a device has been developed for the adjustment of heights, which is based on the same principle of the use of elastic bindings in the common points between strips.

THE STRENGTHENING OF INTERNATIONAL CO-OPERATION IN THE EXECUTION OF AERIAL PHOTOGRAPHIC SURVEYS OVER BORDER AREAS[1]

Background paper submitted by Burma

In all normal aerial survey operations it is impossible to avoid crossing international frontiers when photographing adjoining areas. This is a recognized fact. Even when the region photographed is confined to the limits of one's own territory, frontier crossings will be inevitable in the navigation of the aircraft when banking from strip to strip.

In the interests of mapping, international co-operation, on a basis of reciprocity, for permitting such trans-frontier flying is of the utmost importance. Obstacles imposed by neighbouring countries invariably cause serious handicaps, rendering the task of carrying out photography over border areas extremely difficult, and thereby obstructing the mapping of the Earth, which, after so many centuries of progress, is still far from adequately mapped.

In Burma, the past year has seen the implementation of a vast air survey project covering 100,000 square miles. Though permission to fly across the borders was received from the neighbouring Governments concerned, in some cases this permission was given with varying limitations and restrictions. It was also sometimes received rather late, by which time the weather in those border areas had deteriorated hopelessly, resulting in the suspension of the photographic survey operations along several sections of the boundary. Experience shows that these are indeed the most difficult areas in the whole country. The constant uncertainty associated with weather conditions, coupled with the extremely brief duration of possible photographic periods, dictate a policy of top priority in the photography of these areas. The urgency of the situation is heightened by the fact that these border regions are among the least mapped areas in the country.

[1] The original text of this paper appeared as document E/CONF. 25/L.65.

What would be the total consequences of similar occurrences in other countries? Obviously, large stretches of unsurveyed areas in various parts of the world—a heavy retardation of the programme of mapping the earth.

Thus, it is important not only to obtain the permission of neighbouring Governments for trans-frontier flights, but to be granted such permission promptly and without hindrances.

Our aerial photography project is to be extended through the flying season 1958/59, and it is earnestly hoped that, with better co-operation, the survey of the boundaries will be accomplished this time.

Perhaps an effective means of obviating complications and strengthening intergovernmental co-operation would be to lay down specific acceptable limits defining the maximum distance up to which survey aircraft of one country may be allowed to penetrate across an international boundary into a neighbouring country for the purpose of carrying out photography over border areas.

Finally, the necessity to view this question of international co-operation broadly, rationally and objectively is emphasized, the ultimate aim being contribution of our best efforts towards the realization of our mutual purpose, namely, to expedite the survey of the world.

MODERN APPLICATIONS OF CARTOGRAPHIC TECHNIQUES [1]

Background paper by Gordon B. Littlepage, Jr.,
Technical Assistant to the Chief, Chart Division,
United States Coast and Geodetic Survey

In his inaugural address to the United Nations Regional Cartographic Conference for Asia and the Far East at Mussoorie, India, Dr. Sampurnanand cited the definition of cartography adopted by the Committee of Experts on Cartography at Lake Success in 1949.

Cartography, the Committee agreed, is " the science of preparing all types of maps and charts, and includes every operation from original surveys to final printing of copies ".

This is a broad and challenging definition and, if this all-inclusive scope of the science of cartography is not new, certainly the application of the concept is—at least from the point of view of the technical application and co-ordination necessary to provide better maps and charts, faster, and at lower cost.

In the past, tradition and organizational barriers have presented obstacles to the free exchange of ideas and the application of the science and technology of the several disciplines that comprise the field of cartography. Even the structure and exclusive nature of many of our professional societies tend to legislate against the over-all consideration of an integrated problem; rather, such societies concern themselves with their several specialties.

During the past twenty years cartographic methods and techniques have undergone many changes. The unprecedented demands of the Second World War for maps and charts provided the impetus for better and faster methods that fired the imagination of the cartographer and challenged him to cast aside the conventions of the past.

If we review the events of the past two decades, perhaps the most important contributions have been the introduction of the plastics as a cartographic medium and the development of modern scribing (negative engraving) techniques. Out of these have been derived, either directly or indirectly, the exciting progress of this branch of cartography and the development of many new methods.

The subject of this paper is confined to that area of cartography which concerns itself with the compilation and reproduction of maps and charts, commencing with the receipt of field surveys and related chart data. Its purpose is to provide a working paper in the principal methods and techniques being used in this rapidly developing field.

Cartographic Scribing

Scribing tools

Modern scribing dates back to 1940, when the first instruments specifically designed for the purpose were developed by the Coast and Geodetic Survey. These basic tools included the rigid, swivel and pencil-type gravers, and these were quickly followed by the building graver, the subdividing graver, the electric dot graver and the lettering graver (see figure 62). With the adoption of scribing techniques as a replacement for smooth drafting, many mapping agencies, notably in Europe, Canada and the United States, have introduced aids to the scriber, such as sharpening devices or jigs, templets for symbols, mechanical and electric dot gravers, lettering devices and a host of other side-arms and gadgets.

The cutting points used in the scribing tools are of two principal shapes—the blade type and the round, needle type. The blade-type cutters are used in the swivel graver for double and triple parallel lines and for heavy single lines. The round needle-type cutter points are used in the rigid graver to scribe line widths up to 0.015 inch. Wider lines are obtained up to, say, 0.080 inch by using the blade cutters in the swivel graver. Blade cutters are easily made in a machine shop using " straw " hardened spring steel 0.015 inch thick and of proper width, ground and slit to specifications. Ordinary steel phonograph and sewing needles are used for the rigid and pencil-type gravers respectively. Presharpened jewel-tipped points and hardened alloys are also used. Requirements for sharpening the cutting points are more critical for use on plastic than on glass and some agencies demand exacting angle specifications in the final preparation of the scribing points. Experienced

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.33.

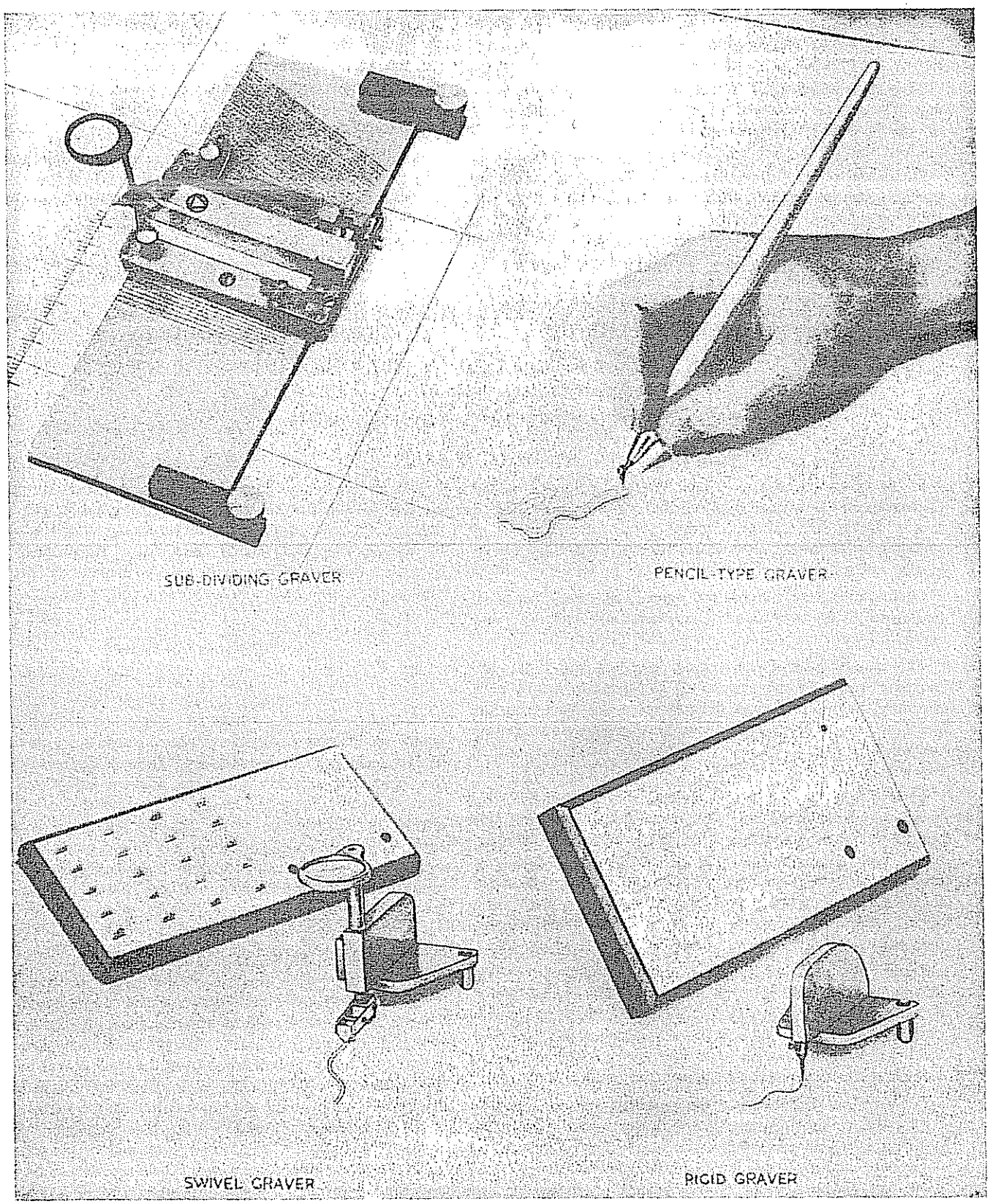

Figure 62. Types of basic scribing tools

scribers soon learn to prepare their own points with little difficulty.

A sample instruction sheet for sharpening scribing points is included in figure 63.

Scribing instruments are available commercially from a number of sources and considerable activity is evident in this field. One word of caution should be given. Good visibility of the scribing point with the scriber in a comfortable position is an important consideration if maximum efficiency is to be realized from the technique.

Base materials for scribing

Base materials for scribing fall into two broad classifications—glass and plastic. Glass should be high-quality photographic glass, polished flat and free of bubbles and imperfections. A thickness of 3/16 inch is usually preferred. Plastics used for scribing are polyvinyl chloride acetate sheeting such as Vinylite, Astralon and Astrafoil, and Type D. Mylar, a polyester film. A wide choice of thickness is available in the plastics; however, for scribing, 0.0075 inch Mylar and 0.010 inch Vinylite are generally preferred.

Glass is the superior base medium for ease of scribing and quality of the scribed image. It also has excellent dimensional stability and lends itself readily to the inclusion of wet-plate photographic methods for combining type and line work on the same negative. An important consideration is the ability to make continuous and extensive corrections. Glass fills this need admirably.

Disadvantages of glass are the obvious danger of breakage, and storage and handling difficulties. These are especially important considerations if the operations of map-making are not centralized in a single installation. For large map sizes two sheets of glass are necessary, because of size limitations, for each colour separation, adding junction and layout problems.

Plastics should have smooth, press polished surfaces to provide a good scribing base. Vinylite and Mylar are acceptable in this respect, although more care and skill are required of the scriber to produce a clean line without leaving a film of the scribe coating or digging into the base material.

From the standpoint of durability, Mylar is far superior, being extremely tough and shatterproof. Vinylite will shatter if dropped on edge, and tends to become brittle with age.

Both Vinylite and Mylar are acceptable for dimensional stability under controlled conditions of temperature and humidity where close registration is required. Mylar is considerably more stable than Vinylite under extremes of temperature, while Vinylite resists the effects of humidity changes better than Mylar. These characteristics should be considered in many applications where extremes are anticipated.

For all practical purposes, Mylar is chemically inert. This is a distinct disadvantage in comparison with Vinylite, which lends itself well to the use of chemical solvents and dyes so convenient to use in many cartographic applications.

As may be seen, the choice of the proper base material must take into consideration many factors, including environment, revision requirements and the related chart production procedures. It should be pointed out that some chart-producing agencies do not hesitate to use glass and the plastics in combination. An understanding of the limitations of each medium is necessary to " live " with what we have until a medium having all the advantages of both is available.

Coatings for scribing

A good scribe coating is probably the most important single requirement in the application of the scribing techniques. In the early days of scribing, the principal requirements were good actinic quality and the ability to engrave as well as a good wet-plate emulsion. As new techniques and uses have been developed, a good coating must have many and seemingly conflicting qualities:

(*a*) It must adhere well to any of the base materials or to a wet-plate emulsion without penetrating, and must be easily and cleanly removed by the scribing points without any lack of definition of borders or at crossing corners;

(*b*) It must be transparent enough to permit overlaying of copy for tracing, and translucent enough when lighted from beneath to permit scribing of guide copy printed on the surface or an underlying wet-plate image to be followed in intricate detail; yet it must be impervious to actinic light so as to permit contact to all photosensitive emulsions even for multiple exposures;

(*c*) It must be tough enough to resist abrasion in handling or damage from the legs of the scribing tools, yet soft enough to permit easy passage of the scribing point and nonabrasive so as not to cause excessive wear of the points;

(*d*) It must be receptive to sensitizing emulsions for printing down keyline guides for the scriber, and accept pencil and ink for other field and office applications;

(*e*) It must be thin enough to avoid undercutting in photomechanical etching with solvents, yet retain its actinic and scribing qualities;

(*f*) It must retain these characteristics for long periods of time.

The most popular coatings for general scribing are of the pigmented type and are orange or yellow in colour. A choice of these will permit contact printing to either photographic film or process coatings on press plates. Some agencies have found it convenient to use a white coating for certain purposes, such as combining lettering with the engraved line work on plastic. In certain instances the engraved line work is dyed and the coating removed with a solvent, thus producing a positive. The dye process requires the use of vinyl plastics. Type lettering and symbols can be applied for photo copying to produce a negative. Some agencies, especially in Europe, prefer the dyed positive method because deep-etch plates are used.

Many good precoated sheets are now available commercially and a great deal of research is being applied to produce better coatings and methods of application. Some agencies still prefer to coat their own sheets, especially where specialized techniques are used, in order to " tailor " the coating to their needs. A typical formula and method of coating are found in appendix I.

The scribing image

The source of the image for preparing the final copy by scribing is the compilation which may have been prepared in one of a number of ways.

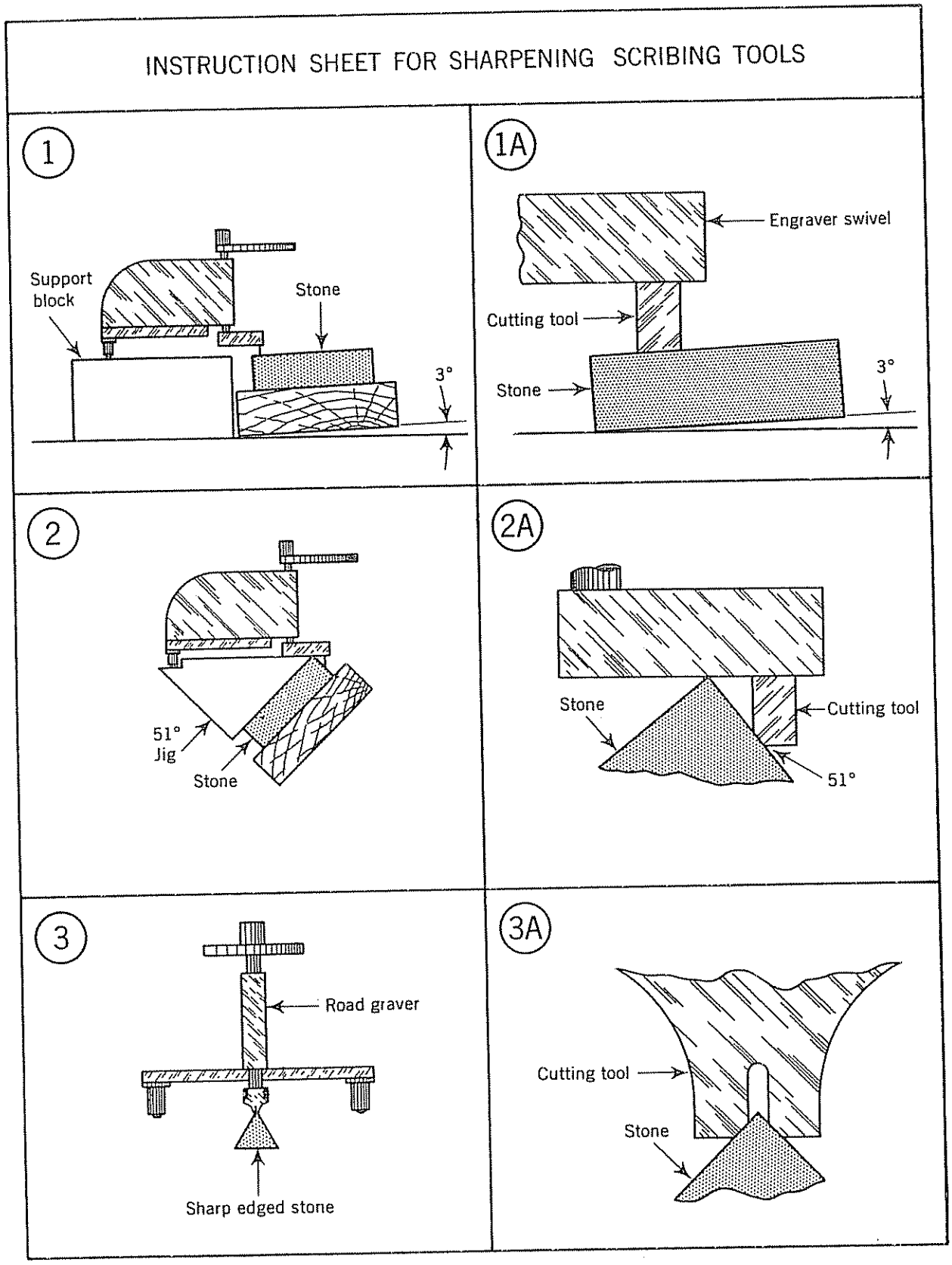
INSTRUCTION SHEET FOR SHARPENING SCRIBING TOOLS
1
Support block
Stone
3°
1A
Engraver swivel
Cutting tool
Stone
3°
2
51°
Jig
Stone
2A
Stone
Cutting tool
51°
3
Road graver
Sharp edged stone
3A
Cutting tool
Stone

Figure 63

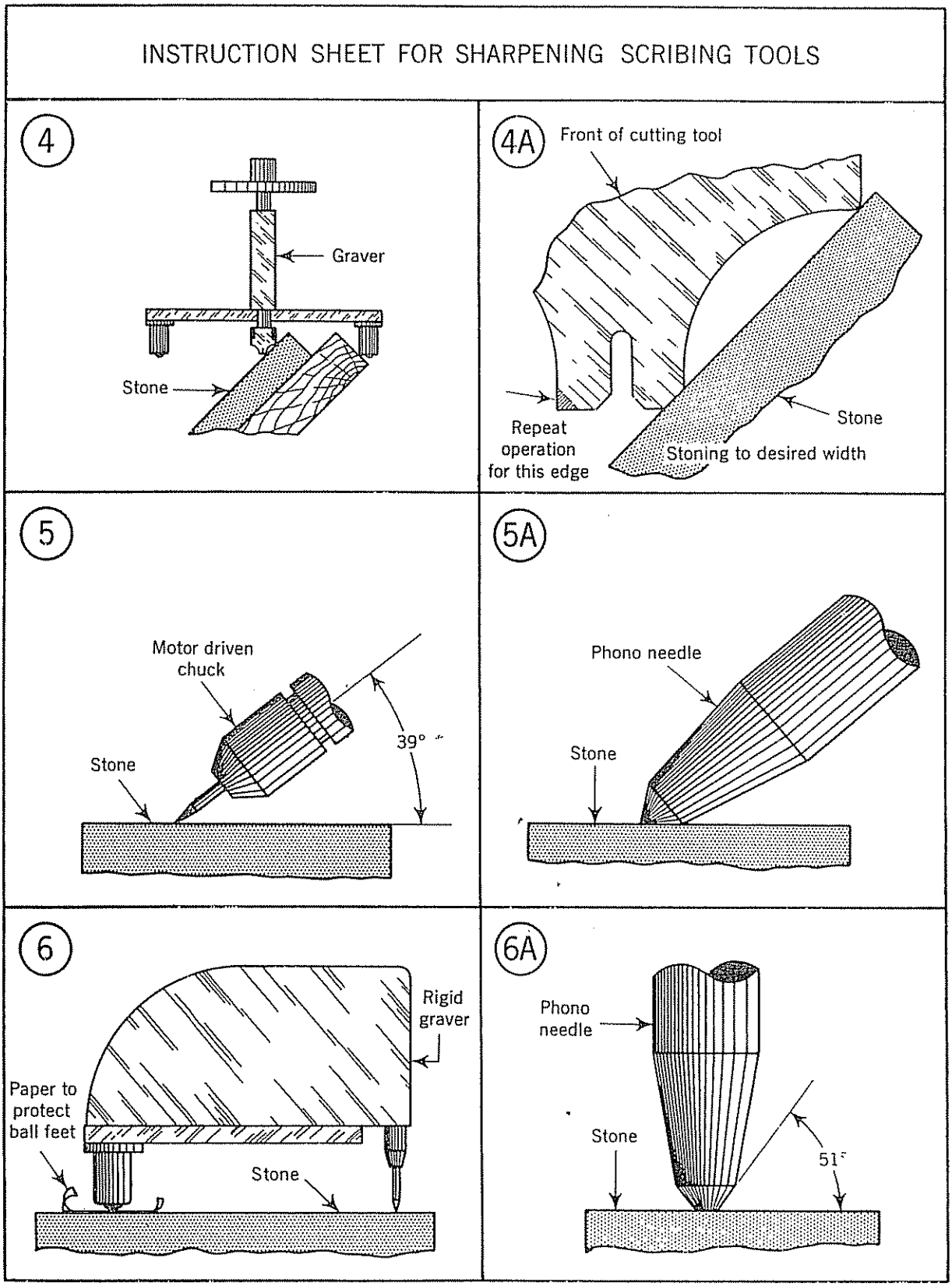

Figure 63 (continued)

(*a*) A compilation manuscript on plastic, on which is compiled all of the detail of the map, such as culture, drainage and topography;

(*b*) A mosaic compilation of waxed, matte-finish stripper film positives of existing map information, photographed to scale and positioned to a projection ruled on plastic;

(*c*) A compilation which separates detail, such as planimetry on one sheet and topography on another sheet. This method is often utilized where stereocompilation methods are employed.

The scribing image is contact printed in a suitable colour on coated plastic or coated glass from a negative of the compilation by conventional surface plate-making processes using sensitized coatings especially adapted for the purpose.

Excellent commercial coatings are available, such as " Watercote " and " Colorline ", which may be applied to the coated base material by flowing, swabbing and rubbing, or by the conventional use of a whirler.

On some jobs final typing of names, symbols and the like is applied directly to the compilation. In this case, a wet-plate negative is made, and, after development, the scribe coating is applied. The coating is removed from the type with a solvent such as benzol and the line image provides the guide for final scribing of the line work.

When preparing a scribing image from a compilation manuscript, one negative, photographed to the final map scale, is used to prepare as many colour separation sheets as needed. If the map features are compiled on separate sheets, separate negatives are required. In some stereocompilation methods, a rough scribing is done directly on the stereoplanograph or made from the pencil plot. In this case direct contact can be made to produce the image for final scribing. A procedure for applying the scribing image is found in appendix II.

Typing

Conventional methods in use for preparing map names, numbers and symbols are those utilizing hot metal type and photolettering machine, with a strong trend to photolettering. The products of these methods, whether it be an ink impression or photographic stripping film, are coated by machine with a thin film of wax to provide a pressure-sensitive adhesive for placement on the name plate.

Scribing techniques have introduced some new methods of typing and have also pointed up certain disadvantages, especially in the use of plastic, which research is working to overcome. The simplest application is to prepare the name sheet for each colour on a separate sheet of plastic, make a negative and double print with the line negative on the printing plate. The disadvantage rests in having multiple negatives and the difficulty of revision.

A considerable amount of research has been expended on the development of techniques which permit combining the name sheet with the engraved line work. Present techniques use photomechanical etching of the coated sheet by the deep-etch process by contacting a positive of the name sheet. The operation is very critical when high-quality results are required, but progress is being made to perfect the method.

When the wet-plate process is used, lettering and line work may be combined easily. A wet-plate negative is made of the name plate and developed normally. The negative is then coated with a scribe coating, the guide image is processed, and the names are cleared with a solvent such as " Cleano " or turpentine. In some cases it is desirable to apply the type directly to the compilation, in which event a wet-plate negative is made of the combination line work and names, this is coated and the names are cleared.

Name corrections to scribed sheets are made by using photographic stripping film or wet-plate stripper. When the negatives are subject to frequent revision and must be retained for many years, wet-plate stripper offers distinct advantages. It will not pop off with age or handling, and may be scribed in the same manner as the scribe coat.

To produce wet-plate stripper a positive from the photolettering machine or type press is sent to the wet-plate camera. A wet-plate negative is made of a number of type orders and processed in the usual manner except that the gum arabic solution is eliminated from the final stage of development. After the negative has dried a thin coating of Neg-O-Lac [2] is flowed over the surface and allowed to dry. The stripper is removed from the glass base by overlaying a sheet of absorbent paper, such as newspaper, and wetting thoroughly. After a few minutes the stripper, usually scored in sections approximately 6 by 9 inches, is lifted or peeled off as it adheres to the paper and is transferred to a piece of plastic. The wet paper is then removed and excess water and air bubbles are blotted out. Placement of type on the scribing sheet is done in the usual manner by spading out an opening and using Eastman stripping cement as an adhesive.

A considerable amount of work has been done, notably in Europe, in developing equipment of various kinds for mechanizing the placement of type. Among these are the French " Nomafot ", nicknamed the " Bibette ", and its successor, the Staphograph. A different machine has been developed in Germany by Hoh and Hahne called the " Kartolux ". In the United States, the Army Map Service has made some interesting studies [3] as a result of its work with the Staphograph.

Three systems of automatic type placement are being researched. The first proposal utilizes a Nistri Electrocoordinatograph with a slug print head which produces a position indicator or overprint guide and a punched tape with x, y and angular information. The operator hand letters a film request. A 70-millimetre film containing the map names is produced on a Fotosetter. A second electrocoördinatograph with a projector head is positioned over a sensitized film. The reel of 70-millimetre film is inserted in the projector head and the coordinatograph reads the punched tape and moves to the x and y position. At the same time the projector head rotates to the correct angular position and exposes the name.

The second proposal is similar except that a composing machine capable of operating from a punched tape such as the Photon is used. This eliminates the need for hand lettering the type request as the operator keyboards the name, size and style together with the x, y and angular information onto a tape. The tape automatically produces the 70-millimetre film and drives the coördinatograph for final positioning and exposing of the map names.

[2] Neg-O-Lac, a commercial stripping solution. Philip Lochman and Co., 2,405 Oakton Street, Evanston, Illinois.

[3] Army Map Service, *Procedural and Performance Analysis of the Staphograph and a Proposed Automatic Type Placement Process* (Washington, D.C.).

A third proposal is all-electronic and uses an electronic image tube. High production speed on some presently available tubes is reported up to 25,000 characters per second. However, image quality is not satisfactory in the present stage of development.

These very interesting developments and proposals show a head-on attack on an area that has resisted automatic methods and one which some cartographers estimate represents 40 to 50 per cent of the total original cartographic costs.

Tints and Area Patterns

Familiar to all are the woodland, water and urban area tints required on topographic maps, the hypsometric and bathymetric tints on aeronautical and nautical charts, the numerous patterns on geologic and soil maps, and other special purpose tints and patterns. Also familiar are the painstaking methods of hand painting applied to delimiting lines on metal printing plates or mounted drawing boards. During the Second World War the alternate band methods were developed which reduced the amount of manual work by using contacting methods on glass or Vinylite. These methods, however, still required a great number of man-hours.

The latest method consists of etching the delimiting lines of the tint boundaries, such as the contours, on a specially coated sheet of plastic which has been sensitized for negative or positive contact printing, and peeling or stripping away the coating in the tint area to produce an open-window negative. If the peeler sheet is vinyl, a penetrating dye may be applied to render the etched key lines opaque for plate-making purposes, thus saving hand opaquing time

When permanent, correctable negatives are required, some agencies make duplicate scribe-coat negatives by direct contact from the peeled sheets or from positives. The same peeler negative can be used to provide a number of tints by combining the two methods.

Excellent materials for stripping are now available commercially as presensitized sheets, for processing from either a negative or a positive.

Occasionally a combination of features on the key negative or lack of continuous line boundaries precludes the use of the peeler method. In this event a keyline image is processed to a scribe-coated plastic. The tint is prepared by painting with a water-soluble opaque [4] which provides a resist for removing the scribe-coat with a solvent in the area of the tint. The opaque is then removed by flushing with water.

These two methods may be combined or supplemented by more conventional methods when the nature of the work so dictates.

Interposing Screen Films

One of the difficult problems facing cartographers is the lack of large-size commercial dot and ruling screens in a wide range of tone values to permit screening of open-window negatives to the press plate and combining a number of tones of the same colour on one press plate. Several United States Government mapping agencies have developed techniques for manufacturing these screens by photographic methods in sizes up to approximately 40 by 50 inches.

[4] Resistopake negatives. *See* appendix III.

Commercial interest in supplying film screens has been small because of the ease with which originals may be duplicated, and where some interest has been aroused the cost has been extremely high.

Because of the great need in this area, the Second International Cartographic Conference, Chicago, Illinois, June 1958, appointed a committee to study the problem. A survey is now being made to determine what interposing screen films have been made by mapping agencies and how they may best be made available.

The aforementioned methods and procedures do not include all of the developments in the rapidly changing technology of map and chart production, but they are indicative of the more important ones for producing better products in less time and for less cost.

It is important to note that most of these developments have derived from the application of photolithographic methods and they have been made possible by the recognition that the compiler and lithographer are interdependent, with interrelated skills. Even more significant, however, is the strong trend to extend this relationship to the entire field of cartography, from the beginning of field surveys to the final printing of maps.

There is a belief among cartographers everywhere that recent contributions are but a prediction of what lies ahead and that we are on the threshold of a really revolutionary period in the science of cartography.

* * *

APPENDIX I

Gravecote Yellow
(for plastic)

Formula:

Solution A:

2 oz Benzol
2 oz Beeswax (white)
96 oz Redistilled turpentine
6 oz Castor oil

Solution B:

Flopaque Yellow Scribecote (approximately 2 gallons)

Directions:

1. Dissolve beeswax in heated turpentine.
2. Mix castor oil and benzol thoroughly.
3. Mix 1 and 2 thoroughly.
4. Add Flopaque until a Baume of 20° is obtained.

Notes:

1. Tape all edges of a polished Vinylite or Mylar sheet to a metal plate.
2. Place mounted sheet in vertical whirler, wipe with sponge and alcohol.
3. Rotate at 30 rpm. Slowly pour coating solution in centre, gradually moving towards the edge.

4. Whirl sheet dry. Drying may be accelerated by use of fan and moderate heat.
5. When dry remove from plate and protect coating with a cover of Kraft paper.

Supplies :

Flopaque

Floquil Products, Cobleskill, New York.

(It is recommended that the usual patent study be made before pursuing application of the processes described.)

APPENDIX II

Notes on the Preparation of Blueline Keys
(scribe-guides)

Two methods are used in preparing a blueline image, or scribe-guide, on Flopaque coated (scribe-coated) plastic. In the first method, a positive is used to produce the image, whereas, in the second method, a negative is used for that purpose. Both methods are described separately here, although the objective of the two methods is identical.

Method using a Positive

Directions :

1. Tape scribe-coated sheet to a metal plate.
2. Place mounted sheet in tank and clean with Plastic Cleaner (pre-etch), using a felt pad.
3. Place mounted sheet in vertical whirler and rotate at 60 to 65 rpm.
4. Flush with water and slowly pour Deep Etch Sensitizer onto the sheet, beginning in the centre and gradually moving towards the edge.
5. Whirl sheet dry. Drying may be accelerated by use of fan and moderate heat.
6. When thoroughly dry, remove sheet from plate, clean and dry back.
7. Expose to positive in vacuum frame for one minute with one 35-ampere arc lamp set at four feet from the frame.
8. Tape sheet on light table, securing all edges. Pour deep-etch developer in centre (pool about 5 per cent of the size of the sheet) and spread over entire sheet using " deep-etch pad ". Use circular motion with little pressure for 3½ minutes. Development is complete when gum coating is removed from unexposed image areas. Remove developer and dry.
9. Turn on bottom lights of light table, moisten a cloth with dye solution and spread rapidly over entire sheet. When the image has been coloured to the desired density this operation should be stopped to avoid piling up the colouring material.
10. Place sheet in tank, wash with Plastic Cleaner. Flush thoroughly with warm water to completely remove the gum stencil. Dry with squeegee and cloth.

Formulae :

Plastic Cleaner (pre-etch)

4 oz Nitric acid (70 to 71 per cent)

4 oz Aerosol solution

8 oz Gum arabic solution 14° Baume

112 oz Water

Dissolve aerosol pellets in enough water to produce a thick mass in the bottom of the jar and a thinner liquid at the top. It is the thin liquid which is used here.

Deep Etch Sensitizer

30 oz Gum arabic solution 14° Baume

10 oz Ammonium dichromate solution 14° Baume.

1½ oz Ammonium hydroxide

Deep Etch Developer

7½ lbs Calcium chloride (commercial grade)

1 gal Water

Cool, filter, and add water to bring to 40° Baume, then add:

6½ oz Lactic acid (85 per cent)

Dye Solution

75 grains Geigy Grazol Blue R

32 oz Toluene

Notes:

1. Baume readings taken at 70° F.
2. Commercially prepared deep-etch sensitizer and developer may be used.
3. Other colouring solutions or compounds may be substituted for the dye solution, such as Xylene and oil-soluble dyes, or alcohol and aniline dyes. The governing factors in the selection of substitutions are:
   a. Must not affect the gum stencil.
   b. Must not damage scribe coating.
   c. Must not be water-soluble.
   d. Must not hinder scribing.

Method using Film Negative

Directions :

1. Tape scribe-coated sheet to a metal plate.
2. Place mounted sheet in tank and clean with Plastic Cleaner (pre-etch) with a felt pad.
3. Place mounted sheet in vertical whirler and rotate at 60 to 65 rpm.
4. Flush with ½ ounce of Blueline Sensitizer mixed with 16 ounces of warm water. Then slowly pour regular Blueline Sensitizer onto the sheet, beginning in the centre and gradually moving towards the edge.
5. Whirl sheet dry. Drying may be accelerated by using fan or moderate heat or both.
6. When thoroughly dry, remove sheet from plate, clean and dry back.
7. Place sheet in vacuum frame, coated side up. Position negative on sheet, emulsion side up (out of contact). Expose for one minute with one 35-ampere arc lamp set four feet from the frame.

7a. (Optional) If a glass negative is used, the following procedure should be followed: Place sheet in vacuum frame coated side *down* (away from lights). Position negative, emulsion side down, in contact with the sheet. Expose for five minutes with two 35-ampere arc lamps set at four feet from the frame.

8. Place the sheet in tank and flush with cold water, then, rock with Blueline Developer solution until background begins to clear. Flow cold water over the sheet and, if necessary, use cotton gently to assist development. Since this is a critical stage of the process, the amount of ammonia used should be varied according to humidity conditions, increasing for dampness, decreasing for dry condition.
9. After the final rinse with cold water, place the sheet face down on clean newsprint stock and blot gently. The image is extremely delicate until after it dries thoroughly.

Note:

The image may be removed with bicarbonate of soda mixed 8 ounces to one gallon of water. Use a felt pad.

Formulae :

Plastic Cleaner (pre-etch)

Same as for the positive method.

Blueline Sensitizer (stock)

1¼ oz Pitman Blueprint Powder for Glass
16 oz Water (140° F).
½ oz Ammonia (28 per cent)

Blueline Developer

½ oz Ammonia (28 per cent)
1 gal Water

APPENDIX III

Resistopake

(Water-soluble resist for preparing artificial negatives)

Purpose :

Resistopake is used in the preparation of artificial negatives of tint areas. It is applied to the Flopaque coated scribe-sheets after a blueline image has been prepared. Its purpose is to provide a solvent resist over all areas of the sheet which are not to print. After the Resistopake has been applied, solvent is used to remove the scribe-coat from those areas not protected by the resist. The result is an artificial negative of the tint area to be printed.

Directions for use :

1. Resistopake may be applied with either a pen or brush.
2. It should be applied in a thick coating so as to offer maximum protection from the solvent.
3. Should it fail to adhere properly, allow to dry, then clean spot with wool-cotton moistened with alcohol.
4. Powder the coating occasionally with French chalk during work and when completed. Avoid placing hands or arms on the work areas.
5. Keep well mixed by stirring occasionally.
6. The properly painted sheet will not transmit light, nor will it show pin holes.
7. When painting is complete, remove the scribe-coat from the unprotected areas with a wad of cotton moistened with a mixture of Cleano and alcohol (water free), mixed in equal parts. Excessive pressure will damage the resist coating. A clean wad moistened with the solvent may be used to remove any residue in the washed out areas.
8. After the unwanted scribe-coat has been removed, place the sheet in a tank and wash with water. A cotton wad may be used to assist in complete removal of the Resistopake. Remove sheet from the tank and dry with a soft cloth and fan.

Formula :

Resistopake

1,880 cc Water
110 cc Glycerine (winter use)
90 cc Glycerine (summer use)
460 cc Glue
4 lbs Rex Red Opaque (to test 41° Baume)

Directions for mixing :

1. Add glycerine to water and mix well for one minute.
2. Add glue. Dissolve completely by mixing for four minutes.
3. Add Opaque until Baume of 41° is obtained (about 4 lbs), stir well for ten minutes.

Note:

Other solvents such as turpentine or mineral spirits may be substituted for the Cleano-alcohol solution, provided they are water free and do not penetrate the resist.

APPENDIX IV

Touch-up Paint for Scribe-coated Negatives

128 oz Red Flopaque Scribecote
128 oz Yellow Flopaque Scribecote
32 oz Varsol (mineral spirits)
5 oz Castor oil

Mix Red and Yellow Flopaque together, then add Varsol (mineral spirits). Mix well. Add castor oil and mix well again.

Pour into small jars (about 4-oz) and label with instructions for use and thinning. Solution is thinned with Varsol. If, however, the Varsol forms a milky white surface on the paint, discard and replace with a fresh supply. Always keep jar covered when not in use, and stir well before each use.

APPENDIX V

Materials, Supplies and Instruments

(A selected list of sources of supply for scribing)

Mylar

E. I. duPont de Nemours and Co.
Film Department
Wilmington 98, Delaware

Mylar-matte surface

American Blueprint Co.
7 East 47th Street
New York, N.Y.

E. I. duPont de Nemours and Co.
666 Driving Park Avenue
Rochester 3, New York
(Pencil and ink surface)

Di-Noc Chemical Arts, Inc.
1,700 London Road
Cleveland 12, Ohio

Eugene Dietzgen Co.
954 Fullerton Avenue
Chicago, Illinois

Keuffel and Esser Co.
Hoboken, New Jersey

Stephen M. Wagner, Inc.
2,235 Chouteau Avenue
St. Louis 3, Missouri

Direct Reproduction Corp.
811-813 Union Street
Brooklyn 15, New York

Scribe-coated sheets

American Blueprint Co.[a]

Camden Products Co.
Box 2,233 Gardner Station
St. Louis, Missouri

Do-Noc Chemical Arts, Inc.

Direct Reproduction Corp.[a]

Eugene Dietzgen Co.[a]

Keuffel and Esser Co.[a]

[a] Addresses of companies are shown under their first listing.

South Wales Chemical
Works, Ltd., Frith Park
Walton-on-the-Hill
Tadworth, Surrey, England

Klimsch and Co.
Schmittstrasse 12
Frankfurt A.M., Germany

Vinyl—various types and surfaces

Bakelite Company
30 East 42nd Street
New York 17, N.Y.

Di-Noc Chemical Arts, Inc.[a]

Direct Reproduction Corp.[a]

N. Teitelbaum Sons
261 Grand Concourse
New York 51, N.Y.

Strip-coated sheets

Di-Noc Chemical Arts, Inc.[a]

Direct Reproduction Corp.[a]

Eugene Dietzgen Co.[a]

Keuffel and Esser Co.[a]

South Wales Chemical Works, Ltd.

Ulano Products Co.[a]
610 Dean Street
Brooklyn 38, New York
(Dystrip process)

Coating materials

Floquil Products Co.
Cobleskill, New York
(Flopaque)

Klimsch and Co.[a]

Sensitizers

American Blueprint Co.[a]
(Colorline)

Direct Reproduction Corp.[a]
(Watercote)

Harold M. Pitman Co.
1,110 13th Street
North Bergen, New Jersey
(Pitman blue)

Hausleiter and Co.
Munchen, Germany

Gravers

Benedum Instrument Co.
8,811 Falls Road
Washington 14, D.C.

Camden Products Co.[a]

Thomas Tool and Die Co.
2,107 Maisel Street
Baltimore 30, Maryland
(Fineline graver)

Haag-Streit, Switzerland
Distributed by:
Aero Service Corp.
Philadelphia 20, Pa.

Keuffel and Esser Co.[a]

Direct Reproduction Corp.[a]

South Wales Chemical Works, Ltd.[a]

Universal Instrument Co.
3,811 Bunker Hill Road
Brentwood, Maryland

Varigraph Co.
Madison, Wisconsin
(Lettering and symbol graver)

Graver points

Aurele M. Gatti
524 Tindall Avenue
Trenton 9, New Jersey
(Sapphire points)

Camden Products Co.[a]

Duotone Company
Locust Street
Keyport, New Jersey
(Phonograph needles)

Keuffel and Esser Co.[a]

M. A. Miller Mfg. Co.
4th and Church Streets
Libertyville, Illinois

Direct Reproduction Corp.[a]

South Wales Chemical Works, Ltd.[a]

Universal Instrument Co.[a]

Miscellaneous

Geigy Co., Inc.
89-91 Barclay Street
New York 8, N.Y.
(Dyes)

Dow Chemical Co.
Midland, Michigan
(Xylene)

Standard Oil Co. of New Jersey
26 Broadway
New York 4, N.Y.

F. G. Okie, Inc.
247 South Third Street
Philadelphia, Pennsylvania
(Rex Red Opaque)

Capital Printing Ink Co.
806 Channing St., N.E.
Washington, D.C.
(Cleano)

Any mention of commercial products in this paper is for information only and does not constitute endorsement by the United States Government.

APPENDIX VI

Cartographic Literature

(A selected reference of recent and current literature describing the development and application of modern cartographic techniques)

General

Current Cartographic Procedures for Topographic Maps of the United States, C. F. Fuechsel, J. A. Law, R. L. Moravetz, U. S. Geological Survey, Washington, D.C.[a]

Techniques In Use by the Coast and Geodetic Survey, G. B. Littlepage, Jr., Coast and Geodetic Survey, Washington, D.C.[a]

Cartographic Compilation Techniques In Use by the Coast and Geodetic Survey, G. K. Emminizer, Jr., Coast and Geodetic Survey, Washington, D.C.[a]

Systems Engineering—A Challenge to Cartographers, C. S. Spooner, Jr., Army Map Service, Washington, D.C.[a]

Proceedings of the Esselte Conference on Applied Cartography Stockholm, Sweden, July 1956 (First International Cartographic

[a] Paper presented at Second International Cartographic Conference Chicago, Illinois, June 1958.

Conference), *Informations Relative to Cartography and Geodesy*, Institute for Applied Geodesy, Frankfurt am Main, Germany.

Some Recent Developments in Map Reproduction, C. S. Spooner, Jr., Army Map Service, Washington, D.C.[b]

Scribing

Application of Corrections on Scribed Map Originals, D. Chervet, Eidgen, Landestopographie, Bern, Switzerland [a]

Negative Engraving Instruments, Aeronautical Chart and Information Center, St. Louis, Missouri [a]

Map Reproduction Using the Negative Engraving Technique, E. D. Baldock, Department of Mines and Technical Surveys, Ottawa, Canada

New Developments in the Production of Map Originals for Printing, Carl Mason Mannerfelt, Esselte, Stockholm, Sweden. Paper presented at Eighth International Congress of Printing and Allied Industries, Venice, Italy, 1954

Report on Scribing, Interagency Committee on Negative Scribing, Bureau of the Budget, Washington, D.C., March 1957

Negative Engraving Techniques for Map Production, G. B. Littlepage, Jr., Coast and Geodetic Survey, Washington, D.C. Paper presented at Forty-seventh Annual Meeting of Canadian Institute of Surveying and Photogrammetry, Ottawa, Canada, February 1954

Scribing on Plastic and Glass at the Army Map Service, C. Westrader, Army Map Service, Washington, D.C.[a]

New Tools for Engraving, C. Westrader, Army Map Service, Washington, D.C.[a]

Gravecote Yellow, Research Bulletin No. 4, Coast and Geodetic Survey, Washington, D.C., 1945

Map Scribing On Plastic Sheets vs Ink Drafting, S. Sachs, Coast and Geodetic Survey, Washington, D.C., 1952

Plastic and Glass Engraving vs Drafting, C. F. Fuechsel, U.S. Geological Survey, Washington, D.C. 1953

Glass Scribing, A. A. Gioiosa, Army Map Service, Washington, D.C., 1953

"Recent Developments in Negative Scribing", C. F. Fuechsel, *Surveying and Mapping*, October-December 1953

Scribing Report on 1 : 1,250 and 1 : 2,500 Series, British Ordnance Survey, London, England, 1955

Photogrammetric and Field Scribing, R. E. Altenhofen, U.S. Geological Survey, Washington, D.C.

Tools for Scribing, D. Chervet, Eidgen, Landestopographie, Bern, Switzerland [b]

Typing

Transparent Negative Stickup, Aeronautical Chart and Information Center, St. Louis, Missouri [a]

Utilization of the Type Placement Machine Called Nomafot or Bibette ..., A. Amiel and G. Thibaut, Manufacture française de pneumatiques Michelin, Paris, France [a]

The Rantone Process in Commercial Mapping, Duncan Fitchet, Rand McNally and Co., Chicago, Illinois [a]

Procedural and Performance Analysis of the Staphograph and a Proposed Automatic Type Placement Process, C. Westrader, Army Map Service, Washington, D.C.[a]

Photo Mechanically Etched Scribing Sheets, J. Manning, Rand McNally and Co., Chicago, Illinois [a]

Photo-Lettering and Photo-Positioning of Cartographic Lettering, S. de Brommer, Institut géographique national, Paris, France [a]

Screens

Standardization and Production of Screen Tints, Aeronautical Chart and Information Center, St. Louis, Missouri [a]

Proving

Some Recent Developments in Map Reproduction, C. S. Spooner, Jr., Army Map Service, Washington, D.C.[b]

Color Proofs on Plastic Directly from Negatives, Research Bulletin No. 2, Coast and Geodetic Survey, Washington, D.C., 1944

Copies, Duplicates and Color Proofs on Plastic, S. Sachs, Coast and Geodetic Survey, Washington, D.C.[b]

Rub-On Color Proving Method, Technical Circular, Army Map Service, Washington, D.C., 1957

Tints

Photo Process Strip Materials, Aeronautical Chart and Information Center, St. Louis, Missouri [a]

Photo Mechanical Vignetting, Technical Report No. 61, Aeronautical Chart and Information Center, St. Louis, Missouri, January 1955

Strip-Mask Process Materials at Rand McNally, F. Cochran, Rand McNally Co., Chicago, Illinois [a]

Duplicate Gravecote Negatives, Research Bulletin No. 5, Coast and Geodetic Survey, Washington, D.C., 1946

Resistopaque Negatives, Research Bulletin No. 3, Coast and Geodetic Survey, Washington, D.C., 1944

Dystrip Technique of Color Separation, Technical Report No. 70, Aeronautical Chart and Information Center, St. Louis, Missouri, 1955

[b] Paper presented at First International Cartographic Conference, Stockholm, Sweden, July 1956.

PROBLEMS RELATING TO THE ESTABLISHMENT OF A NEW LAND REGISTER (CADASTRE) [1]

Background paper by Professor Karl Rinner

Introduction

Inasmuch as the term "cadastre" does not in itself have any clearly-defined meaning, the establishment of a new cadastre must be preceded by an examination of the question as to what purpose the cadastre is to serve and what is to be expected of it.

In a very general sense, a cadastre is a list of homogeneous objects or persons in a given district, which is compiled for a particular purpose, such as taxation or the collection of charges. Thus, in addition to the land register or the landed property cadastre which lists and describes properties and

[1] The original text of this paper, submitted by the Federal Republic of Germany, appeared as document E/CONF.25/L.20.

with which this paper is more directly concerned, there are also economic-planning cadastres, pipe-laying cadastres, hunting cadastres and so on.

A landed property cadastre contains a descriptive part, in which the properties are listed and described, and a cadastral map, which constitutes a geometrically accurate representation of these properties.

Landed property cadastres were originally compiled for the sole object of ensuring the fair taxation of landed properties, but in the course of time they came to serve additional purposes. The cadastre, which has become part of the land register *(Grundbuch)*, is used to describe the properties listed in the register and serves as evidence of ownership. It is a basic requirement for town and country planning, traffic planning and indeed for economic planning of every type. In some countries the cadastre has taken on legal force and become a juridical cadastre and must therefore show the precise boundaries of properties. The old fiscal cadastre has become a multiple-purpose cadastre in which both the descriptive part and the cadastral map must serve many different purposes.

The degree of accuracy required varies with the purposes for which the cadastre is to be used. In the case of fiscal cadastres, approximate accuracy is sufficient, because the land tax is based on the value of the property, and this in turn is determined by the size of the property and the quality of the soil. As soil quality can be estimated only with a 5 to 10 per cent margin of error, the exact size does not have to be ascertained for tax purposes alone.

For planning and economic cadastres, the map must be complete, and the elevation figures must be shown. The degree of accuracy, however, need not be greater than in the case of a large-scale map.

In a property cadastre, on the other hand, accuracy is of the greatest importance, because the boundaries of the properties must be shown in such a manner that they can be clearly marked off on the ground itself. This applies particularly to countries in which the cadastre is part of the land register and is generally relied upon as a document having legal force.

The accuracy required in a cadastral map may therefore be said to depend on the degree of accuracy with which the boundaries of properties must be reproduced on the ground itself.

The beginnings of landed property cadastres date back to the pre-Christian era. Some form of cadastral surveying was known even in ancient Egypt and Rome and was intended to achieve a fair distribution and taxation of land. The first uniform property cadastres, however, were not established until the nineteenth century.

The compilation of such registers required a considerable effort extending over a long period of time. The Bavarian cadastre was established in the period from 1808 to 1864 and thus required almost sixty years for its completion, and the cadastral system of the Austro-Hungarian Monarchy, which included the present Austria, Hungary, Czechoslovakia and part of Italy, took from 1819 to 1860, that is forty years, to prepare. The new Swiss cadastral survey was begun in 1912 and is still continuing.

In addition to the initial cost of establishing a cadastre, there is the current expense of keeping the maps and the descriptive parts up to date in respect of all changes in ownership, type of cultivation and size. In the case of Austria, which has an area of 84,000 square kilometres, some 500,000 out of approximately 11.5 million lots, or 4.5 per cent, undergo some change every year.

European countries are today faced with the task of adapting their old fiscal cadastres to modern conditions. In most cases this entails the establishment of a new cadastral system based so far as possible on the existing material. As there is no complete unanimity of views with regard to the purposes of cadastres, the methods used in the different countries vary, and their suitability is still a subject of discussion. The chief problem is whether a topographic, photogrammetrically established cadastre is sufficient, or whether an attempt should be made to compile a numerical cadastre in which co-ordinates are computed for each boundary point in a uniform system or, lastly, whether the correct solution is to be sought somewhere between these two extremes.

The Topographic Cadastre

In the topographic cadastre, the map is produced by graphic methods, and surface areas are determined by means of horizontal control points. All old cadastral systems were established graphically by means of plane-table surveys. Typographic maps can also be prepared by photogrammetric means. These maps have the following advantages over those based on plane-table surveys: they allow of a higher degree of accuracy, errors are more evenly and more favourably distributed, and they are more economical.

In the case of level ground, a rectified aerial photograph can even replace a cadastral map. One of its chief advantages is that it fully reproduces the details of the terrain and is therefore eminently suitable as a basis for town planning, building supervision and other purposes where a faithful reproduction of details is more important than a high degree of accuracy.

In the case of hilly or mountainous terrain, the familiar radial distortions result in differences in scale. These can be avoided by partial rectification of the surfaces of a polyhedron conforming to the terrain (" facet " procedure) or by the method, as developed in the United States, of differential rectification by means of the orthophotoscope. In all cases, the result is a true-to-scale photographic representation of the terrain showing the boundaries of properties just as they would appear if actually seen from the place at which the photograph was taken.

A higher degree of accuracy can be achieved by stereophotogrammetric plotting. Experiments carried out in various countries have shown that points on 1 : 1,000 maps prepared from 1 : 10,000 photographs can be plotted with a 20-centimetre margin of error. However, the accuracy of measurements relating to neighbouring points, which is very important for cadastral surveys, is even greater if the boundary points on the ground are clearly marked, as is always the case with signalized boundary points. Where boundary points are marked with stones, the tops of the stones need merely to be painted white. Removable white cardboard caps measuring 0.15 metre by 0.15 metre and metal calottes have also been found very useful.

Because in photogrammetric surveys only those objects can be plotted which are visible in the aerial photographs, boun

dary points that are covered by vegetation tend to be overlooked. There will thus be gaps in the plotting that will vary in extent according to the type and density of the vegetation. On completion of the survey, these gaps have to be filled in by terrestrial methods. The supplementary measurements can then be made from the easily identifiable points that have already been plotted.

The advantage of the photogrammetric method lies in its speed and economy. In Switzerland comparisons between the different methods showed that the cost of surveying was reduced in this way by almost 25 per cent. Photogrammetric surveys reproduce the earth's surface exactly as it is, and the actual measurements can be carried out indoors at any season of the year and can be checked through replotting.

If a survey is to be kept properly up to date, a close network of marked and signalized points must be established before the surveying is begun. These points can also be used as boundary points or minor control points for plotting. Any additional measurements to be made by terrestrial methods can then be based on these points. In Austria successful experiments have been made to co-ordinate these fixed points, which are known as supplementary points, so that the surveys might be kept up to date by photogrammetric methods.

In the preparation of topographic cadastres, the photogrammetric method will probably supplant all former methods because of its greater speed and economy. The first stage in preparing a cadastre by this method is the rectified aerial photograph, which in the second stage is further refined through stereophotogrammetric plotting. Thus, the control points needed for rectifying the photographs are obtained from the photographs themselves by means of aerotriangulation. Terrestrial methods, such as plane-table surveys, compass tachymetry and the like, will generally be used only to fill in gaps.

If the aerial photographic flights are so arranged that every other photograph of the series covers a cadastral sheet, this sheet can be used in rectifying the aerial photograph.

The following table shows the annual output of a first-order plotting instrument where an eighteen-hour day is worked in three shifts.

Map scale	*Square kilometres per year*
1 : 1,000	18-54
1 : 2,500	70-100
1 : 5,000	135-270
1 : 10,000	270-700

The great variations are due to differences in the working conditions prevailing in the various offices whose output figures were examined. These data were collected in part before high-efficiency lenses had been introduced and might have been even higher if such lenses had already been in use.

Topographic cadastral maps are now being produced in Switzerland and Austria by stereoplotting, and in France by partial correction. In Switzerland the gaps are filled in by compass tachymetry.

The Numerical Cadastre

A cadastral map in which all boundary points are so defined that rectangular co-ordinates can be calculated for them in a uniform system is said to be a numerical cadastre. A numerical cadastre may be plotted on any scale and therefore corresponds to a topographic cadastre produced on a scale of 1 : 1.

In a numerical cadastre, the co-ordinates facilitate the very precise measurement of areas, and the accuracy of the survey makes it possible to determine the exact position of boundary points. A numerical cadastre therefore represents the highest degree of accuracy that can be obtained in a cadastre and is the ideal form of property register. As, however, it takes a very long time to compile and is very costly, it is justified only where property values are extremely high, as in urban districts and in areas intended to be used for building.

A survey with a very high degree of accuracy is feasible only if the reference points are closely defined. Thus, before a numerical cadastre is compiled, the boundary points should be precisely determined and preferably be permanently marked.

Both terrestrial and photogrammetric methods can also be used in compiling a numerical cadastre. In terrestrial methods, triangulation must be followed by dense traversing. After this, the position of the boundary points and other objects that are to be represented must be determined by the perpendicular offsets method in which the survey lines are taken as the point of departure—that is, by a local rectangular system—or by the polar method using polar co-ordinates. The local co-ordinates thus obtained can then be converted into a uniform system.

The custom in some places (for example, Switzerland and Bavaria) is to prepare the maps on the basis of the local co-ordinates, that is, on the basis of unadjusted values. Surface areas, too, are determined from these maps by planimetric means. In other countries, however, such as in Austria, uniform co-ordinates applicable to the whole country are computed for all points, and the maps are prepared from these. Each boundary point is clearly determined by these co-ordinates, and the subsequent operations required to bring the map up to date are carried out in conformity with them.

The degree of accuracy obtainable by terrestrial methods is ± 2 to ± 3 centimetres. The subsequent operations required to bring the map up to date are carried out from the traverse points or survey lines in order to ensure a uniform degree of accuracy in detail.

Numerical cadastres can also be prepared by stereophotogrammetric means if co-ordinates for each boundary point are incorporated into the co-ordinates system of the plotter by means of a special registering device. These local co-ordinates for each model are converted into the co-ordinates of the country-wide system with the aid of the minor control points which in any event are required for the plotting. The photogrammetric plotting for a numerical cadastre can thus be compared with an ordinary survey in which a special survey line—the x-axis of the plotter—is retained for each photogrammetric model.

The plotting instruments are fitted with printing counters and registering devices by which the machine co-ordinates are either recorded in numerals or entered into a punched strip according to a predetermined code. This information can then be fed into a calculating machine, where it is converted into country-wide co-ordinates. Basic experiments in this regard have been carried out in Austria, and the method has recently been tried out in Germany for land amalgamation purposes.

Various investigations have been and are being made to ascertain the accuracy of points determined by photogram-

metric methods. The results obtained show that the margin of error is between ±5 and ±15 centimetres, but linear accuracy, on which the exact determination of neighbouring points depends, is in all cases greater.

The preparation of the map can proceed simultaneously with the recording of the co-ordinates. Contour lines are entered on the map by the usual methods. Although maps are generally drawn on scales ranging from 1 : 1,000 to 1 : 2,500, considerable latitude can be exercised in the selection of a scale, and instruments are being developed that will make possible the simultaneous compilation of maps on several different scales.

Surface areas can be determined from the co-ordinates of the boundary points or graphically from the map.

A photogrammetric numerical cadastre can be brought up to date by means of the previously mentioned marked control points, which are signalized before the survey is undertaken and are clearly defined as to position by terrestrial and photogrammetric methods.

Photogrammetric methods are less accurate than terrestrial methods because of the greater margin of error that results in determining the position of points. In addition to this, there are always gaps that are caused by the vegetation, and these have to be filled in by supplementary terrestrial measurements. In the photogrammetric determination of points, however, the margin of error is fairly constant within a particular model and is not subject to the systematic propagation of error that is a disadvantage of terrestrial methods. Apart from this, the great advantage of the photogrammetric methods lies in their greater speed and economy which in large measure is due to the fact that much of the surveying can be done in a plotting room and is thus independent of weather conditions. All requirements with regard to the completeness of the survey and the controls can, moreover, be easily met through double plotting. As a further advantage, the photogrammetric picture is an infallible record of the position of objects in the field at the time of the survey and consequently provides documentary evidence of inestimable value in case of dispute. This is of particular importance for landed property cadastres.

The Descriptive Part

The descriptive part of a landed property cadastre consists of a series of lists in which the properties and property numbers and such particulars as size, type of cultivation, buildings and ownership are recorded. Although the lists are arranged according to different principles in the various countries, particular areas are in every case set up as cadastral units within which properties are numbered serially and are arranged by number and owner so that any information required for economic purposes will be readily available.

Any change in a property as regards ownership, size or type of cultivation must be entered in all the lists of the descriptive part. The amount of work which this entails depends on the number and size of the properties and on the activity of the real estate market in a particular area but will in any case be considerable.

In an effort to cope with this work more easily, research into the possibility of using electronic registration equipment is now being conducted in various European countries. Austria has taken the lead in deciding to introduce automatic punch-card equipment for all operations relating to the descriptive part of its cadastre and hopes in this way to achieve a substantial reduction in staff costs and a threefold increase in work output. Similar changes are being discussed and prepared for in other European countries.

There can be no question that in any plan for a new cadastre provision should be made from the outset for dealing with the descriptive part by mechanical means.

Characteristic Examples of Cadastral Systems

The new French cadastre is being compiled entirely by the graphic method with the use of photogrammetric rectification on a scale of 1 : 2,500. The aerial photographs are partially rectified by the " facet " method, and the projections are then superimposed. The cadastral plans are not therefore rectified aerial photographs but geometrical plans derived from these. Elevations are not shown in the plans. In the case of urban areas, the street patterns provide a reliable framework for rectification, and the cadastral maps are drawn on a larger scale. Boundary points are generally not marked; the cadastre does not have the authority of a legal document and is not intended to be legally binding as regards property boundaries. The degree of accuracy aimed at is said to be ±0.25 metre.

The new Swiss cadastre has legal force and is, together with the land register, an authentic public document. Although the maps are in full conformity with the national survey and use the national grid, the accuracy of the surveying methods employed differs according to the land values of the area being surveyed. For this purpose, there are three types of areas: urban, comprising 0.3 per cent of the national territory; valuable arable land, including inhabited localities situated on such land, 33 per cent; and alpine meadows, pasture land and forests. The perpendicular offsets method is used in the first of these areas (method I); the polar method, that is, a numerical method, in the second (method II); and the topographic method (plane-table, stadia or stereoplotting from aerial photographs) in the third (method III). The maps are drawn on scales varying from 1 : 250 to 1 : 10,000, and, in addition, a 1 : 10,000 index map with contour lines is usually compiled photogrammetrically and is available for economic planning. All newly-surveyed boundary points must be marked.

In Austria, the old topographic cadastre, which is on a scale of 1 : 2,880, is being systematically replaced by a numerical cadastre and a map system on a scale of 1 : 1,000. The perpendicular offsets, the polar and the photogrammetric methods are being used. Despite a very high degree of accuracy, the new Austrian cadastre does not have the authority of a legal document. This is due to the prevailing body of legal opinion in the country, but efforts are being made to give the cadastre legal force.

In Germany, each *Land*, in consequence of its separate historical development, has its own cadastral system. Bavaria uses a topographic cadastre on a scale of 1 : 5,000 with uniform sheet format. Since 1874 this has been kept up to date in urban areas by means of the perpendicular offset method, and for some time now the polar method has also been used. For rural areas the old plane-table survey is regarded as sufficient. Photogrammetric methods are not used. Since 1900, a law providing for the marking of boundaries has

been in force, and boundaries marked in conformity with this law are regarded as legally valid. Hesse, Württemberg and Baden also have uniform cadastral systems which in part are being systematically brought up to date. In Hesse, for example, outline maps are prepared on a uniform basis on a scale of 1 : 1,000, and position and contour maps for economic purposes on a scale of 1 : 2,000.

Proposal for the Establishment of a New Cadastre

The experience in European countries has been that the purposes which a cadastre is to serve change in the course of time and become more varied as the economic development of a country progresses. This means that a new cadastre must be planned on a broad scale so that it can keep pace with the developing economy and with changes in the juridical and fiscal systems.

Any new cadastre should therefore in the ordinary course be planned as a multi-purpose cadastre capable of meeting all foreseeable economic, legal and fiscal requirements. The preparation of a cadastre satisfying these requirements is very costly and time-consuming even if modern measurement, calculation and registration methods are used. If, on the other hand, the cadastre is to promote economic development, it should be made available as rapidly as possible, for otherwise it may lose a great deal of its usefulness. This means that a new cadastre cannot be prepared from a survey carried out with the utmost degree of precision in one area after another according to some order of priority but only from a survey that uniformly embraces the entire territory of a country and is carried out in progressive stages of accuracy. If matters are so arranged that the work done at each stage can be used as the foundation for the next stage, the additional costs arising at each stage will be small, especially in the light of the ultimate objective. The cadastre will be quickly available in the simple form it takes at its first stage, and at subsequent stages it can be adapted to special requirements as they arise. The cadastre, like a living organism, will thus grow up from a broad basis and go through different stages of development.

The basic frame for a growing cadastre is provided by a uniform triangulation network with points permanently marked and carefully described. Such triangulation should therefore be carried out either before or at the same time as the compilation of the cadastre. The basic network must be determined in strict accordance with the procedures of triangulation or trilateration. This can be accomplished in a short space of time through the use of self-registering theodolites, electronic distance-measuring instruments and automatic calculating machines. The basic network can then be filled in by stages. At the first stage, approximation methods, such as aerotriangulation and electronic position-finding, may be used.

The marking of points is of the greatest importance. In many European countries inadequate marking and description of triangulation points has caused a great deal of expense and additional work.

In its first stage a cadastre that is prepared in stages represents the simplest form of a topographic cadastre, that is, a series of rectified aerial photographs produced in a uniform format for the whole area. The recommended scale is 1 : 5,000 as this can be derived from photographs taken on scales ranging from 1 : 15,000 to 1 : 20,000 with high-efficiency lenses. As a means of facilitating the rectification, the flights should be so arranged that each photograph covers one or more cadastre sheets. The minor control points required for rectification should be determined by photogrammetric triangulation. Mechanical methods of radial triangulation are particularly suitable for this purpose. Distortions caused by differences in elevation are not taken into account, so that maps are geometrically correct only in the case of a level surface.

Ownership, types of cultivation and the like are ascertained by a field check, and gaps caused by visual obstacles are filled in by terrestrial, topographic surveying. Geometrical tracings of the aerial photographs are made for the purpose of entering property numbers and types of cultivation and the approximate determination of surface areas. All subsequent operations in connexion with the map are carried out on these tracings.

The descriptive part is prepared in its final form from the very outset, and both at this stage and in keeping it up to date modern office equipment and procedures should be used.

At the end of the first stage, the result will be a cadastre that is of great importance for economic purposes and satisfies fiscal requirements. For the purposes of subsequent operations, it should be made compulsory for the boundaries of properties to be marked, and these operations should ordinarily be carried out with the aid of marked points, so that the results may again be used at some later time.

In the second stage, the cadastral map will be provided with contours by means of stereophotogrammetric plotting. In the selection of a scale, the determining factor should be land value, and the entire territory should, on the Swiss model, be classified into three types of areas according to the value of the land. For urban areas the scale should be 1 : 1,000, for arable land, 1 : 2,500, and for other areas, 1 : 5,000. At the same time a 1 : 5,000 index map should be prepared for all areas. All maps should be prepared in the same format as that used at the first stage and should use the grid. One 1 : 5,000 map therefore contains twenty-five 1 : 1,000 maps and four 1 : 2,500 maps.

Before the flight, a network of control points for subsequent operations is permanently marked and signalized. The co-ordinates of these points are either derived by terrestrial methods on the basis of the triangulation carried out in the final phase of the first stage or are found by aerotriangulation. In urban and cultivated areas boundaries should be determined, marked and signalized before the flight.

After the flight a field check is made, and in this connexion the cadastral maps of the first stage offer valuable help. The geometrically correct maps that result from the plotting enable the actual surface areas to be determined and are an accurate guide to property lines.

The topographic cadastre that is produced at the second stage can thus be used as a fiscal, economic and juridical cadastre. Supplementary operations are carried out by terrestrial methods on the basis of the supplementary points, and the descriptive part of the first stage is taken over and supplemented as necessary.

Only in urban areas with a high land value or in areas where property lines are to be determined with a high degree of precision will there be any need to establish a numerical cadastre in a third stage. In this case, however, all boundary points must first be marked, as the attempt to achieve a high degree of precision would otherwise be pointless. According

to the desired degree of precision, the perpendicular offsets, the polar or the photogrammetric method may be used. The numerical cadastre established at the third stage—in conjunction with the 1 : 5,000 index maps obtained at the second stage and the correspondingly corrected descriptive part—represents the most perfect cadastre obtainable and desirable at the present stage of knowledge.

Because the establishment and maintenance of a cadastral system is of great importance to the people in general, it is, and will probably always continue to be, a proper function of a sovereign State. This does not mean, however, that the State itself must direct and carry out the entire operation. The experience of Switzerland shows that by placing contracts for new surveys with private firms the work can be considerably expedited without any increase in costs or reduction in quality. The State merely has to give precise instructions and ensure that they are complied with. The same applies to the procedure for keeping the cadastral system up to date.

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SYSTEMATIC PROCEDURE FOR AFFINE RECTIFICATION [1]

Technical paper by J. Visser,
United Nations Technical Assistance Administration expert attached to the National Cartographic Centre of Iran

I

The subject of the present article is the production of large-scale controlled photomosaics, based on control obtained from slotted templet triangulation in, approximately, negative scale.

In spite of the limited accuracy of this control, a high relative accuracy (a good fitting) of the mosaic can be achieved if all five degrees of freedom of the optical-mechanical rectifier are employed instead of the three used in normal perspective rectification.[2] Through affine rectification, however, the projection can be deformed so that its four corner passpoints are brought into perfect coincidence with those on the control sheet. Because the neighbouring photographs, of the same adjacent strips, will be rectified while using the same points, no discrepancies will show in those points when fitting neighbouring rectified photographs to each other.

The need for affine rectification is especially felt when dealing with large-scale mosaics because the scale of those mosaics is usually three or four times larger than the negative scale. While, after perspective rectification on three points, the residual in the fourth point—caused by the deformation of the control net—would be in the order of 0.5 to one millimetre when the mosaic scale is about equal to the negative scale, this residual would be two to four millimetres when a four times enlargement is used. In the first case the residual might be easily distributed over the four passpoints by some scale—and tilt—changes; in the latter case, however, this would leave intolerable discrepancies and, consequently, another means must be sought.

This means can be found in employing the two, as yet unused, degrees of freedom of the rectifier, namely, both components of displacement of the negative carrier, relative to the rectifying lens. Because the result of this is an *affine* deformation of the projection, the procedure of using all five degrees of freedom of the rectifier is called " affine rectification ".

In the following paragraphs a practical systematic procedure for affine rectification is developed, in which, step by step, the five settings of the rectifier are solved. The method is developed for the Zeiss SEG V rectifier, but can be applied, with slight modification, to any other optical-mechanical rectifier having five degrees of freedom.

It goes without saying that in affine rectification the automatic vanishing point control of the SEG V cannot be used and that, consequently, the mechanism for this control must be uncoupled.

[1] The original text of this paper, submitted by Iran, appeared as document E/CONF.25/L.71.

[2] The expressions " perspective " and " affine " rectification were introduced by Dr. R. Burkhardt in " Über Notwendigkeit und Möglichkeit der Affin-Entzerrung ", *Bildmessung und Luftbildwesen*, 1956, page 10.

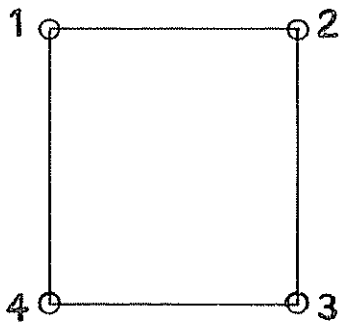


Figure I

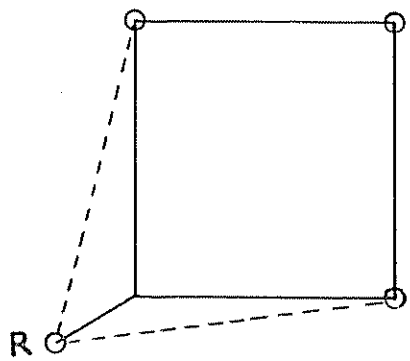


Figure II

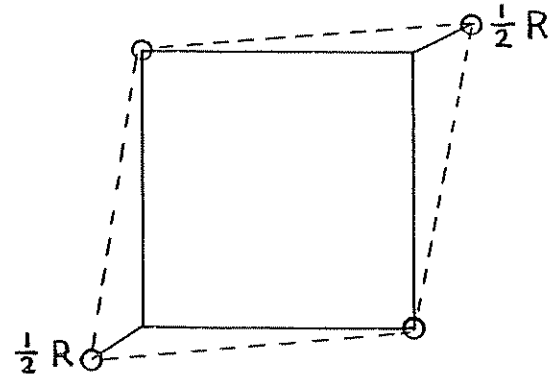


Figure III

II

Following the usual procedure, first by scaling (foot pedal) and then by moving the control sheet on the easel, the projections of the points of a diagonal (points 1 and 3 in figure I) are brought into coincidence with the corresponding points of the control sheet.

The next step—elimination of the discrepancy in point 2—is facilitated if, from now on, the automatic vanishing point control is uncoupled. In practice, the automatic vanishing point control would be uncoupled at the beginning and would not be used at all. Then, half the x discrepancy in point 2 is eliminated by tilting the easel about the x axis; the control sheet is slightly moved until points 1 and 3 of projection and control sheet are in coincidence again and half the y discrepancy in point 2 is eliminated by tilting the easel about the y axis. By a slight movement of the control sheet, its points 1, 2 and 3 can now be brought into perfect coincidence with the corresponding projection points; point 4, however, will show a discrepancy.

Repeating for point 4 the above procedure described for point 2, with the difference that only a quarter of the x and y discrepancies is now eliminated, the situation shown in figure III is obtained—a typical affine deformation.

III

Analytically, any affine transformation may be described as a linear transformation with six elements: a scale change ($\Delta\lambda$), a change in azimuth ($\Delta\psi$), a translation in x direction (C_x), a translation in y direction (C_y), and an elongation (or contrac- tion) of the figure in an arbitrary direction and a shear deformation in a direction perpendicular to the latter.

Let the elongation (in the direction of L, at an angle α with the y axis) be: μ, and the shear deformation (perpendicular to the latter): ρ (see figure IV).

For an arbitrary point P is: $\Delta l = l\mu$ and $\Delta m = l\rho$;

$$\text{thus } \Delta x = \Delta l \sin\alpha + \Delta m \cos\alpha = l(\mu \sin\alpha + \rho \cos\alpha)$$
$$\Delta y = \Delta l \cos\alpha - \Delta m \sin\alpha = l(\mu \cos\alpha - \rho \sin\alpha)$$

Further: $l = y\cos\alpha + x\sin\alpha$, thus

$$\Delta x = (y\cos\alpha + x\sin\alpha)(\mu\sin\alpha + \rho\cos\alpha)$$
$$\Delta y = (y\cos\alpha + x\sin\alpha)(\mu\cos\alpha - \rho\sin\alpha)$$

In the present case, the elements of the necessary affine transformation will be small because the residuals ½R are small—some millimetres only—and consequently the total

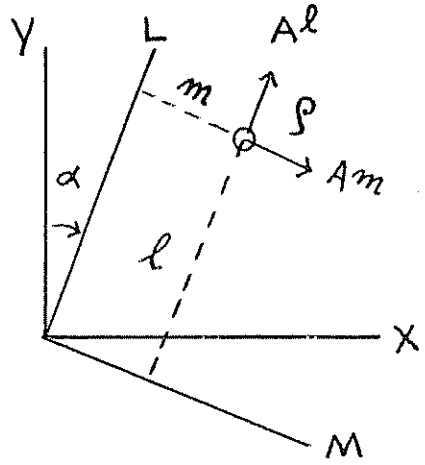


Figure IV

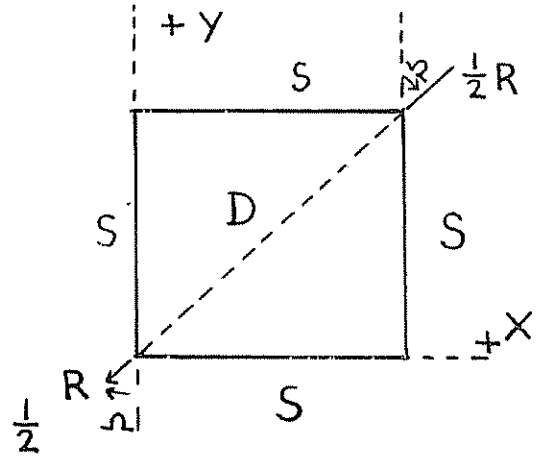


Figure V

change in x and y may be found as the algebraical sum of the individual small changes:

$$\Delta x = (y \cos \alpha + x \sin \alpha)\ (\mu \sin \alpha + \rho \cos \alpha) + x\,\Delta\lambda + y\,\Delta\psi + C_x$$
$$\Delta y = (y \cos \alpha + x \sin \alpha)\ (\mu \cos \alpha - \rho \sin \alpha) + y\,\Delta\lambda - x\,\Delta\psi + C_y$$

Substituting in these equations the known values x, y, Δx and Δy for the points 1, 2 and 3—which, together with point 4, form approximately a square with side lengths S (see figure V)—after computation the following result is found:

$$C_x = \tfrac{1}{2} R \sin \Omega$$
$$C_y = -R \cos \Omega$$
$$\Delta\lambda = \frac{R}{D} \sin (\Omega - \alpha) \cos (\alpha + 45°)$$
$$-\Delta\psi = \frac{R}{D} \cos (\Omega - \alpha) \cos (\alpha + 45°)$$
$$\rho = \frac{R}{2S} \{ \sin (\Omega - 2\alpha) + \cos (\Omega - 2\alpha) \}$$
$$\mu = \frac{R}{2S} \{ \cos (\Omega - 2\alpha) - \sin (\Omega - 2\alpha) \}$$

Substituting the above values, as a check, in the formulae for Δx_4 and Δy_4, the expected values, $\Delta x_4 = \tfrac{1}{2} R \sin \Omega$ and $\Delta y_4 = +\tfrac{1}{2} R \cos \Omega$, are found.

IV

The affine transformation must be performed in the rectifier. Dr. C. A. Traenkle [3] derived the formulae for the settings ΔU and ΔR (respectively, the components of displacement of the negative carrier in the direction of maximum tilt and in the direction perpendicular to the latter) as functions of the required elongation (μ) and shear deformation (ρ) for rectifiers with one easel axis only.

Dr. Traenkle based his formulæ on the known equations:

$$x = \frac{h}{f_a} x^1 + i \frac{h}{f_a} 2 (x^1)^2$$
$$y = \frac{h}{f_a} y^1 + i \frac{h}{f_a} 2 x^1 y^1$$

in which x, y are the co-ordinates in the horizontal projection plane, x^1, y^1 the co-ordinates in the negative plane, while in both planes the principal point acts as the origin of the co-ordinate-system and the x or x^1 axis is in coincidence with the direction of maximum tilt. Further: h=flying height (in scale of projection), f_a=focal distance of the taking camera and i=phototilt.

Differentiation gives:

$$\Delta x = \frac{h}{f_a} \Delta x^1 + 2\,i \frac{h}{f_a} 2\,\Delta x^1\,\Delta x^1$$
$$\Delta y = \frac{h}{f_a} \Delta y^1 + i \frac{h}{f_a} 2 y^1 \Delta x^1 + i \frac{h}{f_a} 2 x^1 \Delta y^1$$

After reduction for scale, azimuth and translations, this appears to correspond with an elongation in x direction for which $\mu = i \frac{\Delta x^1}{f_a}$ and a shear deformation for which $\rho = -i \frac{\Delta y^1}{f_a}$.

Because the pencil of rays in the rectifier has the same perspective properties as the original pencil of rays of the exposure,[4] the derivation given above applies after substitution of $i = \frac{f_a}{f_r} \beta t$ (the known relation between the table tilt βt and the phototilt i where f_r=focal distance of the rectifying lens) and $\Delta x^1 = \Delta U$, $\Delta y^1 = \Delta R$. Dr. Traenkle's result is: $\Delta U = \frac{f_r}{\beta_t}$ and $\Delta R = \frac{-f_r}{\beta_t}$.[5]

For rectifiers with two easel axes, such as the Zeiss SEG V, and corresponding components of displacement of the negative carrier ΔP_x and ΔP_y, where the azimuth of maximum tilt has a random value (α), the above formulæ can be easily converted to:

$$\Delta P_x = \Delta U \sin \alpha - \Delta R \cos \alpha$$
$$\Delta P_y = \Delta U \cos \alpha + \Delta R \sin \alpha$$

(see figure VI).

Thus:

$$\Delta P_x = \frac{f_r}{\beta_t} (\mu \sin \alpha + \rho \cos \alpha)$$
$$\Delta P_y = \frac{f_r}{\beta_t} (\mu \cos \alpha - \rho \sin \alpha).$$

Substituting in this formula the fifth and sixth formulæ found in section III, after computation the following expressions are obtained:

$$\Delta P_x = \frac{f_r R}{\beta_t D} \sin (\Omega - \alpha + 45°)$$
$$\Delta P_y = \frac{f_r R}{\beta_t D} \cos (\Omega - \alpha + 45°).$$

These rather simple formulae[6] are easily solved by the help of simple nomograms.

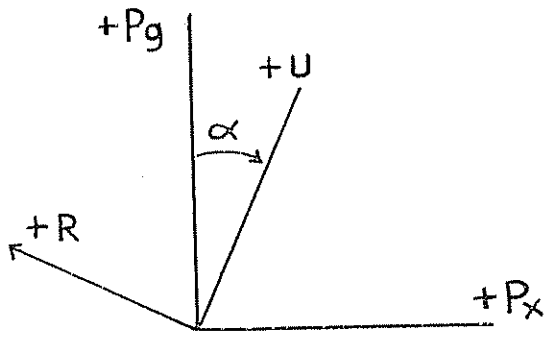


Figure VI

[3] C. A. Traenkle, "Affine Bildumformung Mittels Entzerrungsgerat", *Zeitschrift für Instrumentkunde*, 1944, pages 90 to 96.

[4] C. A. Traenkle, "Die Bestimmung der Räumlichen Lage von Flugzeugen mittels Luftbildmessung", *Bildmessung und Luftbildwesen*, vol. ½, 1943.

[5] C. A. Traenkle, "Affine Bildumformung Mittels Entzerrungsgerat", op. cit.

[6] It will be clear to the reader of Dr. Traenkle's more recent article, "Affinity transformations in photogrammetric rectifiers", *Photogrammetric Engineering*, 1956, pages 750 to 763, that, after some elaboration, the same formulae could be obtained from section 6 of that article.

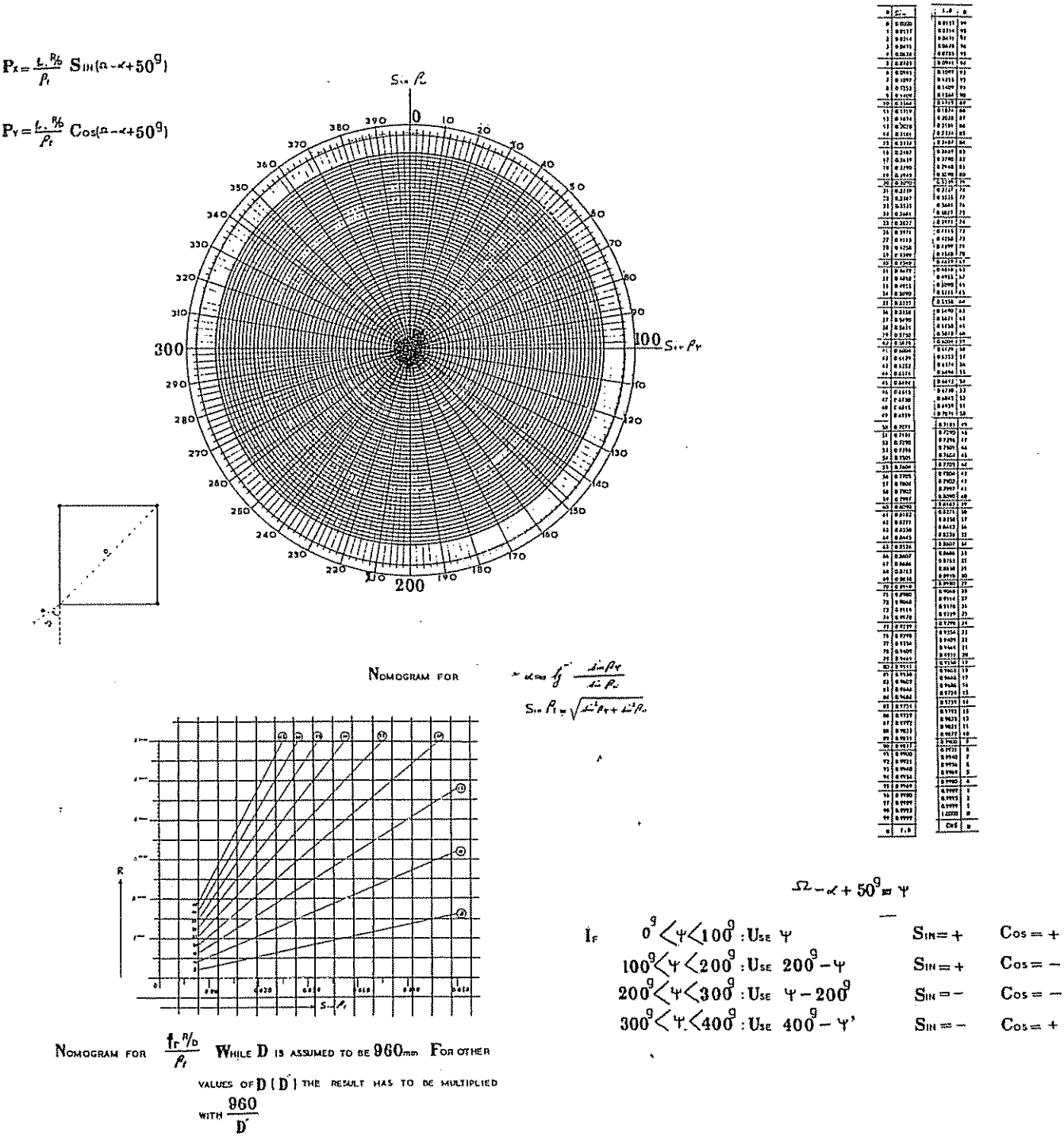


Figure 64. Nomograms for affine rectification

Conclusion

A systematic procedure for affine rectification with a Zeiss SEG V rectifier may be as follows.

1. Scale and orient on diagonal 1.3; remove discrepancies in 2 with the table tilts.
2. Distribute the residual R_4 over the points 4 and 2 with the table tilts.
3. Compute (use nomograms) ΔP_x and ΔP_y and set these values in the rectifier.
4. Repeat step 1.
5. If necessary, repeat step 2, and so on.

The method given above has been developed in the National Cartographic Centre of Iran for the production of large-scale (1 : 5,000) controlled mosaics to be used for the planning of canals and the like in irrigation projects.

With a minimum of ground control (traverses perpendicular to the photo-strips every 20 kilometres) a reasonable absolute accuracy (m_p=20 m) is obtained by slotted templet triangulation, while, with a minimum of time spent at the rectifier, a very high relative accuracy is obtained by application of the described method of systematic affine rectification.

The necessary amounts of P_x and P_y are found from nomographs (see figure 64). Because, in the SEG V, not the table tilts themselves but the sines of these tilts are read on the dials, the latter are used as the variables in the nomograms.

SIMPLIFICATION OF CADASTRAL SURVEY BY USE OF AIR PHOTOGRAPHS [1]

Background paper by Dr. W. Schermerhorn

In many countries some system of land registration exists either to enable the administration to impose a land tax or to ensure the legal rights of owners. We shall not enter into a discussion of the merits of the systems of legal property and tax cadastre which vary from one part of the world to another. From the point of view of surveying and cartography, the legal cadastre has to fulfil the highest requirements; we shall deal especially with this type of cadastre in the following discussion.

We all know that in this kind of cadastre uniformity of the legal position of a piece of land and its uniform legal procedure determine the cadastral parcel. The legal body has its origin in and is created by the establishment of the boundary and its marking by means of prescribed signals, such as stones, poles and the like. Not before this has been executed is the cadastral survey allowed in a legal cadastre. Afterwards, the marks are decisive in so far as they remain in their original position. This original position is secured by its indication on the cadastral map, in the land and on the register. In case of later discrepancies between the situation in the field and the indication on the map, the latter has, within a certain limit of time, priority. In a legal cadastre all maps become part of the legal land register in which the parcels are described. Dr. Härry, the Director of the Swiss Federal Cadastral Survey, gives the following description of the main characteristics and of the purpose of a legal cadastre: the delimitation and marking of the boundaries is a good means, the map made by a licensed surveyor is the best possible means, to individualize a certain parcel as subject for legal transactions. The map gives the best possible description of the parcel. In this description not the surface area, but the position of the boundaries is the most important element. The landowner obtains a subject, a parcel of land, and not a number of square metres.

What is the advantage of starting from this point? That the surveyor may be able at any time to reconstruct in the field the boundaries as they were set up at the time the parcel was established. Every cadastral method must first fulfil this requirement in order to secure the legal rights.

The second purpose is to determine the surface area of the parcel enclosed by the boundaries. This is important to the owner, but not as important as securing the position of the boundaries. Cadastral administrations in every country use a combination of geometrical representation of boundaries and description of the position of each parcel relative to surrounding parcels or to certain topographic details. Ordinary surveying methods provide the data for geometrical representation, as there has been no other method to obtain these since early times. In some countries this geometrical representation is carried out for individual parcels only, in others for several parcels together, and in yet other countries for cadastral maps covering large areas. These cadastral maps were sometimes in the past set up on a local grid system; for modern, high-precision cadastral surveys they are nowadays based on the national grid system. It is obvious that such cadastral maps could also be used as large-scale maps, needing only the addition of topographic details and contours to become large-scale precision topographic maps for engineering purposes and the like.

It is evident that these different methods give different degrees of precision which, in turn, determine the possible accuracy for the reconstruction, in the field, of the boundaries of individual parcels.

Now, how can the use of air photographs simplify a cadastral survey? We shall distinguish between two different cases:

(*a*) In highly cultivated areas in which the government can afford the high cost of establishing new high-precision cadastral maps, with the corresponding administrative services;

(*b*) In those countries where an unsatisfactory administration exists, but where a complete re-survey of the country would constitute such a heavy burden that neither the requisite financial means nor the personnel are available for establishing the type of cadastral administration mentioned in (*a*).

[1] The original text of this paper, submitted by the Netherlands, appeared as document E/CONF.25/L.9.

High-precision cadastral surveys

It has been proved in different countries that the precision obtainable by means of photogrammetric determination of boundary corners is, with certain precautions, so high that, except for areas of class I—the so-called built-up areas of cities—photogrammetry can be applied almost everywhere to cadastral surveys. Although a few other examples have been published, the work of the Austrian Cadastral Service can be used as the best proof of the possibilities of photogrammetry, and as an example of what can be achieved. It is, however, also an indication of the precautions necessary for this high-precision work.

Photographs are taken on so-called ultra flat glass plates with a Wild RC 7 plate camera. Boundary stones are signalized before the photographs are taken. Restitution is carried out by highly skilled personnel under favourable circumstances—that is, on well adjusted first-order plotting machines, such as Wild Autograph A7, installed in air-conditioned rooms.

In particular, the signalization will be considered by many services as difficult and a drawback of this method. We have, however, demonstrated in Delft that the mean square error in the determination of natural points is almost twice as high as that in signalized points. The cost of signalization is, on the average, less than 10 per cent of the total cost of the survey.

It is sometimes considered as a special drawback that only small areas can be prepared and signalized for each flight mission, because with a longer period there is a risk that the signals will disappear. Consequently, if the system of signalization is accepted, large contracts for air photography are impossible, and an air photography unit must always be available in the country. It can be concluded that the aim of obtaining the highest possible precision for cadastral survey has certain consequences for the organization of the entire photogrammetric unit, including air photography.

The Austrian example also proves that the photogrammetric method enables a sufficient number of points of a geometrical network to be determined which can later be used as basic points for local ground surveys. They placed signalized monuments about 400 metres apart and determined photogrammetrically the co-ordinates of these points in the grid system of the country. As a check on these co-ordinates they measured traverses between those points by normal ground survey methods. The average length of these traverses was about 400 metres. The average closing error of each traverse in the direction of the line between the end points and the closing error of each traverse in azimuth was 44 centimetres. These values show that the precision of the co-ordinates of the points determined by photogrammetry is more than sufficient and very probably, on an average, better than the co-ordinates determined by regular ground survey.

Therefore, the Chief of the Austrian Survey, Professor Hofrat Neumaier, decided that no traversing would be carried out and that the points for future cadastral revision surveys would be determined only from the machine co-ordinates in the autographs. It is also remarkable that there is no difference between the traverses crossing from one pair to another and those remaining on the same pair.

A further important question is related to cost. Publications over the past three years show that the savings obtained by application of photogrammetry, as compared with classical ground survey methods, are between 30 and 50 per cent. It is obvious that the administrative operations of a cadastral survey, being the same in both cases, are omitted here.

Not all cadastral surveys will require the high precision mentioned above. In cases where it is not required, it will not be necessary to determine co-ordinates of all boundary corners; a graphical cadastre consisting of the necessary administration limits and maps on a sufficiently large scale will be acceptable. On these maps all natural boundaries should be represented and plotted as well as possible from the air photographs. With regard to instruments it may be mentioned that in such cases the so-called second-order plotting machines can be used. There exist a few kinds of such machines which have about the same linear precision as first-order machines.

Simplified methods

It is obvious that the speed of production, even with photogrammetric methods, is rather limited. With an average scale of maps of 1 : 2,000 we found three hectares per hour to be a reasonable production of a plotting machine. If we take a country of 100,000 square kilometres, which is still a small country, and presume working in two shifts, making 4,000 hours a year for each instrument, a cadastral survey in a scale of 1 : 2,000 would take about 800 instrument years. Therefore, to finish the job within twenty-five years, over thirty plotting machines would be needed. Consequently, many countries have no other solution than to make good maps for only very small areas and to apply to other parts of the country simpler methods which, nevertheless, can fulfil one of the main requirements of a cadastral administration. We believe that this last solution is so important and has so far found so little application that we shall pay special attention to it here.

There is a wide variety of methods between the use of the photograph as the only cartographic document and the precise method described above. In all these methods, however, the basic principle is that we must represent the boundaries of each parcel in such a way that they can be reconstructed at any time in the field. We believe that the air photograph as such can fulfil this condition. If we take high-quality photographs in a scale of about 1 : 7,000 with a 9 by 9 inch camera, preferably with a 12-inch principal distance, and we enlarge these photographs to the scale of 1 : 2,000, each enlargement would represent a map sheet. The problem now is to identify in the field the boundaries of all parcels. This is not difficult as long as the boundaries are natural features, visible on the photographs. When they are not visible, they must be identified and surveyed on the ground. As starting points for these surveys arbitrary details should be used which can be identified with certainty in the field as well as in the photographs.

In order to plot these survey results on the enlargement, it will be necessary to know the scale. This can be obtained with sufficient precision by using for the rectification two mutually perpendicular check lines between identifiable points which are measured in the field.

It will be possible to indicate in this way—in either white or black ink—the exact position of each boundary on the photographic enlargement with a precision which is at least as good as can be obtained in a graphical cadastral map.

Reconstruction of these boundaries will be facilitated by all the topographical details visible in the photographic image. It is hardly possible for the terrain to change to such an

extent that nothing will remain. In extreme cases, it will always be possible to put the original negatives into a plotting machine and determine co-ordinates of the vanished boundary stones in a system which can be laid down either in the same pair or in a combination of a few pairs. This local restitution would have to be based on an aerial triangulation until the local grid system on the ground could be identified; this would be as soon as a sufficient number of identifiable points, both in machine and ground co-ordinates, had been determined.

The necessity to plot some pairs, later, in emergency cases, would require the photographs to have the normal 60 per cent overlap; enlargements would be made only from each second photograph.

This is the cheapest method. It will also give good results for the surface area of parcels in flat terrain

In mountainous or rolling terrain the problem of identifying boundaries remains the same. Except on very steep slopes, normal photography with standard angle lenses will enable the parcels to be identified. The complication in this case, however, is that the scale will be different at different heights and on the rectified photographs. One solution would be to determine the scale by measuring either distances at different heights or heights of boundary corners by means of barometers. Since in mountainous terrain the tolerances for the determination of the surface area are in general much larger than in flat terrain, it is believed that this approximate method will be satisfactory in all rolling terrains.

This method can be improved by using auxiliary instruments during air photography to provide the elements of orientation of each photograph. Horizon camera, solar periscope and gyroscope give tilt values with sufficient precision for rectification.

The scale remains a problem. Modern statoscopes give on short strips, such as we have here, a standard deviation of about one metre, at a flying height of 2,000 metres on the scale 1 : 2,000. The corresponding mean square error of 5 centimetres for parcels of 100 metres can practically always be ignored. It is obvious that the statoscope is not effective in rolling terrain; there, no better or cheaper method exists than measuring distances in the field.

The method outlined above results in a set of island maps without any co-ordinate system; the next step for improvement could be the introduction of such a system. This, however, will make the cadastral survey much more expensive and, above all, will take much more time. It involves the calculation of a geometrical network of triangles and traverses for the determination of control points in all photographs. In flat terrain these control points can be used as the basis for rectification of the photographs which can then be treated as photo-maps on which parcels may be identified and indicated.

A cheaper method would be the application of a slotted templet lay-out in order to produce a grid system of limited accuracy in the absolute position of the points. This would be acceptable because the relative positions of the different photographs against each other will ensue a satisfactory degree of accuracy. We believe, however, that the advantage of such a grid system, as compared to island maps without a grid, is very small and not commensurate with the cost. Only when photo-maps have to be made for other than cadastral purposes can the establishment of a basic geometrical network be justified.

If a geometrical network in rolling or mountainous terrain is needed for other purposes, the use of photographs alone for the cadastral administration will not be advantageous. In such a case, it would be better to make line maps by the ordinary restitution method since other users will probably also need the contour lines.

Our conclusion from these considerations is that often, particularly in the case of rather flat terrain, a great improvement in the present cadastre can be obtained by the production of enlargements of high-quality large-scale air photographs on which boundaries are identified and indicated, and on which the scale is determined by a few check lines.

AGENDA ITEM 11

Photo-interpretation

FOREST RESOURCE AND LAND USE SURVEY [1]

Background paper submitted by China

The Forest Resource and Land Use Survey of Taiwan was carried out from April 1954 to March 1956 with the combined use of aerial photos and ground survey. Estimates of land use areas, forested area and timber volume are based upon data obtained from a double-sampling survey.

Aerial photography

Twenty-four sample strips of aerial photography were flown in an east-west direction—at right angles to the general topography. The photography was done with a twenty-four-inch focal length lens minus blue filter and infra-red film at an elevation of 20,000 feet, with from 1,500 to 3,000 feet between photo centres, with flight lines 10 miles apart according to a random-systematic system.

In addition to the sample strip photos, a set of 1 : 40,000 panchromatic aerial photos, almost complete coverage of the island taken during the period 1948 to 1952, was used for type delineation. The delineated data were transferred, through the stereoplotting method by K.E.K. and Kail plotters, to 1 : 50,000 topographic maps.

Photo-plot interpretation

A large number of photo-plots (37,495) were distributed over the twenty-four sample strip large-scale photographs and were classified by forest type and volume classes—based on height and density. Unforested areas were classified by present use classes.

Ground plot examination

A total of 545 of the ground plots established on the aerial photos were chosen from each stratum—based on volume for forest plots—by random selection for examination on the ground.

Compilation of data

Photo-plot interpretation and ground plot data were entered on punch cards from which tabulations were made to obtain the data set forth in the final report.

The Forest Resource and Land Use Survey also brought about three outstanding events in the history of both forestry and photogrammetric development in Taiwan: (1) the provision of facts essential to the review of Taiwan forest policies; (2) the establishment of the Agriculture and Forestry Aerial Survey Team in 1956; (3) the extensive use of aerial photos for various purposes.

[1] The original text of this paper appeared as document E/CONF. 25/L.30.

THE TAKING AND USE OF INFRA-RED AERIAL PHOTOGRAPHY AT THE INSTITUT GÉOGRAPHIQUE NATIONAL [1]

Technical paper by the Institut géographique national, France

Introduction

Aerial photography is becoming an increasingly useful tool for many specialists and its value is increased as more territories are covered by aerial surveys and the surveys are repeated regularly and often enough.

Aerial photography is the basis of two different but often complementary techniques: photogrammetric plotting and photo-interpretation. The purposes of the two are not identical since for plotting purposes as many details as possible must be recorded, whereas the interpreter, as a specialist in a highly specific field, requires clear and unequivocal discrimination of the details in which he is interested (species of trees, soil or rock types, presence of water and the like). The two techniques, however, have this in common: the ease and value of the work depend directly upon the variety and fidelity of

[1] The original text of this paper, submitted by France, under the title " L'exécution et l'exploitation de photographies aériennes infra-rouges à l'Institut géographique national français ", appeared in French as document E/CONF.25/L.49.

the photographic tones, whether in the negatives or on the prints.

The question naturally arose whether these qualities would not be appreciably enhanced by the use of new emulsions whose sensitivity differed from that of ordinary panchromatic emulsions.

Various countries have been making studies and trials of infra-red and colour emulsions for several years. The major obstacle hitherto has been the development by the photographic industry of stable sensitive surfaces with sufficiently high speed for aerial photography. Encouraged by recent advances in infra-red emulsions, the National Geographical Institute (Institut géographique national) has, since 1955, used its own facilities to conduct a number of trials, the practical lessons of which are summarized below.

After a brief review of the theoretical advantages of infra-red emulsions, an indication will be given below of what is now being done to solve the various technical problems involved in the use of these new materials for aerial photography.

Moreover, the print quality obtained since 1955 has enabled the Geographical Institute to repeat several tests under very different conditions, and careful study of the sets of photographs obtained has produced a number of results relevant to both photogrammetric plotting and photo-interpretation.

Taken as a whole, these results provide sufficient basis for general conclusions regarding the value of infra-red emulsions.

Theoretical Considerations regarding the Value of Infra-red Emulsions

The value of infra-red emulsions results from two properties which these emulsions have for many years been known to possess: clearer representation of distant objects in certain atmospheric conditions, and sensitiveness to several specific factors of interest.

The improvement in the clarity of the photographs is readily explained by a few simple theoretical considerations which are briefly summarized below.

Light passing through a disturbed transparent medium, such as the atmosphere, is diffused by the particles in the medium, which thus act as secondary sources. In aerial photography this diffused light is added to the light which forms the true optical image of the ground on the negative, and the additional light is particularly troublesome when the phenomenon of diffusion is more selective—that is, when the resulting radiation consists mainly of short-wave rays.

The diffusion, obviously, depends directly on the distance between the camera and the subject. In the case of aerial photography, the diffusion increases with the distance the light reflected from the objects photographed travels through the atmosphere—in other words, with the height of the aircraft.

The problem is therefore to eliminate as far as possible this parasitic diffused light, to which all emulsions, regardless of type, are highly sensitive and which causes general fogging of the negative.

The selectivity of atmospheric diffusion is a function of the dimensions of the diffusing particles. If the atmosphere is sufficiently pure, the diffusion produced by the molecules is highly selective, and the parasitic light, consisting of ultra-violet and blue rays, is adequately eliminated by the use of panchromatic emulsions in conjunction with a yellow filter which cuts out rays with a wave-length of less than 0.5 μ.

If the atmosphere contains particles—fine dust or water vapour—which are not small in relation to the wave-lengths of light, the diffusion is less selective and the proportion of diffused light greatly increases in the visible spectrum. In order to eliminate it, therefore, it is desirable to use only rays of even greater wave-length—that is, to use an emulsion sensitive only to red and infra-red.

Thus in zones of dry haze—equatorial or desert areas—it is possible to increase the number of days per year suitable for aerial photography or to obtain generally clearer photographs.

It is in the light of these theoretical considerations, coupled with the peculiar sensitiveness of infra-red emulsion to certain factors of interest to various specialists, that studies have been carried out in many countries and practical trials have been made by the National Geographical Institute.

In practice the use of infra-red emulsions in aerial photography involves various technical difficulties for which the National Geographical Institute has adopted the solutions described below.

Practical Solutions adopted for Aerial Infra-red Photography

Choice of infra-red emulsions and conditions for use

Emulsions available

No infra-red emulsion that could be used successfully for aerial photography was available on the market in France until 1955.

In 1955 Kodak infra-red Aviation film, with which the National Geographical Institute was able to begin worth-while trials, was placed on the market by the Société Kodak-Pathé. Apart from speed, this film is identical with the Aero infra-red film made at Rochester.

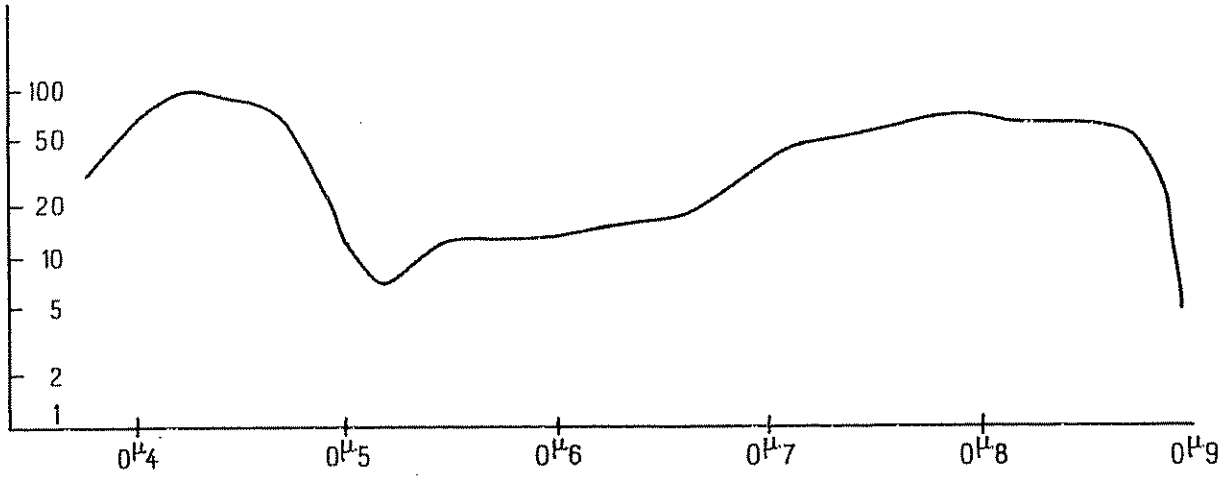
The National Geographical Institute then sought other possible manufacturers of infra-red material—in particular, plates—since it is the National Geographical Institute's policy to use plates exclusively for all precision work. The inquiries proved very difficult, because the supplier approached did not make an infra-red emulsion suitable for aerial photography or was unable to supply plates meeting our requirements, especially as regards planeness. This is the case with the Société Kodak which, despite the National Geographical Institute's representations, no longer produces plates for aerial photography.

Other firms, including Guilleminot, Lumière, Ilford and Gevaert, were also approached. Only Gevaert, which was already making panchromatic plates for the Institute, was able after several trials to put forward a suitable emulsion, but the material is not available commercially. The only infra-red emulsion so far offered by Guilleminot, also a supplier of good panchromatic plates, is not sufficiently sensitive.

At present, therefore, the only material available to the National Geographical Institute is, for practical purposes, Kodak infra-red Aviation film.

Chromatic sensitivity of emulsions

The chromatic sensitivity curve of Kodak infra-red film is shown in the following diagram:



This diagram shows two peaks of sensitivity, one in the region of 0.42 μ (violet), and the other (lower) peak in the region of 0.75 μ (close to infra-red). Moreover, the sensitivity to long wave-lengths extends to almost 0.90 μ. Sensitivity is lowest at about 0.55 μ (green).

The chromatic sensitivity curve of the Gevaert infra-red tested in 1957 is substantially similar and extends just as far into the infra-red range. The only difference is that the sensitivity to long wave-lengths is slightly lower than for the Kodak film.

Choice of filter for use with the emulsion

To obtain a true infra-red effect, the sensitivity of the emulsions to blue-violet rays must so far as possible be eliminated. On *a priori* grounds the choice would appear to be between a dark-yellow filter which stops all rays with a wave-length under 0.5 μ and a red filter which stops all rays with a wave-length over 0.6 μ.

In theory the yellow filter should give less dense shadows than the red filter. The lighting of shadows is largely due to diffused light which consists mainly of short-wave rays, more of which are stopped by a red than by a yellow filter. Again in theory, the yellow filter, which cuts out a smaller proportion of the total spectrum, should give a higher apparent speed than the red filter. In practice there is little difference between them; for example, the following speeds, in NF (degree NF identical with degree ASA), were obtained with a Kodak infra-red emulsion:

8.5 NF with the Wratten No. 12 filter;

7 NF with the Wratten No. 25 filter.

The gain is therefore insignificant. With the Gevaert emulsion the difference is even less. There is therefore little to choose between the two types of filter; and experience has confirmed that photographs of the same area using the two filters differ very little (*cf.* infra-red tests, Madagascar 1957, using Gevaert plates).

In practice the National Geographical Institute has always used a filter which cuts the visible spectrum at about 0.6 μ; this may be a red glass filter or a Kodak Wratten No. 25 gelatine filter. The factors of the two filters are approximately the same.

Gelatine filters may be either used without protection, or set in an ordinary filter-holder between two plane-parallel glass plates, or mounted as above, but cemented to the two glass plates.

The second method is used at the National Geographical Institute because it has the advantage that tests can be carried out easily with different filters, Wratten filters being inexpensive and many types being available.

Resolving power of emulsions

The resolving power of infra-red emulsions is sufficient for aerial photography:

for Kodak infra-red film: between 16 and 18 μ

for Gevaert plates: 17 μ.

It should be noted that panchromatic emulsions are usually of finer grain and have a resolving power of between 12 and 16 μ.

General sensitivity and exposure of emulsions

To be suitable for aerial photography, infra-red emulsions must be sufficiently sensitive when used in conjunction with a filter which eliminates sensitivity to short-wave rays. Sensitivity " with filter " often differs greatly from total sensitivity in the absence of a filter; and, for a given filter, the filter factor (the number by which speed without filter must be divided in order to obtain speed with filter) may vary greatly according to the type of emulsion used. For example, with the Wratten No. 25 filter:

Kodak infra-red film has a factor of 2.6;

the Gevaert infra-red plate has a factor of 6.0.

In practice the National Geographical Institute cannot consider using, with a filter, an emulsion with a speed of less than 20° Scheiner (=6 ASA). The reason for this limitation is that all the cameras used for cartographic photography are equipped with a small-aperture lens (the Aquilor, with a maximum aperture of f.6.3) [2] and intra-lens shutters, with a minimum shutter speed of 1/75 second. This low-speed threshold explains the difficulties, already described, of finding a satisfactory infra-red emulsion on the market.

[2] The 210 and 300 mm focal length cones are fitted with Orthor lenses with a maximum aperture of f.5.0, but the gain in clarity is slight.

Storage of emulsions

Infra-red emulsions do not keep well and must be used as quickly as possible. Ideally they should be kept under refrigeration. As yet the National Geographical Institute has not used infra-red material on a sufficient scale to require storage under refrigeration and emulsions not used immediately have been stored without special precautions. It was found that after six months the speed of the emulsion is halved and fogging doubled. It is therefore always advisable to re-examine the material before use

Processing of emulsions

The National Geographical Institute has always followed the manufacturer's instructions for the processing of exposed material:

for Kodak infra-red film: D 19 developer diluted with one part of water;

for Gevaert infra-red plates: G 201 developer.

The development times are also those recommended by the makers.

Adaptation of photographic equipment

The National Geographical Institute's interest in infra-red aerial photography is comparatively recent and it has no photographic equipment specially designed and built for this purpose. In particular, it has no camera with lenses specifically designed for infra-red photography. Such lenses are not obtainable in France.

It will be recalled that the cameras normally used by the National Geographical Institute are the Poivilliers SOM 96-plate automatic camera, which may be fitted with f 125, 210 and 300 mm cones, and the SOM film camera.

Infra-red photographs are taken in a region of the spectrum lying between 0.6 and 0.9 μ. However, the lenses used have been calculated and corrected for chromatic aberrations for wave-lengths of 0.49 and 0.66 μ and are therefore required in infra-red photography to function in quite a different region, using rays of greater wave-length. Therefore, both the focal length and the mean extension at which the camera must be set are slightly higher than those normally used in conventional photography. The correction for chromatism is also decidedly less effective in the infra-red region than in the normal working region for which the lenses were calculated. Experience showed, however, that the latter problem did not give rise to any appreciable defects in the image. It remained, therefore, to solve the first problem: modification of the extension.

This depends both on the focal length in question and the type of lens used, since the correction for chromatism for two lenses of different types obviously gives different results for extrapolation beyond the range of correction. For the lenses used at the National Geographical Institute, assuming that infra-red emulsion is used in a region in the neighbourhood of 0.8 μ, the modifications to be made in the extension are as follows:

Aquilor, f=125 mm: 8/10 mm

Orthor, f=210 mm: 5/10 mm

Orthor, f=300 mm: 7/10 mm.

These differences are too great to be absorbed by the depth of field when the lenses concerned are fully open.

At the National Geographical Institute this problem has been solved in two different ways:

(*a*) By modifying the extension of some cameras as a permanent adaptation for infra-red photography. This was done only in the case of a few SOM film cameras, a type of equipment seldom used nowadays for ordinary photography;

(*b*) By fitting a plane-convex slide in front of the lens, the front face being so curved as to offset the difference in extension to be applied; the curve is slight, the radius of curvature being close to ten metres. The advantage of this solution is that the same equipment can be used for both panchromatic and infra-red photography; it has been adopted at the National Geographical Institute for plate cameras.

Thus the two problems, that of the sharpness of the infra-red image and that of working with a red filter, can be solved either independently (special camera and normal filter) or simultaneously (normal camera and filter with convex front face). Practical trials carried out by the National Geographical Institute showed that the two solutions gave identical results.

To sum up, the National Geographical Institute uses the following equipment for infra-red photography:

Poivilliers SOM automatic plate camera, with:

either a red glass filter, with convex front face,

or a Wratten No. 25 gelatine filter set between a plane-parallel slide and a plane-convex slide;

SOM film camera, extension unchanged, with:

either a red glass filter with convex front face,

or a Wratten No. 25 gelatine filter set between a plane-parallel slide and a plane-convex slide;

SOM film camera, with modified extension, with a Wratten No. 25 gelatine filter set between two plane-parallel slides.

Conditions in Infra-red Trials carried out since 1955

The successive trials since 1955 were organized by the National Geographical Institute in such a way as to avoid prejudging the issue and to provide a series of tests under the most varied conditions. So far, three factors have been regarded as possible variables: photographic scale, season and terrain.

As regards scale, the photographs of the forest of Compiègne (1955) and the Bray area (1956) were made on each occasion on four different scales ranging from 1 : 5,000 to 1 : 50,000 (usually 1 : 5,000, 1 : 10,000; 1 : 25,000 and 1 : 50,000).

In order to study the effect of the seasons, the same strip of ground was photographed four times in 1955—in spring, summer, autumn and winter.

The first step was the selection of the terrain, after consultation with several interested specialists. In 1955 a north-south strip, some twenty kilometres long and very homogeneous, was chosen in the forest of Compiègne. In 1956, in contrast, the chief consideration was variety of soil (mud, clay, chalk, gaize, sand, alluvia, calcareous rocks) and landscape (state forest, woodland, marsh, ploughland, natural meadow, plantations): an east-west strip some forty kilometres in length was selected, running across the Bray area

from the forest of Hez to the valley of the Epte. In 1957, at the French Petroleum Institute's request, the terrain photographed—the Suzette *massif*—was selected in view of the very detailed information available on its geological structure.

However, the results of photographic interpretation by specialists were very disappointing. The university teachers and the technicians, geologists, prospectors, foresters, soil scientists and archaeologists who examined the photographs were unable to draw from them any significant conclusions. It would seem that photographic interpretation is, in many hands, still only of little scientific value.

Consequently, in order to provide a basis for more general conclusions, the National Geographical Institute in 1957 carried out several missions in the former Overseas Territories, including Gabon (cape west of the Gabon estuary and lower Ogoué valley from the neighbourhood of Booué) and Madagascar (strip to the west of Tananarive). The photographs were taken on the normal scale of 1 : 50,000.

These trials, however, were intended not merely to demonstrate the possibilities of infra-red photography as such, but also to investigate its advantages as a substitute for or as an addition to the panchromatic photography currently employed. Accordingly, both emulsions were used throughout the trials. Furthermore, in order to bring out the infra-red effect, all rays of shorter wave-length than red were stopped by the use of a filter as described above

After each set of photographs had been taken the National Geographical Institute studied the differences between the two emulsions used; however, experience showed as early as 1955 that interpretation was difficult unless a field inspection of the ground photographed was carried out shortly after the pictures were taken. In 1956 the following procedure was adopted: after photography, the photographs taken simultaneously were compared stereoscopically in the office on all four scales and a brief visit was made to the area photographed some ten days later in an attempt to elucidate differences which could not be interpreted purely from existing knowledge of the characteristics of the two emulsions. It was then possible to build up a coherent explanation of the results obtained. Needless to say, interpretation was far more difficult in the case of the photographs taken in the former Overseas Territories, for which no basic documentation was available; some of the explanations given must therefore be accepted with reservations.

Comparison of Data Provided by the Different Emulsions

Aerial photography is the basis of two techniques: photographic interpretation and photogrammetric plotting. The value of infra-red emulsions for each of these techniques is considered below

Photographic interpretation

The function of photographic interpretation is to identify soils, facies, types of vegetation, agrarian structure and the like from standards of comparison which are established in the field, and which associate a photographic aspect or tone with every feature shown.

Hence the essential properties which the interpreter requires of the photographs in order to identify the features investigated are fidelity and tone differentiation.

Infra-red emulsion would seem *a priori* to be suitable from both these points of view. In the first place the photographs show far more contrast and a greater tone range; in the second place the results attained with infra-red emulsion, which is more insensitive to polarized diffused light, should, by comparison with those obtained with panchromatic emulsion, be more independent of variations in light—in other words, of the time of day and the conditions under which photography is carried out.

Since the interpreter's interest is usually focused on a particular feature, the special characteristics ascertained from the missions carried out to date have been classified according to such features. The comments are based on what are considered the most typical pairs, but it is essential to note that information can be obtained only from the comparison (and not from the study in isolation) of both pairs taken simultaneously with panchromatic and infra-red emulsion, respectively.[3]

Moisture

The fact that every damp area appears as a black patch in infra-red enables us to observe certain facts: first, the remarkable differentiation of the degree of dampness of soils, both bare and covered with vegetation; secondly, the deep black which characterizes all stretches of water and which enables us to distinguish between areas that are merely wet and those that are actually covered with water, and between dry valleys and thalwegs still holding water.

This property was recently put to use in taking simultaneous photographs of the Marne valley during the floods of March 1958. The boundaries of the flood-waters are shown on infra-red with remarkable clarity, which increases when the photographs are enlarged, whereas on the panchromatic prints water sometimes has a grey tint similar to that of soil, so that delimitation is difficult even when the stereoscope is used.

This twofold property of infra-red photographs—that both the presence of water and the degree of wetness of most soils can be clearly discerned—should prove of real value in prospecting for water in arid zones or, conversely, in the development of swampy areas.

Vegetation

Infra-red emulsions are also highly sensitive to differences in the colour of foliage. The photographic image varies greatly in accordance with differences in leaf and pigmentation and the absorption of light rays by the vegetation.

This characteristic makes it possible to distinguish the different species of forest trees. In France, conifers, whether they occur singly or in groups, are sharply differentiated from deciduous trees, and, among the latter, poplars and birches, which come into leaf earlier, appear on photographs taken in springtime as white patches among the still leafless oaks and beeches; below the trees, but without giving any impression of relief, bracken and gorse form small black patches. Since other factors, such as canopy, density, shadow, homogeneity and height, can also be used to differentiate between tree species, forestry experts can reasonably expect interpretation to be of great value both in enumerating species and in evaluating soils or plantations.

[3] All the photographic tones referred to in the text which follows are those appearing on positive prints made from the negative.

Differences in leaf pigmentation are equally significant in an unforested area like Bray;

Meadows and watercress beds appear very white;

Dark streaks show differences in vegetation;

Mown hay, endive beds, straw spread on a meadow or dead branches appear as dark tones;

Grain-crops sprouting in ploughed land, or tufts of vegetation, form light patches;

Meadows and brush are differentiated, whereas they are sometimes indistinguishable on panchromatic photographs;

The variety of tones of grey in the same area would be particularly useful in interpretation as a means of determining the value—in terms of quality or density—of pasturage.

The interpretation of photographs of vegetation, however, is of greatest interest in the former Overseas Territories, where it is considered to be of direct value in the development of local resources, especially forest. A fact of importance from this standpoint is that it is already easy to tell mangrove, or wet forest, from dry forest. Also of interest is the deep black tone of vegetation burned in a bush-fire; the more recent the fire, the deeper the black. The identification of species is of course difficult in the present state of knowledge and can be undertaken only after field inspection of exactly similar terrain at an exactly similar time of year. However, once the relationship between the photograph and the area photographed under the conditions in question has been definitely established, interpreters with little knowledge should be able to relate the two without difficulty provided they have " identification keys ". In contrast to the almost uniformly grey tone of forests on panchromatic prints, infra-red emulsions discriminate between groups of trees, or even between individual trees. Thus, plantations of palm or coconut and some details of undergrowth can be made out. As an exception to the general rule, a very tall tree, possibly the okoume, is far more noticeable on panchromatic photographs, where it appears as a white patch; this is quite understandable since the photographs were taken in June, when the trees are in blossom.

This form of interpretation is important because it seems to be of general application. Experience gained with the forest of Compiègne in France and the fragmentary results achieved overseas appear to indicate that, to make a reasonably thorough study of the vegetation and, in particular, to localize the species with a reasonable degree of accuracy, it is advisable to photograph a forest, not on one occasion, however well chosen, but at several times of the year ; the quicker the development of the annual vegetative cycle, the shorter should be the interval between coverages. Infra-red emulsions should allow of more accurate interpretation in this respect.

Type of soil

In most cases these two factors of essential importance in infra-red photography—wetness and differences in foliage—act simultaneously, either against each other or in combination. Thus, marshes or grasslands covered with dense vegetation appear very white in infra-red photographs even though they are very wet. It is necessary, therefore, to consider the vegetation before drawing any conclusions about the humidity of the soil and only to compare identical features, that is, those with identical vegetation cover; in this connexion it is illuminating to compare the meadows of the Therain or Epte valleys with those of the plateau, whose general tone is greyer because they are less moist.

Conversely, the effects of humidity and leaf pigmentation may act in combination and even invert the tone arrangement; thus, in France, ploughed land, which shows light grey on panchromatic photographs, is black in infra-red—and the more freshly turned over, the blacker it appears. This also explains why the tracks of livestock, woodland paths sometimes invisible on panchromatic photographs, and patches of the same field which have been ploughed at different times or by different methods are so easy to identify. In contrast, meadows, which are very light in infra-red, are dark on panchromatic photographs.

The same observations apply to photographs taken overseas: where the earth—sand and mud—is bare, panchromatic photographs show white patches which stand out from the grey tone of the vegetation cover; in infra-red the same areas are white or black according to the degree of humidity, which in this case is the deciding factor.

Apart from this inversion of tones, the most striking feature on monocular examination of simultaneous photographs of the same area is the variety of tones occurring within a single parcel of land on the infra-red photographs, whereas what emerges most clearly from the panchromatic photographs is the division into parcels. This variety, assuming that the soil has no general cover, is due mainly to a further feature of particular importance: the composition of the soil. Thus the high chalk content of the surface layer on the southern slope of the " *boutonnière* " in the Bray area explains the white streaks and light patches on several pairs, features which are sometimes invisible in the panchromatic photographs. Similarly, some outcrops of laterite or sand are clearly differentiated in the photographs taken overseas. Still more illuminating is the study of the small black patches which dot some ploughlands, very clearly on infra-red and with uneven visibility on panchromatic photographs. Laboratory analysis of samples of the soil showed that their composition differed substantially.[4] The photographic differences may be due to variations in permeability and thus in residual surface moisture; whatever the explanation may be, the information provided in this way is highly accurate and should enable the pedologist to determine the surface soil type by the general technique of photographic interpretation.

The geologist can also make use of the density of shadows in infra-red photographs; their interpretation is simple because the red filter eliminates scattered light, the only light received from areas not directly illuminated. These shadows are useful in picking out structural features. Thus, they reveal the line west of Franceville at which—through faulting or erosion—the granite, covered with dense forest and cut by small, more or less well-drained valleys, meets newer land covered with savannah interspersed with bands of forest. Similarly, on the southern edge of the Bray anticline, they bring out the talus of structural origin; here again, the shadow effect may be accentuated by a related change in foliage and

[4] For example, two samples were taken at points some fifteen metres apart. Result of analysis: first soil: fine quartzose sand, very rich in organic matter and ferric oxide, consisting of 90 per cent sand and 10 per cent clay; second soil: fine quartzose sand, rich in ferric oxide, poor in organic matter, consisting of only 60 per cent sand and as much as 40 per cent clay.

low vegetation density due both to a less favourable exposure and to an inferior soil; whatever the explanation, the effect is present, and may be useful for purposes of geomorphology.

Archaelogical research

Reference should also be made to the sensitivity of infra-red to traces of former land divisions: in the Bray area traces of former boundaries can be identified in many places.

It is possible, if not probable, that infra-red photography may also be helpful in archaeological research. This hypothesis is confirmed by examination of the Roman ruins at Vaison.

Photogrammetric plotting

When aerial photographs are taken for the purpose of mapping a territory, the choice of emulsion depends upon its advantages in the photography, preparation and plotting stages. Any conclusions drawn must take into account the negatives, as well as the prints, which are all that is needed for interpretation.

Photography

Experience has shown that the use of infra-red emulsion for aerial photography involves no special practical difficulties.

No special precautions have been taken so far with regard to the storage of film although instructions have been given that the film should not be stored in magazines in aircraft, where temperatures may vary widely. While it is true that infra-red photography is not yet a standard procedure at the National Geographical Institute, it has been found by experience that the infra-red material used can be kept for two or three months in the Overseas Territories without special precautions of any kind and will show no fog due to aging provided it is well packed. Units operating overseas can in any case be supplied by air, making it unnecessary for them to keep films in stock for long periods.

Contrary to the normal practice in the air photography unit of the National Geographical Institute, all the films have been developed [5] in France. Immediately after exposure the rolls are sent to Paris, since there would be no advantage, from the point of view of security or checking, in processing them locally. In any case it seems unlikely that processing in the field would involve any major difficulty in view of the simplicity of the process in the laboratory.

The aperture and exposure for the actual photography have been determined more or less empirically in the light of the experience of the aerial photographers and by comparison with those selected for the simultaneous panchromatic photography.

Exposure meters have not been found particularly helpful. In most missions, an aperture of f.6.2 and a shutter speed of 1/100 second have been used, and as a rule the exposure has been correct. The use of infra-red does not, therefore, appear to present any particular difficulty with regard to the selection of aperture settings and shutter speeds.

For the reasons already stated, it should be possible, using infra-red material, to take photographs under atmospheric conditions normally considered unfavourable, for example, dry haze. Thus, in equatorial or desert areas the use of this emulsion should facilitate aerial photography in two ways: there will be a greater number of suitable days in the year, and the clarity of the negatives will normally be greater.

Aerial triangulation

In the former Overseas Territories, where travel is usually difficult, aerial triangulation is the only economic method of making regular surveys on a medium scale. In all aerial triangulation techniques the position and orientation elements of the perspective rays are calculated from measurements made on the successive negatives of a strip at homologous points.

Hence, the value of the elements given by the calculation of an aerial traverse depends directly on the ease of identification, and therefore on the general quality of the negatives, especially the absence of fogging. This is the first advantage of infra-red emulsions in certain regions.

In aerial traversing, even more serious consequences attach to errors in the transfer of a particular point on different photographs or negatives. This transfer is effected in three stages: the points of aerial triangulation control network are chosen by a specialist in the favourable areas on each photograph and transferred from one strip to the next; then, on placing in the instrument, the plotter must identify the same point on three successive negatives from the detail pricked out on the middle photograph; [6] lastly, in plotting, the same detail, whose co-ordinates have been calculated, must be marked. There is thus a transfer operation between strips, from photograph to photograph, and on the same strip, from photograph to negative (but under different conditions of examination); and the latter operation must be done twice.

The precision of any transfer operation obviously depends on the definition of the details. The better an emulsion shows local contrasts the more useful it will be. Among the examples studied in this connexion, the most frequent and the most typical is the photographic representation of forests in the former Overseas Territories; their uniformly grey tone in panchromatic pictures contrasts with characteristic differentiation of species of trees in infra-red photography, which greatly facilitates identification.

This significant advantage of infra-red emulsions, observed from the prints, was confirmed on examining the actual negatives in the plotting instrument. The lower the clarity of the instrumental optics, the more marked is this advantage; it is therefore much more noticeable in the Poivilliers SOM type B instruments used in aerotriangulation than in the type D instruments used in plotting for the former Overseas Territories.

In view of these advantages, the only defect of infra-red emulsions for aerial triangulation at the present time is the fact that only films are available; there is every reason to hope, however, that this disadvantage will not long persist.

[5] To assist in determining the correct development time, the photographer takes a few test pictures on the end of each roll of film. A short strip of film is developed in a dish and the time of treatment and bath temperature are noted. From these factors the time for which a whole film should be developed, taking into account the length of the film and the bath temperature, can be worked out using the ready reckoner prepared by the National Geographical Institute for the processing of Super XX panchromatic films.

[6] In some cases, where identification is difficult, this transfer operation can be avoided by making a fine mark directly on one of the negatives and using the instrument to locate the homologue of the marked point stereoscopically. However, transfer from strip to strip is not eliminated and, furthermore, if the area immediately surrounding the point is not flat (for example, trees in a forest). some of the accuracy of the stereoscopic plotting is lost.

Plotting

The value of plotting depends first on the qualities of the photographic coverage and secondly on the ease with which the details regarded as important enough to appear on a map can be identified.

Qualities of the photographic coverage

While the quality of the aerial coverage from the purely photographic standpoint is an essential factor in plotting, we do not propose to reopen the question of the comparative advantages of the two emulsions under discussion. It is proposed to deal only with factors, other than faulty navigation, which are liable to cause " blanks " in the survey: cloud, parasitic reflections, and cast or tone shadows.

As regards cloud, the smoke of bush-fires and small cumulus clouds are as a rule more effectively penetrated by infra-red rays since a thin layer of haze is not sufficient to stop them; this explains why each cumulus cloud hides a smaller area of the ground. This observation is confirmed by the somewhat unexpected results obtained from a simultaneous photography operation carried out in France in winter (March 1958). The results of the mission as a whole are good, but light local haze has eliminated all details on some panchromatic photographs whereas the corresponding infra-red films are usable. This does not of course mean that infra-red rays pierce fog; experience, backed by general opinion, shows that this is not the case, but they do pierce some kinds of haze —dry or of low density—which is in itself a very valuable property.

Although cumulus clouds are more effectively penetrated, the shadows they cast are unfortunately deep black and a major obstacle to plotting. This general weakness is explained by the density of shadows—cast or true—in infra-red photographs. While such shadows emphasize some details of relief or morphological characteristics (for example, the very clearly shown talus or structural origin in the Bray area or the general relief) and permit the identification of planimetric details such as fences between fields, their density makes them a great hindrance to the plotter. Thus—in France especially—they impair visibility, in villages, at the edges of woods, under tall trees and in a very rugged terrain.

Parasitic reflections of light from water are also found in infra-red photographs but do not cause the same halation as in panchromatic photographs and, as a rule, leave the boundaries of the water clear.

It will be apparent that photographs taken with panchromatic and infra-red emulsions complement rather than compete with each other.

Planimetric plotting

Panchromatic emulsion has marked advantages for all planimetric details of a cultural nature: roads, tracks, footpaths, isolated buildings, villages and the like. In France, secondary roads and tracks are easily distinguished in panchromatic photographs by their very white tone, whereas on infra-red they become far less clear and sometimes invisible because their grey tone does not stand out well against some soils. Examples are equally numerous in the results of all missions carried out overseas; in infra-red, tracks are as difficult to trace on bare soil as in forest.

The same applies to structural features—forest huts, buildings and villages—which are often difficult to detect in infra-red owing to the density of the shadows or to the tone of the surrounding soils.

Plotting of water features

On the other hand, infra-red emulsion is of very real value in plotting water features. The deep black tone of any area under water explains the clarity of:

Bodies of water, streams and the like, which are in wooded areas sometimes invisible on panchromatic prints;

The coastline, for example where landlocked lagoons are surrounded by dunes which would not be correctly plotted using panchromatic negatives;

The differentiation between submerged and other shoals; the outline of islands;

Marshes which are difficult to distinguish on panchromatic photographs, whether on the coast or not;

Pools and ponds, especially in villages;

Ponds for livestock, which appear as deep-black round patches;

Peat-bogs where cutting is in progress;

Canals and ditches, which are shown by typical black lines.

The deep-black tone of water distinguishes stretches of water from areas which are merely damp; it shows up watercourses and bodies of water, making it possible to distinguish between dry thalwegs and irrigated valleys. It also explains why submerged shoals and rapids in rivers are not visible in infra-red photographs.

The double aerial coverage thus eliminates ambiguities which cannot readily be resolved by other means in the former Overseas Territories.

Representation of vegetation

Where the map shows only the boundaries of types of vegetation, the types being determined according to the density and height of the species concerned, infra-red photography contributes little additional information; as a rule, there is also less differentiation between forest on the one hand and clearings, savannah or crops on the other, or even between different crops, because the sharpness of tone contrast depends upon the soil type, the soil cover and the local humidity. Thus, in mapping vegetation, the needs of the plotter and the interpreter seem to be opposed, the one being concerned with the over-all picture and the other with the determination of local details.

Plotting of heights

The accuracy of elevation depends directly upon the clarity of the negatives and the absence of excessively black areas, such as shadows. It also depends on the proper reconstitution of the perspective rays, and hence on the qualities of the support, as regards planeness, and on the local formations.

This consideration is sufficient to indicate the advantages and disadvantages of infra-red and panchromatic emulsions in the light of the atmospheric or local conditions.

Conclusion

What lessons can be drawn from this study with regard to the choice between panchromatic and infra-red emulsion for use in aerial photography?

It is first necessary to recapitulate the conclusions drawn in the individual sections of this study:

(1) In theory the use of infra-red should, by eliminating scattered light, facilitate photography under some atmospheric conditions.

(2) In practice the practical problems involved in the use of infra-red emulsions have been or are on the point of being solved, and in inexpensive ways.

(3) The trials with infra-red photographs, of which a fair number have been carried out in France, have revealed the existing lack of real experts in photographic interpretation—of specialists capable of deriving full benefit from the stereoscopic study of sets of air photographs for the purpose of their own discipline.

(4) Examination of the prints shows that infra-red emulsion is so sensitive to certain factors that, because of the contrasts produced, it cannot take the place of the existing panchromatic emulsion for a regular coverage. Contrasts emphasize some information, the presence of some objects, to a remarkable degree; but, except in special cases, the same information, the presence of the same objects, marked by differences in tone which are often less sharp but still appreciable, can on careful examination be found on panchromatic photographs. In other words, the sharpness of contrasts in infra-red provides excellent training for getting the most out of panchromatic photographs. However, maximum recording of details is a desideratum only for organizations wishing to make the maximum use of photographs, whether for their own work or in order to meet simultaneously the varied requirements of different users. To the specialized interpreter, whether geologist or prospector, soil scientist or agronomist, forester or ecologist, hydrologist or economist, the important consideration is the clear and unambiguous discrimination of the detail sought. Herein lies the particular usefulness of infra-red, which is far more sensitive to local details and which enables us to discern and to compare with accuracy such features as humidity, species of vegetation and soil type.

(5) Infra-red emulsions can make an equally significant contribution to photogrammetric map-making in certain of the former Overseas Territories:

Photography presents no special difficulties and is facilitated under some atmospheric conditions;

Under the same conditions, the quality of the negatives is far superior;

The quality and ease of identification improve aerial triangulation;

While there does not seem to be any specific advantage in plotting from infra-red photographs, the parallel examination of these may be of assistance in the plotting process; at all events no major technical problem is involved if, in some cases, the aerial triangulation is effected with one emulsion and the plotting with the other.

By the variety of considerations involved, this summary shows how difficult it is to make a final choice between panchromatic and infra-red emulsion; it means that such a choice would be justified only when absolutely unavoidable.

On the other hand, it proves the value of the contribution which, under some circumstances, infra-red emulsion can make as regards both information and accuracy.

The aircraft of the National Geographical Institute have the real advantage of being fitted with vertical camera positions from which two photographs can be taken simultaneously, each with a different emulsion. Other weighty arguments are that the cost of the extra emulsion is negligible in comparison with the cost of a mission, and that dual photography presents no additional difficulty.

It may be objected that systematic dual photography is not necessary in all cases. It is true that in several areas, especially very dry areas, say, of calcareous rocks, where the vegetation and soil are fairly uniform (the Madagascar mission is an example), double coverage may seem useless because little additional information is obtained. This, however, is difficult to predict, and it must never be forgotten that one of the main requirements of an aerial coverage is that it should be systematic.

The systematic use of both infra-red and panchromatic material in all air photography may now be envisaged; until such time as coverage in colour becomes feasible, faithful and useful, the first logical conclusion to be drawn from this study would seem to be that simultaneous photography is of undeniable value from every point of view.

The second conclusion relates to photographic interpretation, whose field and potential usefulness have been extended by the use of new emulsions. It is becoming clear that the general principles and the procedures for use of photographic interpretation must be perfected before the development of this too novel technique is thwarted by unduly narrow approaches prompted by the use of empirical methods, often of highly specific application. Only at a later stage will it be possible to go into the needs of users and facilitate their work in accordance with the principles established. The danger is only too evident that specialists may wish to generalize to all areas results obtained in one particular terrain, or to use a single set of photographs without regard to scale, favourable period, emulsion and so on. On the contrary, it would appear that interpretation can be made valuable only by comparative studies of photographs taken under different conditions, with different emulsions, at different times; comparative study of the prints with the terrain; and comparative study of the prints, whether simultaneous or not, with one another.

The existence of increasingly comprehensive collections of photographs, the systematic and regular execution of coverages by trained units, the minute stereoscopic examination of photographs by trained staff, and the experience gained with a variety of photographic materials—all these are prerequisites, but also reasons, for increasing the scientific applications of aerial photography.

GEOGRAPHIC EVALUATION OF AERIAL PHOTOGRAPHS [1]

Background paper by Dr. E. Meynen

Aerial surveying and interpretation of picture content are closely related. When an aerial photograph is taken at right angles to the ground, its picture content is topographic. While the study of the land is the primary subject matter of topographic research, it is also the subject matter of many other physical sciences. Evaluations of aerial photographs for the most diverse purposes are frequently based on comparable methods of approach and interpretation. The aerial photograph is a pictorial representation of the land configuration, which in turn results from the manifold interrelationships between the subsurface rock and the surface rock, the various types of soil, the hydrographic features and the vegetation. An aerial photograph clearly shows how the action of the various types of phenomena upon each other leads through the effect of natural laws to functional unity. *The broad synopsis which thus results is the key to the usefulness of evaluating aerial photographs* and compels the person working with such photographs to concentrate his attention on the complex of factors that go to make up the land. Even where the evaluation of aerial photographs is undertaken for a specific purpose, all the various components of land configuration must be taken into account. When the relationship of the parts to the whole has thus been established, the knowledge gained concerning this whole will in turn throw light on the particular matter that is being investigated.

In an aerial photograph the form of an area is usually indicative of its structure—for example, chalky formations indicate that the rocks in the substratum are rich in carbonates, and a highly subdivided land surface indicates the presence of small holdings. One of the main advantages of an aerial photograph is its ability to reveal the limits of particular areas on the basis of the contrasting gradations in the surface structure.

In the topographic evaluation of aerial photographs, the photographs taken in the past continue to be valuable for the information they provide on topographic changes and are an indispensable element in the historical record of such changes —for example, a balance-sheet of the areas suitable for agriculture. Aerial photographs also provide useful data for research into such periodic phenomena as tides.

The questions to which the evaluation of the aerial photograph is expected to provide an answer are as varied as the features of the landscape themselves. In addition to the widespread application of this technique in geology and forestry, the following examples are indicative of the other fields where it is used. The particularly acute need for farming and other economically useful land in post-war Japan made it essential to carry out a land-use survey. In 1953, eighty sheets of a land-use map on a scale of 1 : 50,000 and with a detailed legend of 100 items were prepared from an aerial survey by a staff of fifteen persons trained in evaluation techniques.

In addition to the frequent use of air surveys for estimating the approximate extent of agricultural and forest areas and of surface deposits of minerals, this procedure is also useful in connexion with the exploration and preliminary planning required for projects relating to land settlement, transport, water power and coastal reinforcement. The broad range of purposes for which the topographic evaluation of aerial photographs is particularly effective can be illustrated by the following examples.

For the purpose of a land-settlement scheme in an area of fallow land, the land suitable for cultivation must be set off from the land which is fit only for pasture; for a similar scheme in connexion with a forest which is to be converted into arable land, the areas of cultivable loam must be set off from the areas of barren sand. In an undeveloped forest area, the forestry administration desires to find out where there are utilizable stands of a particular kind of timber. On a large lake with growths of sedge, reed mace and rushes, it is desired to lease out the exploitation of rushes for industrial purposes, but the area of the exploitable surfaces is unknown and cannot be ascertained by a ground survey. Gravel is required for a large building scheme in a region overgrown with vegetation where other forms of stone are predominant. In connexion with plans for a heavy dam to be built on marshy land, technologists are searching for local deposits of firm sandy soil. A defence establishment needs to know whether a particular area is suitable for heavy vehicles. Improved agricultural methods are to be applied to a large and inadequately exploited region although the financial resources available are insufficient to meet the needs of the whole area, the question then being which parts of the area promise the best return on the investment to be made. A mining company is searching for outcrops of a particular kind of rock very different in character from other rocks in the area and associated with particular forms of vegetation. In the tropics a new area that is to be developed must have a good supply of water, be free of any danger of flooding and be away from any fever centres. A river running through a valley is to be regulated, and information is sought on the course of the main currents in periods of high water. An extensive survey is to be made of an unknown area to see what are the prospects of exploitation.

It is impossible to lay down hard and fast rules for the topographic evaluation of aerial photographs. The individual character of each area, the special questions to be answered by each survey and the resources available in each particular case are all factors which make it necessary to select, from the many well-tried methods which can be used, the one best suited to the particular occasion. It may be said, as a general rule, that the maximum number of indirect pointers, selected from a wide field, should be gathered to form a mosaic of evidence on which conclusions can be based. Wherever possible, there should also be a ground survey of selected areas, as this provides a key to the effective interpretation of the larger areas in the aerial photographs.

There is no one *method of interpreting aerial photographs* that is universally valid. All the data bearing on topographic structure in the photographs—that is, light gradations, boundaries, the sizes of objects in relation to one another and every ascertainable correlation between the particular characteristics in the photograph and in the area itself—are combined on each occasion to provide a suitable " aerial-

[1] The original text of this paper, submitted by the Federal Republic of Germany, appeared as document E/CONF.25/L.19.

photograph key ". It must also be borne in mind that many of the relationships which can be recognized between the picture and the natural objects are subject to spatial limitations and to some extent to limitations in time, that is, their usefulness depends on the seasons. Thus, the validity of any method of interpreting aerial photographs must be thoroughly tested.

Because of the wide diversity of land features and the variety of relationships between them, the topographic evaluation of aerial photographs requires a person who, through experience, is able to recognize all the clues in a photograph and is conversant with the many details involved. He must also have some talent for synthesis and be able to arrange details quickly in the correct relationship to one another. The type of person best fitted for this work is a geographer with a good general training.

In many cases the photographs will not be interpreted on the basis of scientific data alone, but also from historico-geographical and economico-geographical points of view. The common element which here brings together diverging branches of knowledge is the topographic research that is involved in the topographic evaluation of aerial photographs. As the connecting link among the *various* branches of science that come into play in such evaluation is thus geographical in character, the evaluation of aerial photographs becomes in this case a cohesive force in the realm of science.

Team-work in the evaluation of aerial photographs will accordingly be successful only if the team can integrate the many separate details into a single composite result.

In the topographic evaluation of aerial photographs, unrectified vertical photographs suitable for stereoscopic viewing are usually satisfactory from the standpoint of quality. Only when precise measurements must be made will rectified photographs be required. The use of colour photography will greatly facilitate the ecological evaluation of aerial photographs.

In a number of countries, including the Federal Republic of Germany and Japan, the geographic and topographic interpretation of aerial photographs is still in an early stage of development. In both these countries a high density of population is found on a relatively small food-producing area. They must therefore be constantly on the search for raw materials, water and power and must make every effort to improve the cultivation of the land and conserve their existing natural resources. Soil research and comprehensive land-use surveys are thus indispensable. In this respect the evaluation of aerial photographs can provide help within a relatively short period of time, as was shown by the " Land Classification Survey, 1953-1955 " in Japan, which was undertaken with an evaluating staff of only fifteen. In Japan there is a regrettable shortage of trained staff for the evaluation of aerial photographs, and the position in Germany is similar. This pressing need calls for national action and international co-operation along the following lines.

(*a*) Establishment in each country of centres for the topographic evaluation of aerial photographs. These centres would be attached to the photogrammetric institutes and would be provided with a complete file of aerial photographs for the particular country. This file would contain as complete a collection as possible of photographs taken at various times. These photographs would be arranged in accordance with geographical and other scientific criteria and would be provisionally evaluated (punch-card index), catalogued and made available for regular use.

(*b*) Establishment at universities of aerial-photography research centres that would give particular attention to the methods by which aerial photography was being used for purposes of geographic research in various parts of the world.

(*c*) The training, at special international institutes, of qualified and experienced geographers as aerial photograph evaluators.

(*d*) The international exchange of information on progress, methods and equipment in the field of geographic and topographic evaluation of aerial photographs, such exchange of information to be effected through a professional association, discussions and publications.

NEW METHODS OF AERIAL PHOTO-INTERPRETATION FOR SOIL SURVEYS [1]

Background paper by Dr. P. Buringh,
Head of the Soils Section of the International Training Centre for Aerial Survey, Delft

A few years ago some new methods of aerial photo-interpretation suitable for soil survey purposes were developed.[2]

These methods were improved upon after they were applied to large project areas in certain countries. Articles explaining details and techniques are now being prepared and will appear in publications pertaining to soil science. The principles on which the new methods are based are the following.

(1) Although aerial photographs show many physical and cultural details of the earth's surface, they do not show details of the soils, consequently the application of aerial photo-interpretation to detailed soil surveys is limited. The photographs are used only as field-working and reporting maps.

(2) In other types of soil survey aerial photographs can be of great assistance, in particular in the second phase of the soil survey. The first phase comprises the study of soils in the field and in the laboratory and the classification of soils, in particular into soil mapping units. The second phase begins with the mapping of the soil units in the field. It is then that aerial photo-interpretation assumes importance. Systematic analysis and unit classification can be carried out in advance; consequently, the regular field work can be done in less than half the time needed for normal soil surveys.

[1] The original text of this paper, submitted by the Netherlands, appeared as document E/CONF.25/L.75.

[2] Notably, by the present writer in 1954, and by Veenenbos in 1956.

(3) The techniques of aerial photo-interpretation are developed along the same lines as photogrammetry, which means that everything done on the photographs is accurate and exact, since it can be measured and reproduced. The so-called " black magic " is entirely omitted from aerial photo-interpretation.

(4) The introduction of aerial photo-interpretation techniques has changed the working procedure of soil surveys. After a preliminary study of aerial photographs and mosaics in the office and in the field, small-scale sketch maps of soils are drawn and a number of characteristic areas (approximately 500 to 1,000 hectares) are selected. In these so-called " sample areas " detailed field studies are made, and the legend for a semi-detailed soil map, scale 1 : 50,000, is set up. This is followed by aerial photo-interpretation, resulting in a map which is called a "photo map for soil survey purposes". Almost all soil boundaries are indicated and the units are classified according to measured characteristics of the earth's surface. Then the routine field work is carried out. The information on the map is checked and, if necessary, additional data are added.

The result is a semidetailed soil map of at least the same or even higher quality than a map prepared by normal soil survey techniques.

Advantages of the foregoing methods

The soil survey is done with greater speed, accuracy and efficiency and at less cost. Although these advantages are quite important, there are others of still more vital consequence.

(1) The soil survey capacity of a group of soil specialists is much higher than before. As much work still remains to be done and as there is a shortage of soil specialists in every country, this is quite important.

(2) Areas which previously could not be surveyed because of the high cost involved can now be studied, as the reduction in these costs is at least of the order of fifty per cent.

(3) During normal soil surveys many soil specialists have not enough time for real soil research. Since more time is now available, the basic soil study—and consequently also the quality of the soil map—can be improved.

(4) Until recently it was almost impossible to prepare semidetailed soil studies of large areas, because much time-consuming field work had to be done, rendering this type of soil survey extremely difficult. Therefore, reconnaissance surveys of large areas or detailed surveys of small areas were mostly carried out. For almost all development projects the reconnaissance soil survey gives insufficient basic information, while the detailed surveys take so much time—sometimes a period of years—that no project planner can use the results; they are always too late. The semidetailed soil surveys made with the help of modern aerial photo-interpretation techniques fill the gap between the detailed and the reconnaissance soil surveys. They provide the information required for development planning and, what is even more important, the information is available in time. The results, therefore, can be applied and consequently, the possibilities of a failure of the project greatly decrease. This is highly important from both the economic and social viewpoint. Experience has shown that the last-mentioned advantage is the most important of all.

In modern agricultural development projects a series of studies (one of them a soil survey) has to be carried out to supply the basic information for the plan. During three years' service in Iraq, the writer learned from a number of projects in that country that the cost of the soil survey itself is approximately 25 per cent of the planning cost. The cost of the aerial survey, photoprints and uncontrolled mosaics is about 5 per cent of the cost of the soil survey. This demonstrates that the cost factor of the aerial survey is unimportant. Therefore, the best aerial photographs are just good enough for soil survey purposes. In Iraq the development programme is thus not only planned, but also carried out. The total cost of planning amounts to 1.5 per cent of the cost of executing a development plan. On this basis the cost of the soil survey is 0.4 per cent, and the cost of the aerial survey, etc., only 0.02 per cent of the cost spent on the project area ! On the basis of this information, a rapid increase in the application of aerial photography to other than topographical or military purposes may be expected.

SOME AIDS FOR PHOTOGEOLOGY [1]

Background paper by Dr. K. Völger

During the past twenty-five years photogeology has become more and more important as a tool in the search for mineral deposits. The first successful photogeologic exploration on a large scale was carried out in the early nineteen thirties by a Dutch petroleum company for jungle areas in New Guinea.[2] The volume of photogeologic investigations enormously increased in the years after the Second World War and it was estimated that, in 1955 alone, areas totalling one million square miles were mapped by photogeologic methods.[3]

The procedures in photogeologic work may be divided into two kinds: (*a*) interpretation of the geology on the photographs, including annotation of the phenomena, and (*b*) transfer of the annotations (contacts, joints, etc.) from the central perspective photographs to a map-like orthogonic projection of a uniform scale; sometimes various measurements, such as those of spot elevations, thickness, dip, strike and angle of slope, may also be executed in the photographs. While (*a*) is

[1] The original text of this paper, submitted by the Federal Republic of Germany, appeared as document E/CONF.25/L.13.

[2] J. Krebs, " The Application of Aerial Geology and Aero-Photogrammetry in Petroleum Exploration ", *Photogrammetria*, No. 2, 1941 (Amsterdam), page 53.

[3] L. Brundall, " Photogeology Permits Rapid Mapping of Wide Areas ", *World Oil* (Houston, Texas), April 1956.

a purely geological problem, (*b*) may as well be carried out by photogrammetrists provided that close co-operation can be maintained between the geologist and the photogrammetrist.

Although much progress has been made in methods, one general difficulty still remains largely to be overcome in the opinion of the author. This difficulty lies in the fact that most field geologists, when facing the problem of working with aerial pictures, do not have the opportunity (or time) for a sufficient training in photogeologic methods. It seems that few efforts have been made to facilitate photogeologic work for those field geologists who use pictures only occasionally. This happens quite often, particularly when the limited scope of the exploration or other reasons make it appear impracticable to turn over the work to a photogeological organization or firm. This paper will deal with that problem and, in particular, with materials, instruments and methods that may contribute to a more efficient work in photogeology.

Aids through improving monochromes

It seems to be the general understanding that, even within the range of so-called "acceptable pictures" in terms of contracts, the photographic quality of the aerial pictures, quite apart from their geometric characteristics, influences the quality and also the accuracy of topographic stereo-mapping. This is even more so for geologic mapping by air photos. Special attention should be directed therefore to the photographic system whenever an exploration is the main reason for an aerial survey. During the past few years lenses have been designed that are distinguished by their superior resolution of details and also, though a matter of less concern to the photogeologist, by a smaller distortion. Aerial pictures taken with these modern so-called "high-performance" lenses can be expected to supply more information to the interpreter than pictures taken with older, inferior types, of which surprisingly many are still in use.

In order to yield a maximum of information from a given aerial negative, a diapositive on film or on a glass plate is certainly the safest way, because the very dark parts—for example, shadow side of hills—and the highlights—for example, bright rocks—are poorly resolved in ordinary paper prints. Whereas most of the stereo-plotters in topographic mapping—and all of the precision types—are used with diapositives, transparencies seem impractical for photogeological work. As in field work, the piecing together of at first incoherent geologic data in a graphic form finally results in a preliminary sketch of the geology of the area. This, in turn, while working from the known to the unknown, helps to bring about a more or less complete geologic sketch on the photo. As it is more inconvenient to mark formational contacts, joints and the like on diapositives than on paper prints, the latter will usually be preferred. When, furthermore, field work has to fill the gaps, paper prints seem to be the only practical material. As the annotations do not have to be applied to every single picture in a sequence with stereoscopic overlap but rather to every alternate picture, a combination of diapositive (that is, even number) and paper prints (odd numbers) is possible. Such a system poses some problems of illumination for stereoscopic viewing. The results, although quite gratifying as far as resolution is concerned, do not usually justify this more circumstantial method. It may be pointed out that in those instances where the shadowed slopes of mountains make an interpretation otherwise virtually impossible, diapositives with or without paper prints for annotations provide the simplest solution.

In case a topographic stereo-evaluation by precision instruments is carried out, as a rule through different organizations, diapositives can be expected to be available there.

A new plastic product called "Opal-Film" (Mimosa, Kiel, Germany) permits viewing in either transparent or reflected light; the prints are also well suited for handling in the field. The resolution for the individual parts of the tonal range has not yet been studied, however.

The maximum resolution of a paper print of medium or contrasty grade is for a narrow section of the density range not necessarily much smaller than that of the original negative.[4] It is possible therefore to come rather close to the resolution of the negative by selecting the appropriate exposure for reproduction of the desired density range. One has to compromise, however, as only about one-third, either the bright, the middle or the dark tones, of the complete tonal range will be resolved at a maximum. Whenever necessary, a stereopair should be preferred of which one picture (on medium or contrasty grade paper) is printed for resolution of darker tones, whereas the other print is exposed for better resolution of bright tones, as mentioned by G. C. Brock. In the experience of the present writer, printing alternately on soft and medium grade paper has also yielded more satisfactory pictures for soil studies than those from normal printing procedures, that is, on soft prints. However, if the printing of pictures is beyond the control of the interpreter, at least soft pictures rather than eye-catching, contrasty prints should be ordered for photogeologic studies.

Recently electronic printers have been devised in which the exposure is adapted by electronic means to the density of small individual areas in the negative. The negative and the printing paper are scanned by a cathode ray of varying intensity. While the detail resolution is reportedly excellent for topographic mapping, the suitability for geologic interpretation with its emphasis on minute detail remains still to be investigated.

Colour photography

In the course of the foregoing discussion it has been tacitly assumed that the limit of the recognizability is set by the resolution of the black and white aerial negative, commonly of the panchromatic kind such as Kodak Aero Super XX, Gevaert Aviphot and Perutz Pervola. If we try to leave that assumption and want to study the usefulness of colour photography to aerial survey in general, it will be noticed that the opinions of authors are divided on that subject. It is probably true that there would be little opposition to colour photography if the material would be equal or at least comparable to monochromatic material in regard to costs, ease of processing and printing and, last but not least, resolution. But the latter point is often used as an argument against colour photography; in fact, it is frequently stated that colour pictures provide very little additional information which would warrant the more complicated exposing (filters), processing and printing and the higher costs that go with them, to say nothing of the higher initial cost for the film. It is true that for general topographic mapping, monochromatic pictures contain more than enough information so that there is little

[4] G. C. Brock, *Physical Aspect of Air Photography* (Longmans, Green and Company, London, 1952)

need for colour. For forestry purposes the advantages of colour pictures are at best doubtful, the differentiation of green hues being not much better in colour pictures than in monochromatic ones.

For a less specialized question in botanical interpretation, the mapping of plant associations, colour is a definite advantage as the differentiation is based not only on the green hues and the shape of the object but on the brown, yellow and red hues which can be taken into account too. Particularly, the ground growth can be determined with an accuracy unobtainable from monochromes, as G. Kragh [5] has discovered. Among low plant associations, indicators to the lithology can be found more frequently than is the case among trees, a point that should not be overlooked in evaluating the possibilities of colour photography.

In areas of scattered outcrops, it is often quite difficult to correlate the individual exposures. Here the photogeologist will be grateful for every bit of additional information. In well-exposed sedimentary regions where individual beds can be traced without too much difficulty, the need for colour is less urgent, particularly when structural mapping is the main purpose. A study with colour photos carried out in the semi-arid parts of the south-western United States [6] yielded some interesting information. Colour sequences, for instance, aided in finding isolated occurrences of a stratigraphic unit. Furthermore, anomalies of colour sequences, established elsewhere, supplied indications of faulting. It is possible that similar results could have been obtained from monochromes by compiling and comparing columnar sections at a uniform scale in the same way as for the thickness of the units, and with the width of the column indicating resistant and soft beds.[7] Such a compilation from photographs requires considerable skill in photogeologic and photogrammetric techniques. Colour photography is of a definite advantage here, particularly for the less experienced interpreter.

In areas of igneous and metamorphic rocks, where irregular contacts make their determination quite difficult, colour photography again may provide the desired additional information, to say nothing of zones of alteration and mineralization. The vivid colours so often associated with gossans as well as the change in vegetation can also be distinguished better in colour than in black and white. The viewing of the stereomodel in colour rather than in grey tones presents a very valuable aid to the photogeologist working in hard-rock areas. A true colour representation is not as important for photogeologic purposes as for other non-aerial applications of colour photography. Some time ago aerial colour photos were taken of Triassic strata in the Alps that showed weakly red, iron-bearing portions and zones in spite of an over-all bluish tint that was the result of not having used an ultra-violet filter.

The colour films available for aerial photography are of two types, the reversal and the negative-positive kind. The following advantages of the reversal film may be listed.

(1) No printing process required as the original film (diapositive) can be viewed, therefore less material, labour and costs;

(2) No loss of resolution due to contact printing as original diapositives can be viewed

Experience with the new Agfacolor CN 17 has shown the following advantages of the negative-positive film quite clearly.[8]

(1) Greater latitude of exposure reduces flight risk;

(2) Direct production of paper prints, as required for some stereo-instruments and also for handling under field conditions, is relatively simple although somewhat more expensive than the production of monochromatic prints;

(3) Black and white paper prints of excellent quality can be made from the negative colour film just as easily as from any other, for example, panchromatic aerial film. Even when the underexposed colour film yields only unsatisfactory colour prints, fair monochromes can still be made. Monochromes from colour negatives show much better definition in the shadows than pictures from panchromatic film. Monochromes can be used for many purposes, such as indexing and radial triangulation, and also as diapositives for topographic mapping in instruments that work on the anaglyph principle and therefore can take only monochromatic diapositives;

(4) The original negative film is used only in contact printing and thus can be preserved much better;

(5) There is no need to use special gelatine filters, with a possible loss of resolution, in order to compensate for emulsion peculiarities. Colour corrections can be applied in contact printing;

(6) The resolution of the new Agfacolor film that was used in our experiments seems to equal that of fast panchromatic emulsions (about 21/10 DIN or 100 ASA).

From his own satisfactory experiences with negative-positive colour photography the writer is inclined to advocate an application of this type whenever possible. The additional cost in comparison with panchromatic photography can be kept relatively small, because of the universality of the negative-positive system. The decision whether to use colour paper prints or just monochromes made from the colour film can be reserved until the interpretation necessitates the former; until then black and white pictures with an occasional colour print for key localities can be used. Up to that point the additional cost, so often prohibitive to the application of colour photography, is relatively small.

A statistical approach to interpretation

Most of what could be said about the technique of discerning geologic phenomena, from obvious to veiled, in aerial pictures has already aptly been said by several authors.[9] The rest must be left to the experience, intuition and patience of the photogeologist. In the foregoing section the writer has tried to express his views on how the basic material, the aerial photographic image, could be improved in order to convey a maximum of information. Whatever the quality of the pictures may be, the photogeologist will have to exhaust them com-

[5] Personal communication to the writer.

[6] B. H. Kent, "Status of Color Aerial Photography in Geologic Studies of the U.S. Geological Survey", *Proceedings of the VIII International Congress on Photogrammetry*.

[7] L. Desjardins, "Techniques in Photogeology", *Bulletin of the American Association of Petroleum Geologists*, 34, 2284 (1950 a).

[8] K. Völger, "Neue Versuche mit farbigen Luftaufnahmen", *Bildmessung und Luftbildwesen*, 1957, page 4.

[9] T. Hagen, *Das Westliche Säntisgebirge photogeologisch gesehen und bearbeitet*, Publication No. 6 of the Geodätisches Institut (Zurich, 1952). *See* also footnotes 2 and 7.

pletely. In undisturbed or gently folded sedimentary regions the position of the bedding planes, particularly those of stratigraphic boundaries, will be the main object of the study. In hard-rock regions the interest will be focused on lithology and structure. Although the latter is especially suited for a statistical analysis, that is, of joints or, in general, of surfaces of all kinds, very little in this direction seems to have been done by means of photogeology.

Terrestrial pictures were taken of a trachyte quarry in order to study the possibilities of a determination of strike and dip of joints by stereo-evaluation. This work should be described here briefly.[10] Although joint diagrams are commonly prepared only of plutonic and metamorphic rocks, the sub-volcanic body offered itself for an experiment on account of its vicinity. Two pictures were taken with a phototheodolite (c=19 cm) as well as with a small 6×9 cm plate camera (f=10.5 cm). A few distances were measured with a chain, one of them being between two control points, marked with a small tape cross, that were in the photographed part of the exposure. The distance between both exposure stations, commonly one-sixth to one-tenth of the distance to the object, was 323 cm. The azimuth was determined with a geologist's compass for the direction between the two control points and one direction camera-control point. The small plate camera was levelled with a spirit level. The direction of the camera axes was horizontal and ± normal to the base, with a small convergence for almost complete overlap of the pictures. For the stereo-evaluation in a stereoplanigraph C-8 the pictures were enlarged in order to compensate for the difference between the focal length of the cameras and that of the projectors of the C-8.

By the stereo-evaluation it was intended to obtain the strike and the dip of even surfaces with no regard to their location within the exposure of the rock. This location plays no important role, because the mode of graphic presentation by means of a Schmidt net, as is common in petrofabric work, does not take it into account. Rather, every plane (joints, etc.) is thought to be moved parallel to itself until it runs through the centre of the reference sphere. Therefore the individual joints could be mapped by way of two elevation contour lines at a very large scale (1 : 10), the drafting pencil of the plotting instrument being shifted to wherever space was available on the drafting paper. Mapping was begun in the upper left corner of the paper, then the pencil was disconnected and moved by about 10 cm. All individual contour lines were of the same orientation in regard to North. After all visible points had been measured, the draft was put into a drawing machine and the strike of the joints was very simply determined. As, for every surface, one vertical and one horizontal distance (map distance between two contour lines) were available, the dips could be calculated in a simple manner. Thereupon each surface was plotted on the equal-area net (Schmidt net) by the intersection of its normal with the lower hemisphere. The contouring of the areas of equal frequency was done in the usual way.

The advantage of taking " oriented " stereopictures lies in the fact that the time-consuming determination of dip and strike of joints can be transferred to the office. Quite often the author has been able to eliminate certain questions about the structure by inspecting his stereopictures in the office when there was no opportunity for another field check. In this way, and particularly when the time element is critical, the geologist is enabled to concentrate on the petrology during his field work. In those cases where the joints are inaccessible, such as on steep mountain sides, the stereo-evaluation may very well be the only way to obtain structural data. The field geologist cannot be expected to carry around bulky photo-theodolite equipment. But, as was shown by past work, pictures with an ordinary plate camera are sufficient, as long as enough data (azimuths, distances) are secured for later orientation of the model as well as for the determination of the exact focal length.

[10] The writer is indebted to Dr. Lindig, Frankfurt am Main, for his support on this project

Aids in plotting

When a greater number of aerial photos has been filled with geologic annotations—it is immaterial whether these data were secured by photo-interpretation alone or in connexion with field work—the need arises to compile them on a map of a uniform scale. In the simplest form this can be accomplished by putting a sheet of tracing paper over the pictures and compiling a rough but continuous sketch. With regard to location, accuracy can be improved by control points either from ground observation, or radial or aerial triangulation. In this case it would be better to trace the geology and, for orientation purposes, parts of the topography, onto individual overlaps. These overlaps could then be rectified by either visual (Sketchmaster) or photographic (rectifier, projector) means. The disadvantage of these methods lies in their inaccuracy where mountainous terrain is concerned. They require, however, little in the way of instruments.

A few years ago, the company Zeiss-Aerotopograph put out a simple plotting instrument which takes paper prints and can thus be used rather easily for plotting the interpreted geology true to scale. While in the rectification procedures mentioned above no compensations can be made for the photographic central perspective, the " Stereotope " contains mechanical devices that transform the latter into a map-like orthogonic projection with an accuracy that will be sufficient for practically all photogeologic purposes.

The instrument is primarily designed for small-scale mapping of planimetry and elevation contour lines. The determination of differences of elevation can be carried out after some practice. Spot elevations, as used for structural mapping, can thus be measured in the pictures. In order to get a continuous geologic map from a number of aerial pictures, the control points, or whatever is available, are plotted on a sheet and the individual models are oriented accordingly, just as in topographic mapping.

When the contents of a great number of pictures has to be compiled, it is more economical to distribute the work: the interpretation is in this case carried out by the geologist while the photogrammetric plotting can be turned over to a technician, provided that the annotations to be plotted by the technician are such that they cannot be misunderstood. It is best if the photogeologist sits in the same room in order to be able to decide upon individual problems as they arise. This division of work gives the interpreter the time to concentrate upon the purely geologic problems. It should be mentioned that some of the steps in the photogrammetric compilation are rather time-consuming, especially the preparation of the mapping sheet as well as the orientation of the model.

AGENDA ITEM 12

Topical Mapping

THE ATLAS OF ISRAEL [1]

Information paper submitted by Israel

Following the lead given by Finland in 1899, Israel, in common with many other countries, is now producing a national atlas—the *Atlas of Israel*.[2] To the geographer Israel poses some peculiar problems, which become very prominent during compilation of a national atlas and make an atlas of Israel distinct in quite a number of ways from the average atlas of this type.

First and foremost, only few national atlases—as distinct from atlases of limited local regions—portray such a small area as the *Atlas of Israel*, the total area of Israel being no more than 20,700 square kilometres, comparable in size to the State of Massachusetts. This allows and even requires the cartographic representation in an atlas of Israel to be given on a scale much larger than that used in most other atlases. Whereas the average map in most national atlases is of the scale of 1 : 1,000,000 to 1 : 15,000,000,[3] most of the scales employed in the *Atlas of Israel* range from 1 : 750,000 to 1 : 2,000,000, with a few maps drawn to a scale of 1 : 500,000.[4] (In fact, the size of the *Atlas of Israel* was so chosen that a sheet exactly accommodates four maps of Israel to a scale of 1 : 1,000,000.)

These relatively large scales make the compilation of the *Atlas of Israel* much easier in so far as generalization is concerned. On the other hand they require a high standard of accuracy and detail for a country-wide cover. Considerations of scale apply not only to the map base, but also to the conventional signs used. When a subject is portrayed with the aid of signs—for example, circles—which are proportional in size to the quantity of the phenomena, the scale of magnitudes has to be carefully chosen, so that in its smallest size the sign can still be perceived without difficulty, while the largest size does not cover a disproportionate area of the map. This problem is ever-present in Israel, where a marked concentration of population, industry and commerce is found in and around Tel Aviv.

Maps generally, and topical maps in particular, become outdated and obsolete. Every map requires revision in order to keep it up to date, and this also applies to topical maps. But in few countries is the rate of development as high as in Israel. Here, within the last two generations throughout most of the country, agriculture has changed from extensive growing of field crops to a highly intensive agriculture which, in a considerable part of the State of Israel, is based entirely on irrigation. Population has increased by nearly 100 per cent and the increase in the number of settlements, too, is extremely high. Parallel with this is the encroachment of built-up areas on former agricultural land. Needless to say, the development of the road net, industrial installations and all kinds of public services is in keeping with this, and profound changes have also affected the trade pattern.

It is this dynamic quality, despite the small size of the country, which has distinguished Israel since the end of the last century, and which makes the country so interesting a field of study that it is worth devoting a full-sized national atlas to it.[5] It has, therefore, been a guiding principle of the editors of the *Atlas of Israel* to provide time-sequence maps for as many aspects of the geography of the country as possible.

The political changes which have taken place in Palestine on both sides of the river Jordan within the period for which cartographic representation could be achieved in the Atlas, that is since 1870, have repeatedly changed the documentary basis for the material used in its compilation. Coverage of topographic and geological maps, climatological, population and economic statistics, and information of a more specialized scientific nature are available for various periods and for varying areas. At the highest level of reliability detailed information was available during the mandatory period for the British-mandated territory west of the Jordan, that is, exclusive of Trans-Jordan. Today, equally reliable and often more reliable material is available for the State of Israel. The *Atlas of Israel* has found no satisfactory way to even out these

[1] The original text of this paper appeared as document E/CONF. 25/L.76.

[2] *Atlas of Israel*, published by the Survey of Israel and the Bialik Institute, Jerusalem, 1956 ff. (Editorial Board: D. H. K. Amiran, J. Elster, M. Gilead, M. Gordon, U. Zidon and N. Kadmon).

[3] Range of scales of some national atlases: *Suomen Kartasto* (Atlas of Finland): 1 : 1,000,000 – 1 : 13,000,000; *Atlante Fisico-Economico d'Italia*: 1 : 2,500,000 – 1 : 15,000,000; *Atlas de France*: 1 : 1,000,000 – 1 : 10,000,000; *Atlas over Sverige* (Atlas of Sweden): 1 : 2,000,000 – 1 : 12,000,000; *Atlas de Belgique*: 1: 500,000 – 1: 2,000,000.

[4] A collection of topical maps at such scales dealing with various subjects constitutes a useful tool for geographic study—the primary objective of an atlas—and also for economic planning.

[5] The *Atlas of Israel* will contain some 100 sheets with a total of over 600 maps; the size of each sheet is 50 by 70 centimetres (20 by 28 inches).

differences in the reliability of its sources and has therefore referred maps of a given feature at various periods to various areas. Phytogeographic maps, for example, are given in a generalized form for most of the Near East, and in greater detail for all of Palestine, including the former Trans-Jordan. Most of the maps in the sections on human and economic geography show the former mandated territory of Palestine until 1947 and Israel only for later dates.

One particular difficulty in comprehensive mapping work in Israel is that the country lies on both sides of a major climatic boundary—the border of aridity. This divides the very intensively settled and cultivated northern part from the rather monotonous and empty southern section. To include the two in the same map and provide for a sufficient degree of variation in the representation of features in the north without creating a too monotonous picture in the south gives rise to intriguing cartographic problems. Still, on most maps the contrast between the Mediterranean section and the desert parts of Israel is clearly evident. Furthermore, the high intensity of many features, especially those of human and economic geography, in rather small areas, poses the task of giving adequate expression to both high and low values at the two ends of one and the same set of symbols, the extreme values occurring on the map quite close to one another.

The topography of Israel, too, poses a peculiar problem to which it is very difficult to find a satisfactory solution. As is well known, the surface of the Dead Sea is the lowest point on the surface of the globe, nearly 400 metres below sea level. Not far from it the mountains of Edom rise to 1,200 and 1,600 metres above sea level. We therefore have to cover an altitude range of two kilometres on the map of Palestine. At the same time throughout most of the country features are rather moderate, with low mountains or hills rising between 150 and 500 metres above their bases. To represent these on a map requires a close spacing of altitude tints. To achieve this satisfactorily within a vertical interval of two kilometres, without arriving at the higher end of the scale at colour values suggesting "alpine" mountains, is a rather difficult task. Furthermore, there is no set relation between certain types of surface features and certain levels of altitude, even within as small a country as Israel. To cite but a few instances: south of Haifa the coastal plain terminates at less than 50 metres above sea level, and above it rise the steep slopes, and sometimes cliffs, of Mount Carmel, In the south, however, the coastal plain. without any definite break, rises to about 350 metres. The ridge and basin topography of Lower Galilee requires a clear distinction between the basins at 100 to 200 metres and the ridges at 400 to 600 metres. These ridges have well-pronounced features, and therefore require either a suitably diversified sequence of altitude tints or additional methods of representation. At the same time these tints have to form part of a sufficiently continuous sequence in order not to convey the appearance of breaking up slopes of a relative altitude of one kilometre and over, as found in the Dead Sea region, into a number of artificial steps not existing in nature. Moreover, one has to avoid showing the highest part of the walls overlooking the Dead Sea and the Araba Valley to the south of it, as knife-edge crests, as a result of their rising into the highest altitude range, while in actual fact they are merely the highest parts of consecutive, steep, west-facing slopes from which the land dips gradually and very slowly towards the east. The base map on some of the early sheets of the *Atlas of Israel*—for example, sheet IX 2—shows the errors of this method of representation, a method which has been rectified on subsequent sheets.

The subjects dealt with in the *Atlas* comprise the following:

A. Cartography (planned to contain fourteen sheets). Reproductions of ancient maps and such maps from the recent past as are milestones in the cartography of Palestine. Specimen maps of series of the Survey of Israel and index maps to them.

B. Geomorphology (seven sheets). Landform maps, soil maps and topographic cross sections.

C. Geology (three sheets). Geological and structural maps and geological cross-sections.

D. Climate (five sheets). Detailed information on temperature and rainfall, a rather original representation of wind distribution, a cartographic representation of dew, and others.

E. Hydrology (three sheets). Maps on underground water resources, and bottom contour maps for the inland lakes of the country.

F. Phytogeography (two sheets). A large number of distribution maps of characteristic indicator plants.

G. Zoogeography (three sheets). Information similar to that in the preceding section for the fauna.

H. Landscape evolution (three sheets). Cartographical presentation of transformation of the landscape of Palestine, which has been deeply influenced by man.

I. History (fifteen sheets).

J. Population (seven sheets). Distribution and density of the population, its increase, and other demographic factors.

K. Settlements (six sheets). Distribution of settlements according to size, topographic types of settlements accompanied by sketches of types, development of Jewish settlement and of the built-up area of the three major cities, and maps of typical rural settlements.

L. Agriculture (twelve sheets). Distribution maps for various crops and agricultural practices as well as for resources and utilization of water.

M. Industry and commerce (eleven sheets). Maps on industry, finance and trade, electricity production and consumption, and the distribution of industrial manpower.

N. Communications (three maps). Sequence series for roads, railways and development of air and sea communications.

O. Services (five sheets). Maps of educational and cultural services, as well as postal, health and judicial facilities. A special sheet portrays the distribution of malaria and bilharziasis, the most interesting endemic diseases in the country from the point of view of the health and medical authorities.

The *Atlas of Israel* is published in a number of folders, two of which are issued annually; each contains eight to twelve sheets. Maps are published as they are completed; the folders therefore do not contain maps of any particular section of the *Atlas*. Publication started at the end of 1956; four folders have been published so far, containing thirty-nine sheets with 245 maps.

LAND USE MAP (1 : 50,000) [1]

Technical paper by the Geographical Survey Institute, Japan

Introduction

The 1 : 50,000-scale land use map is being prepared in connexion with the law on national integrated development. It is therefore required to be of high value as the basic material for achieving the aims of that law, and also as the base map and the planning map for various investigations in this field. Thus, the contents of the map must cover all the phenomena concerning land use, for works relating to land development and conservation, the prevention of disasters, the intensification of land use, and improvement in industrial location. In addition, it is necessary to show all these phenomena throughout the entire country with uniform accuracy and method of representation.

Principles of investigation

The items to be investigated should be of value as common denominators among various works and projects, for, in an integrated land development programme with multiple objectives, a map whose contents are limited to a specific field is also limited in its range of use. The contents of the land use map should not be restricted to agriculture, but should also be applicable to urban land, transportation and activities concerning land development and conservation.

The map must show the present status of items and those only in the planning stage should be omitted. Furthermore, what are considered as mere interpretations arrived at by measuring, calculating and other scientific research should be excluded, because only facts are relevant to the purposes of the map.

In view of the fact that the main purpose of the integrated land development programme lies in the harmonious adjustment between the utilization and conservation of land, equal emphasis should be given to the phenomena relating to both.

The physical conditions of the land should be shown on the land use map, the topographic map being used as a base map. However, since tables are required for such features as climate and rivers, as well as for marshy lands, peatbog land and hydrographic features, including small ponds, marshes, irrigation ponds and the like, a more detailed representation is required than that found in the common topographic map.

Survey items

Survey items are shown in table 1.

Map-making process

Land use survey through aerial photographs

Aerial photographs on a scale of approximately 1 : 40,000 and enlargements up to double this size are to be used in making a base map for land use survey through delineating the investigation items readable on the photographs.

Delineation will be based on photo-interpretation and photogrammetry; those items for which priority is given to photo-interpretation are marked (O) in table 1.

Field reconnaissance

As for small areas of land use types and items indicating the intensity of land use, which are not revealed through photo-interpretation—such as crop rotation systems, kinds of crops and forests, and the facilities concerning them—and also any changes that have occurred since the photographs were taken, it will be necessary to carry out land use surveys in the field in which necessary items are shown on aerial photographs.

Drafting

The final result of a land use survey will be delineated on the base map from which the original land use map will be drawn. The land use patterns of the original map are drafted.

Printing

In accordance with the original map, colour separation is carried out on the drafted map. Eight different plates are made in colour which are then printed over the 1 : 50,000 topographic map, as the base map.

Inspection and proof-reading

Inspection and proof-reading are carried out at every phase of map-making.

The investigation method

General rules

A. Land use survey shall be carried out through aero-photo interpretation, aero-photo survey and field reconnaissance.

B. The survey items may be classified as follows: I. Arable land; II. Forest area; III. Grassland; IV. Others; V. Urban land use; VI. Transportation facilities; VII. Land improvement and land conservation facilities; VIII. Special facilities; IX. Special land features.

C. The delineating methods shall conform to the following principles:

1. Boundaries between primary divisions of such land use types as arable land, forest area and grassland shall be delineated most accurately. In order of importance, the distinction among paddy fields, ordinary fields, free gardens, various forests and the like comes next, followed by that among single-cropped, double-cropped and triple-cropped fields, and among conifers, broad-leaf trees and mixed coniferous and broad-leaf forest. Lastly, with regard to such detailed land use types as the distribution of kinds of crops and trees, a general delineation shall be sufficient.

2. If the distance between land use types is less than 25 metres, they are regarded as one group, and if the distance is 25 metres or more, both land use types are treated as independent ones.

[1] The original text of this paper, submitted by Japan, appeared as document E/CONF.25/L.61.

The method is as follows:

(*a*) In case the area of a land use type exceeds the stipulated area (given in each item), the actual form shall be delineated by full use of aerial photographs. However, in case the distance between delineated land use types is less than 25 metres, only the outside contours put together shall be considered as actual forms.

(*b*) In case the area of a land use type is less than the stipulated area, the delineation shall conform to the following principles.

(1) If the land use type is independent, no delineation shall be made.

(2) If the land use types (numbering more than two) are regarded as a group, the following procedures shall be observed.
  (i) The generalized picture shall be drawn by connecting the outside contours.
  (ii) If the area of the generalized picture is less than the stipulated unit area, no delineation shall be made.
  (iii) If the area of the generalized picture exceeds the stipulated unit area, it shall be subdivided into unit areas on the basis of such landmarks as nearby valleys and roads.
  (iv) Every subdivided area, as shown in the preceding item, shall be characterized by a land use type that covers the majority of the area.

(3) For a technical reason pertaining to the reduced scale, if the shortest side of a section is less than 1.5 millimetres (25 metres in actual size), it shall be enlarged up to 0.5 millimetre.

(4) In case of enlarged delineation, the actual position shall be the centre around which the real form is copied.

D. The distribution of every land use item shall be delineated in harmony with the topographic features with reference to aerial photographs.

E. With regard to the boundaries of national forests, national parks and pastures, if they have been surveyed with the same accuracy throughout the country, the boundaries so fixed shall be adopted; in other cases, some other means shall be used for determining the boundaries.

F. The classification of land use types shall conform to some comparatively uniform classifications established in various government ministries and other special organizations.

G. Technical terms whose definition is clearly given shall be adopted in preference to administrative terms that are liable to misunderstanding.

H. The primary classification of land use types shall be given in separate colours, but symbols shall be used for details.

TABLE 1. SURVEY ITEMS

I Arable land > 50 square metres	A. Paddy field ○	1. Triple-cropped ✳ +	*Kind of crops* ✳	1. Rice, wheat and potatoes +
		2. Double-cropped ✳		2. Vegetables
		3. Single-cropped ✳ +		3. Flowers
		4. Perennial crops ✳		4. Industrial crops
				5. Green fertilizer
				6. Forage crops
				7. Other special crops
	B. Upland fields ○	1. Ordinary field		
		(*a*) Triple-cropped ✳ +		
		(*b*) Double-cropped ✳ +		
		(*c*) Three crops every two years ✳ +		
		(*d*) Single-cropped ✳ +		
		2. Fire field ✳		
	C. Tree crops ○	1. Orchards ✳ ○	*Kind of fruit trees* ✳ +	
		2. Orchards inter-cropped with field crops ✳	Citrus, Loquat, Pear, Peach, Grapes, Persimmon, Apple, Cherry	
		3. Mulberry garden ✳	Other fruit trees ✳	

		4. Mulberry garden ✱ intercropped with field crops		
		5. Tea garden and other tree crops ○ ✱		
		6. Tea garden and other tree crops intercropped with field crops ✱		
				✱
			Kind of trees	+
II. Forest area <200 square metres	A. Dense forest ○	1. Conifers	○ ✱ +	Cedar, Japanese Cypress, Pine, Fir, Larch
		2. Mixed coniferous and broad-leaf	○ ✱ +	White Fir, Hemlock-spruce, Beech, Zelkova
		3. Broad-leaf trees	○ ✱ +	Oak, Quercus serrata, Birch, Chestnut, Quercus glandulifera, Paulownia, others
	B. Other type of forest ○	1. Bamboo	○	
		2. Thin forest	✱	
		3. Deforested land	✱	
		4. Newly afforested land	✱ +	
		5. Dwarf trees and shrubs	✱	
III. Grassland >100 square metres	A. Grass ✱ B. Water-weeds ✱ C. Dwarf bamboo ✱ D. Meadow ✱			
IV. Others ○ >100 ✱ square + metres	A. Boundary of pasture ✱ +			
	B. Boundary of seasonal grazing land +			
	C. Barren land ○			
	D. Salt bed			
	E. Fish culture area +			
	F. Boundary of national park +			
	G. Boundary of national forest +			
V. Urban land use ○ >100 square metres	A. City ○	1. Commercial area	✱	
		2. Heavy industrial area	✱	
		3. Light industrial area	✱	
		4. Fishery area	✱	

		5. Housing area *	
		6. Transportation area *	
		7. Public area *	
	B. Rural settlement O		
VI. Transportation facilities O	A. Road O	1. Bus route * +	
		2. Main auto route +	
	B. Railroad O	1. Railroad +	Single, Double +
		2 Electric railroad +	Single, Double +
VII. Land improvement and land conservation facilities >200 square metres	A. Boundary of newly readjusted arable land O +		
	B. Boundary of well-drained arable land +		
	C. Boundary of terraced field area *		
	D. Boundary of area under reclamation O * +		
	E. Main irrigation canals +		
	F Boundary of authorized soil conservation area +		
	G. Breakwater +		
	H. Pier +		
	I. Reserved forest area +		
	J. Jetty O *		
	K. Cemented river bed * +		
	L. Sea wall *		
	M. Levee O *		
	N. Weir O *	1 For power plant use +	
		2 For agricultural use +	
		3. For soil conservation and water level control use +	
		4. For water supply use +	
VIII Special facilities	A. Greenhouse *		
	B. Mine + *		
	C. Power plant *		
	D. Weather observatory *		
	E. Water level observatory *		

IX. Special land features	A. Swampy land	○ ✱	
	B. Peatbog	✱ +	
	C. Pond (Reservoir)	○ ✱	
X. Table	A. River water table	+	1. Name of river 2. Observation station 3. Maximum flow recorded 4. Flow at the time of mean water level 5. Flow at the time of lowest water level during 355 days in a year 6. Highest water level recorded 7. Mean water level 8. Lowest water level during 355 days in a year
	B. Climate table	+	1. Observatory 2. Elevation 3. Maximum temperature 4. Minimum temperature 5. Growing season 6. Precipitation: annual, summer (Apr.-Sep.), winter (Oct.-Mar.) 7. Maximum daily precipitation recorded 8. Annual rainy days 9. Maximum snow depth recorded 10. Annual snowy days 11. Earliest frost 12. Latest frost 13. Prevalent wind direction and wind velocity 14. Mean wind velocity 15. Annual stormy days

NOTE: The values in square metres show the minimum area of items to be taken up on this map.

Principal sources:

○ Photo-interpretation
✱ Field reconnaissance
\+ Previous map source materials

SELECTION FROM STANDARD REGULATION OF LANDFORM SURVEY [1]

(The Prime Minister's Office, Ordinance No. 50, issued 2 July 1954)

Information paper by the Geographical Survey Institute, Japan

Chapter I. General provisions

Purpose

Article 1. The standard regulations concerning landform survey among various surveys to establish the standards for land classification survey in accordance with article II, item II of the land survey law (Law No. 180 of 1951) shall be given in this ordinance.

Contents of landform survey

Article 2. In landform survey, general survey (including the analysis and morphometry of landform) is made to clarify the character and distribution of the landform related principally with the development, conservation and utilization of

[1] The original text of this paper, submitted by Japan, appeared as document E/CONF.25/L.62.

national land, and the results are expressed in maps and an explanatory text.

Landform survey

Article 3. Landform survey consists of reconnaissance work, field work and final editing.

Final editing

Article 6. Final editing is defined as the making of the maps and landform explanation, as given below, on the basis of the results of reconnaissance and field work.

1. Drainage system map	1: 50,000
2. Drainage density map	1: 50,000
3. Gradient distribution map	1: 50,000
4. Landform classification map	1: 50,000

Chapter II. Reconnaissance work

Air-photo interpretation

Article 11. In interpreting air-photos in reconnaissance work, the spots where such interpretation is difficult must be edited so that they may be conveniently recognized in field work.

Making of reconnaissance drainage system map

Article 12. The reconnaissance map of the drainage system shall be made so as to represent the present state of level form of drainage system.

2. With regard to drainages, all the area as far as prominent ravines on the slopes of mountains shall be represented in order to clarify the dissected state of landform.[2]

3. The reconnaissance map of the drainage system shall be made from air-photos transcribed on the topographic map, after the drainage system is represented on the air-photo concerned, with the interpretation of the photo. However, in case the position and form of principal river systems on the topographical map are different from those on the air-photo, the difference shall be rectified with the help of air-photos and other means.

Making of reconnaissance gradient distribution map

Article 13. The reconnaissance gradient distribution map shall be made by representing the landform gradient according to the classified degrees of gradient.

4. The gradient classification ... is as follows:

(*a*) 40 degrees and up;

(*b*) 30 degrees and up—under 40 degrees;

(*c*) 20 degrees and up—under 30 degrees;

(*d*) 15 degrees and up—under 20 degrees;

(*e*) 8 degrees and up—under 15 degrees;

(*f*) 3 degrees and up—under 8 degrees;

(*g*) under 3 degrees.

Making of reconnaissance landform classification map

Article 14. The reconnaissance map of landform classification shall be made so as to represent the character and distribution of landform.

2. The reconnaissance landform classification map is made by interpreting air-photos, with reference to ready materials, to classify landform, then representing the distribution boundaries on the photo concerned, and finally transcribing the results on the topographic map, with additional representation of necessary items according to the legends given in table 7.[3]

4 (*a*) In case a rocky plateau or a gravelly plateau consists of several stages, they shall be classified by terracing landform.

Chapter III. Field work

Surface material

Article 19. The investigation of surface material ... shall be carried out with regard to such kinds of material and area as in the following list.

Material to be investigated	*Area*
Volcanic detritus, loam	Piedmont gentle slope, terrace, plain, landform due to mud flow, landform due to mud avalanche
Angular and round stone	Piedmont gentle slope, shingle bed
Angular and round gravels, soil beach, talus	Colluvial slope, sand and gravel bar, landform due to mud avalanche

4. Only surface material more than one metre deep shall be collected.

Chapter IV. Final editing

Making of drainage system map and gradient distribution map

Article 23. The drainage system and the gradient distribution maps shall be made by editing and rectifying the reconnaissance maps of both based on the results of field work, and transcribing the information thus obtained on to the topographic map.

Making of drainage density map

Article 24. The drainage density map shall be made on the basis of the map of the drainage system so as to represent the dissected state of landform numerically.

2. Drainage density shall be shown with the numerical values of the valley to be read in the unit section of one square kilometre of the map of the drainage system.

3. The measurement of the number of valleys shall include both the number of the main and branch streams in a unit section, plus the numbers of sub-branches, if any.

4. The drainage density map shall be made with the density in each unit square section as in item 2.

Making of landform classification map

Article 25. The map of landform classification shall be made by transcribing on the topographic map the edited and rectified results of the reconnaissance map based on field work plus the results of the investigation of the surface material prescribed in article 19.

2. In order to make it easy to read the landform classification map, section profiles of landform shall be prepared and affixed to the bottom of it, outside the map itself.

[2] The original numbering of paragraphs and tables in this paper has been retained to indicate items excerpted from Ordinance No. 50 of 2 July 1954.

[3] See footnote 2.

3. The section profiles of landform shall be made in a direction suitable to indicate the character of landform on a horizontal scale of 1 : 10,000 and the position of the section is to be shown on the landform classification map.

Explanatory text

Article 26. In the landform explanatory text, all the items that facilitate the use of the landform classification map, such as items regarding the character of landform, the development, conservation and utilization of landform and land, as stipulated in table 8, and any items that cannot be delineated on the topographic map, are to be entered.

Table 7

PART 1. LEGEND

Classification	*Abbreviation*
Gentle slope on mountain ridge	mT
Gentle slope on mountain side	mF
Mountain slope:	
Valley density 80/km²	mSI
Valley density 80/km²	mSII
Piedmont gentle slope	mP
+	
Gravel terraces	GtI
Gravel terraces	GtI
+	
Gravel terraces	GtII
Gravel terraces	GtII
+	
Gravel terraces	GtIII
Gravel terraces	GtIII
+	
Rocky terraces	RtI
Rocky terraces	RtI
+	
Rocky terraces	RtII
Rocky terraces	RtII
+	
Rocky terraces	RtIII
Rocky terraces	RtIII
Karst upland	K
Pyroclastic plateau	AP
Lava plateau	LP
Fan:	
Areas not flooded	FI
Areas flooded by unusual flood	FII
Areas flooded by usual flood	FIII
Valley plain:	
Areas not flooded	PI
Areas flooded by unusual flood	PII
Areas flooded by usual flood	PIII
Delta:	
Areas not flooded	DI
Areas flooded by unusual flood	DII
Areas flooded by usual flood	DIII
Coastal plain	Lg
Landform due to volcanic mud flow	M
Landform due to debris avalanche	R
Sandy or gravelly mound	Sh
Bare sand dune	Nd
Sand dune covered with vegetation	Cd
Peaty wet land	W
Peatbog land	P
Aggraded river-bed by building banks	Fr
Dry river-bed	Sr
Sandy beach	Sb
Rocky ledge	Rb
Cliff	e
Landform due to landslide	ls
Land collapse	df
Break-down of river bank	c
Colluvial slope	co
Talus	tl
Inner limit of unusual high water	ah
Outer limit of tidal plain	tf
Topographic discordant line	i
Boundary of volcanic area	mv
Boundary of density	vd
Boundary of landform	ld
Knic Point	n
Volcanic detritus	v
Loam	L
Angular stone:	
Maximum diameter 1,000 mm	a4
Maximum diameter 500-1,000 mm	a3
Maximum diameter 100-500 mm	a2
Maximum diameter 20-100 mm	a1
Round stone:	
Maximum diameter 1,000 mm	r4
Maximum diameter 500-1,000 mm	r3
Maximum diameter 100-500 mm	r2
Maximum diameter 20-100 mm	r1
Angular gravel	ao
Round gravel	ro
Soil:	
Sand	s
Silt	si
Clay	cl
River course recently changed	
N.B. × Unit: mm	

4. With regard to gravel terraces and rocky terraces, the following classification shall be made, according to the necessity, in the order of height: GtI, GtII, GtIII, or RtI, RtII, RtIII. If it is necessary to subdivide, the legends above shall be modified, according to the character of each landform to GtI, GtII, GtIII, or RtI, RtII, RtIII.

Table 8

Items to be entered	*Contents to be entered*
I. General description of landform	1. The location of the area to be investigated, the general idea of the arrangement of chief landforms and of the character of landform (including the general description of the geological features and soil), and a general view of inland water distribution and climate.

Items to be entered	*Contents to be entered*
	2. Special geographical items (such as the ground subsidence and earth movement, dislocation due to earthquakes, and other noteworthy items related to landform)
	3. The construction of geological tectonics, and the history of landform development.
II. Detailed description of landform	1. The character and distribution in each large and small classification of landform. However, if an explanation is required for each landform division (which means a region of uniform character), the character and distribution on each landform division shall be given according to large and small classifications.
	2. Observations or measurements on such items as surface materials and outcrop, which serve as the basis of landform classification.
	3. For landforms connected with land disasters, observations on representative ones to give the character, scale and cause of the disasters.
III. The relation between landform and land disaster and land use	1. The history, distribution, character, frequency, and tendency of land disaster.
	2. The present state of development and conservation of the landform surface in relation to land disaster.
	3. The relation between landform and land disaster.
	4. The relation between landform and land use.
IV. Table of rivers	The names, extension and basin area of principal rivers. For the elevation of river-beds, the location and cause shall be given. Seasonal change of flux (if necessary, the longitudinal profile of river should be attached)
V. Table of mountains	In each group, the altitude of principal mountains, the altitude of ridges, indication of whether volcanic or non-volcanic, the altitude of upper limits of forests and the state of nivation.
VI. Table of disasters	The main causes, location, period, and scale of every flooding, landslide, collapse, bank rip, eruption and great earthquake.
VII. Table of areas	Total area in every large landform classification inside the investigation district.
VIII. Reference documents or materials used	

SPECIAL MAPS FOR LAND DEVELOPMENT [1]

Technical paper by the Geographical Survey Institute, Japan

The importance of maps in promoting economic development can hardly be overrated. Without precise graphic descriptions of terrain features, water supply conditions and transportation facilities, no concrete regional plan would be possible. Needless to say, maps and statistics serve as an international language, and are most effective means for enabling data selected for a certain purpose to be scientifically grasped in an objective manner.

However, maps are even more important than statistics in integrated land development, the purpose of which is to utilize land by arranging, in a comprehensive manner, a large number of phenomena according to the quality of the land. Where a large number of phenomena are combined in too complicated a manner to allow for a statistical grasp of their distribution, maps are the only source from which scientifically exact data are obtainable.

The maps essential for economic development may be classified as general and special. Not only do general maps

[1] The original text of this paper, submitted by Japan, appeared as document E/CONF.25/L.63.

indicate with exactitude the geographical location, the area and height of every place on the earth's surface and delineate natural features, such as rivers, coastlines and land relief, but they also show clearly the distribution of such major cultural features as principal roads, railroads and cities, giving at the same time the location of every place in relation to transport and marketing.

In short, general maps show fundamental facts, which are commonly important to subject phenomena on special maps related to land development. Consequently, general maps are indispensable as base maps for all special maps. This is the reason why the first step to be taken in furthering integrated land development is said to consist in the preparation of general maps.

There is a great variety of special maps. Those closely connected with economic development are of many kinds—the land classification map, the geological and mineralogical map, the inland water map, the climate map, and others. From the viewpoint of map scale, the following three kinds must be mentioned.

The first is the chorographic scale map, which is necessary for planning nation-wide or region-wide projects. It is for this reason that the international 1 : 1,000,000-scale map was designated as the base map for integrated development at the first Regional Cartographic Conference in 1955. The scale of this kind of map is from 1 : 1,000,000 to 1 : 5,000,000.

The second is the topographic scale map, which shows the exact distribution of related phenomena on a regional scale and which is one of the most important maps for concrete integrated planning. The comprehensive arrangement of various cultural features in a given catchment basin and the adjustment of land use in a given area are effectively planned on this scale map. The proper scale of this map is approximately from 1 : 50,000 to 1 : 100,000, though it depends upon the complexity of surface features in a specific area.

The third is the large-scale map designed for construction projects. In keeping with the differences in such works, the scales are not unified, but range approximately from 1 : 500 to 1 : 10,000.

As has been stated above, the types of maps necessary for expediting economic development are numerous and varied, and each of them is required to be excellent in content and must be prepared in a short period. Production of these maps is facilitated first by standardizing specifications, secondly, by making full use of air-photos and maps already published, beginning with general maps, and thirdly, by arranging the topographic map and the special map as a series production so as to minimize duplication of work in production procedures.

(1) When the specifications for and the method of producing maps are standardized, not only domestically but also internationally, the mass training of technicians becomes possible, and the exchange of technicians as well as of technical knowledge among countries can be smoothly carried on through international co-operation. Furthermore, the knowledge of one country supplements that of others, which is of mutual benefit in developing and raising technical standards.

This is the reason why the problem of the above-stated specifications, centring on the general map, has always been an important item on the agenda of international cartographic conferences. However, in the case of the special map, the standardization of specification and investigation methods is far more necessary than in the case of the general map, for the special map deals with special subjects, and there are comparatively few technicians in this field in each country. The standardization of specification and investigation methods for the special map generally lags behind that of the topographic map.

An international technical agreement along this line has been established of late. However, as yet, we can mention only such settlements as the compilation of an international geological map on a 1 : 5,000,000 scale effected by the Economic Commission for Asia and the Far East in 1954, the international exchange of technique and knowledge for the purpose of preparing international land use maps based on a proposal by the World Land Use Committee, and the compilation of a world population map on the millionth scale planned by a global committee. One of the reasons for delay in standardizing special maps is that there are many kinds; also, the very fact that their contents are so specialized presents problems in the way of standardization that seem incapable of being solved. However, if the problem is ignored because of its difficulty, it will remain forever unsolved.

(2) Recent developments in photogrammetry and photo-interpretation have greatly contributed to the production of special maps as well as of topographic maps. Further studies will enable more economies to be made in map production processes and procedures than can be made today. No comment is necessary on the desirability of making full use of general maps, the characteristics of which have been classified above.

(3) The adjustment of specifications between the general map and the special map also contributes to minimum effort in map preparation.

Needless to say, each special map treats of its own specific phenomena, while the general map, at least in its ideal state, shows the common denominator of principal phenomena for all kinds of maps and at the same time should serve as a base map for all special maps. This is the very point through which standardization between the special map and the topographic map can be achieved.

In view of the considerations mentioned, some examples of fundamental ideas on the subject will be given in the following paragraphs; in this way we hope to contribute to the standardization in specification and investigation methods.

The three maps under discussion are: (*a*) the topographic scale map which is necessary in every country for coverage over a vast area. In connexion with this map will be treated the land use map and the landform classification map, which are as important as the geological and mineralogical map from the viewpoint of land development; (*b*) large-scale maps—as an example the lake chart will be treated here, and (*c*) the chorographic scale map; the significance of general maps as the base for variegated special maps on this scale will be studied with some examples.

Topographic scale map

Land use map

No plan of action can be made without proceeding from factual data. As background material for land development, nothing is more valuable than a precise map delineating the actual land use.

It is desirable that this kind of map should be the so-called integrated land use map, showing not only the actual state of agricultural land use but also the use of mineral and water resources, communications facilities, settlement land use, land improvement, soil conservation, and so on.

Improvement in land use patterns should not be local or one-sided but should be many-sided, integrated and should cover a large area. Therefore, even for those areas for which a topographic map is not yet ready, land use maps are prepared by means of mosaic and photo-interpretation because of the pressing need for such maps. In Africa and in South American countries, a considerable number of land use maps have been produced by these methods.

The integrated land use map mentioned above clarifies more than actual land use and, to some degree, the quality of the land and its availability for future utilization. It is, in fact, a type of land classification map. Another reason why plans for the development of under-developed areas cannot be made without the land use map is that vegetation cover, which is a principal indicator for land use type classification, is controlled by a variety of physical conditions—climate, landform, water supply and so on.

First, vegetation cover corresponds to climate: for example, tropical rain forests flourish only in a tropical humid region; evergreen broad-leaf trees in a subtropical and warm-temperate humid region, and savanna-steppe ecosystem plants in an arid region. Secondly, vegetation cover is controlled by surface features. Even in a warm-temperate humid region, plants naturally belonging to an arid region, like the spinescent plant, flourish on steep land owing to good drainage, and also on coastal sand dunes because of the sandy soil and dryness caused by wind. Thirdly, ground water acts as a factor of vegetation cover. Regardless of climate, wet plants flourish everywhere on marshy land. In addition, fertility of soil controls vegetation cover; it is thus possible to predict the success or failure of crops on uncultivated land from the density of the weed growth.

Major land use types such as forests, grassland, agricultural land, settlements and so on are primarily classified in accordance with landscape or physiognomy—to use a botanical term—then subclassified by the index of intensity of land use.

For instance, according to the physiognomical features, forests are divided into tropical rain forests, bamboo forests, palm forests, evergreen broad-leaf forests, deciduous broad-leaf forests, coniferous forests, shrub forests and dwarf tree forests. These are then divided into dense and thin forests. Likewise, grasslands are divided into savanna, steppe and bare land; agricultural lands into ordinary fields, paddy fields and tree gardens; settlements into urban communities and rural settlements. All of these land use types are again subdivided by indicators of intensity of land use; forests are divided into afforested regions and renovated natural regions, according to the kinds of trees and forest managing methods; grasslands are classified according to the utilization methods of grass procurement, grazing land, periodical grazing land, or by the kinds of grasses; agricultural lands are classified according to the crop rotation system and the kinds of crops.

In this case, conceptual, abstract specifications, such as utilized land and unutilized land, are not used to good purpose. The reason is that, in all places, whatever meaning such terms have is connected with human life in its relation to space, wind, water and communication. In other words, any place on earth is at least indirectly utilized. A classification like utilized or unutilized land lacks a concrete basis, so that the division depends on the subjective view of the person who does the classifying. On the other hand, anyone can make objective classifications on the basis of landscape, appearance or physiognomy. Moreover, such classifications can be made only by means of air-photo interpretation and some minor field checking.

Land use type classifications based on landscape have another strong point. The appearance of an area will depend on the character of the targets, the degree of visibility, and trafficability, which are major indices in classifying cultural features in the general map. Consequently, the cultural features in the general map precisely correspond to the primary classifications of major land use types. The detailed specifications on the land use map can be obtained only by subclassifying the items of cultural features in the general map. Therefore, this manner of specification enables the production process of the land use map to keep pace with that of the general map, thus saving double labour and time.

For making specifications of the integrated land use map as explained above, air-photos on a scale of 1 : 10,000 are ideal, but those on scales of about 1 : 20,000 are also applicable. The scales of the photos vary owing to the type of aeroplane or camera used for photography, but these are the ones that have been frequently adopted for the production of topographical maps.

Land classification map

The land use map and the land classification map are, so to speak, reverse sides of the same thing. Land classification clarifies the quality of the land and aims at showing the potentiality of land use. In short, it is a land grade classification for land use.

The quality of the land is controlled not only by the present situation of land use, but also by such physical conditions as geographical location, climate, water supply (rivers, lakes, ponds, marshes and underground water), rocks, minerals, animals and vegetation cover. Although each of these physical conditions controls land use, it is the total of all of them and not any individual factor which affects the possibility of using a certain area of land. Even if one of these natural land factors acts favourably on land use, the possibility of the land use of each area, as a whole, is affected by other, unfavourable factors. Also, when a number of factors work favourably together, the usability of the land will increase cumulatively, while in the opposite case it will decrease. Therefore, the best method of classifying land is to investigate each factor of land conditions and then give an integrated evaluation of the land.

The fraction system adopted by the United States in the all-out planning for the Tennessee Valley Authority is typical of the land classification method recommended above, with all its representations put together into one form. The Oekotop method advocated by Carl Troll is also, in principle, a method of investigating each factor first and then obtaining an integrated result, although it lays emphasis on vegetation cover as an integrated result of land conditions.

These systems are the most dependable, although some problems of integration remain. However, immense expenditures of time, labour and technical knowledge are required in order to investigate every one of the land conditions

over a vast area. For the sake of expediting economic development, it is necessary to find methods that can be put into practice rapidly, even though the results may be incomplete as compared with the above systems.

The first of the suggested methods is to indicate vegetation cover. As is well known, the life form of a plant community is the result of its adaptability and its successful struggle against various kinds of land conditions, such as climate, landform, soil, underground water and the like. In consequence, a proper classification of a plant community gives an integrated picture of land conditions to some extent. In particular, the climatic conditions of an area where meteorological observation data over a long period are not available can be precisely deduced by an indication of the vegetation cover. However, natural vegetation cover remains nowadays only on extremely limited areas on the earth, and most vegetation covers are under constant human alteration. That is, in forests as well as agricultural land, natural growths are exceedingly few, and it is said that grassland has been remarkably extended by artificial means. Therefore, land classification by natural vegetation cover is applicable only to limited areas.

The second method is to proceed according to the law of minimum rate in plant ecology: that is, to investigate and integrate only those land conditions that are the common denominators in all cases. Among various land conditions, basic ones in most cases are climate, landform, and soil. These are, to some extent, closely related with other land conditions controlling land use. Consequently, a good result will be obtained from the method of investigating the three factors (climate, landform, and soil) and integrating the result. However, the variety of soil in different places is very great, and soil investigation requires much time and labour.

The third method of land classification is based on the two factors, landform classification and climate. When landform is classified by the geomorphological method, not only the inclination of the ground surface and the distribution pattern of level land, but also the state of soil, water supply conditions and even accessibility are, to some degree, reflected in the topography. For example, if mountainous land is divided into volcanic and non-volcanic, the soil in both regions is lithozol, but the piedmont of a volcano is covered with volcanic ejecta and the underground water level is located deep in the ground. On the other hand, the soil on the non-volcanic mountain foot is mature residual soil, and water supply conditions are far more favourable there than in the case of the piedmont of a volcano. The plateaux and terraces are covered with residual soil and their height is proportionate to the maturity of the soil. On the other hand, the soil of an alluvial plain is generally fertile alluvial soil, rich in organic material and colloid. The nature of the soil and the distribution of underground water are clearly varied according to landforms due to deposition, such as fan delta, natural levee and back marsh. Each of these landforms composes a unit region, at least in character of soil and underground water.

The vegetation cover of representative areas can be obtained by meteorological observation values and air-photo interpretation. The climate is made known in this way, and landform classification is then achieved by means of map reading and statistical analysis of the topographic map, air-photo interpretation and field check on the preceding results. Finally, the natural characteristics of each area can be grasped in an integrated manner.

The specifications of marshy land and peatbog land are important in land classification, and they are also the main items that should be delineated on the topographic map.

Large-scale maps

The 1 : 10,000-scale lake chart

The lake chart is treated here as an example of large-scale maps indispensable for integrated land development programmes.

Among various works related to integrated land development, the water supply project is a central one and the lake chart must be considered as an important map for this project. It is used for the development of fishing industries and transport on lakes and marshes, and also for water supply projects. Generally speaking, this type of map is drawn up on the basis of surveys concerning the following items, and the scales used are desirably from 1 : 5,000 to 1 : 10,000.

The items to be surveyed are the shoreline, depth contour, bottom materials, water weeds, water supply facilities around the coast, harbour transport facilities and the land use pattern on the coast. However, the lake chart for integrated land development programmes has to include the following factors as well.

For the purpose of regulating water supply and preventing flood disasters, the rise as well as the fall of the lake surface must be indicated on the lake chart. Consequently, both the portion of land that sinks below the water with the rising of the lake surface, at least as far as it can be anticipated, and the portion of land that lies constantly below the surface ought to be surveyed with the same accuracy. In order to maintain accuracy, it is essential to establish a large number of control points along the shoreline, to carry out levelling on the area above lake water level, to use the sounder with high accuracy to survey this portion in the water and also to ascertain the precise position of sounding points. The survey accuracy in Japan, for such a 1 : 10,000-scale lake chart, is prescribed as follows.

(1) *Observation stations*

The observation stations of the survey boat are set at the rate of one point every kilometre on an average. The accuracy should conform to that of the fourth-order triangulation or the third-order traverse survey.

(2) *Water level observation*

(*a*) Water level observation points are set along the shoreline, with one point at every four kilometres.

(*b*) The height of water gauge stations are surveyed by means of levelling with the accuracy of the second-order levelling.

(*c*) The maximum error of water level observation is about one centimetre.

(3) *Coast survey*

Metric details of the shoreline and of the plain about 500 metres from the shoreline are surveyed by ordinary photogrammetric methods.

(4) *Topographic survey of lake bottom*

(*a*) Scale—1 : 10,000

Irrespective of depth and distance from the shoreline, all the area surveyed is delineated on the scale of 1 : 10,000.

(*b*) Maximum error

0-35 metres	10 centimetres
35-100 metres	50 centimetres
100 metres or more	One per cent of the depth

(*c*) Sounding course intervals

Specific area	within 0.5 centimetre on the chart
Littoral zone	within 1.5 centimetres on the chart
Profound zone	within 2.5 centimetres on the chart

The intervals above are the minimum standards, so that the density may increase according to variation in the bottom landform and the importance of the area.

The direction and extent of the course is to be decided finally by a reconnaissance survey.

(*d*) Observation of sounding course

In order to plot the sounding course on the map, the position of the boat is precisely observed from observation stations on the land along the shore at the intervals shown below.

The intervals may be decided by three elements: (1) the required accuracy, (2) the time required to observe the boat with the theodolite and (3) the boat speed.

Specific area	within 0.5 centimetre on the chart
Littoral zone	within 1.5 centimetres on the chart
Profound zone	within 2.5 centimetres on the chart

Points along the sounding course are surveyed by means of the forward intersection method by using the theodolite. The allowable limit of the triangle of error is within the diameter of 0.4 millimetre of the inscribed circle.

(5) *Bottom material investigation*

The intervals of the points for bottom material investigation are :

Specific area	within 1 centimetre by 1 centimetre
Littoral zone	within 2 centimetres by 2 centimetres
Profound zone	within 5 centimetres by 5 centimetres

Density of the points is to be increased in regions where bottom landform and distribution of bottom materials are markedly varied, or in regions where two areas with different bottom material and landform meet.

(6) *Bottom plantation investigation*

The geographical distribution of bottom plantation is learned by analysing sounding records and is checked by samples collected. The bottom plantation is classified by its life forms and cover density and delineated on the chart.

In addition, lake charts covering both land and water, based on such surveys of high accuracy as the above-mentioned will be immediately incorporated into the topographical maps on medium scales.

Chorographic scale maps

(1 : 800,000-scale geographical maps)

As was the case at the first Regional Cartographic Conference for Asia and the Far East in 1955, the International Map of the World on the Millionth Scale has been internationally regarded as the proper base map for the chorographic scale map to be used for economic development. However, in Japan, which is characterized by a complexity of terrain features and by highly intensive land use, it is almost impossible to delineate the intricate distribution pattern of a subject phenomenon on the millionth-scale map. The scale of 1 : 800,000 may be suitable for Japanese chorographic maps.

Chorographic scale maps are prepared as basic material for establishing the principles and methods of investigating various phenomena associated with economic development of large areas, such as a whole country or state. It is desirable that the subject phenomena of special maps on the chorographic scale should include all important physical, biological and cultural items, and that their representation should give an extensive view of the national and local characteristics of the present state and development of the phenomena.

Therefore, in the first place, it is essential to publish these maps as a series on the same scale. When these maps are put together, it will be seen how the subject phenomena are interdisposed, how closely they are related with one another, how they interact and how they influence one another. In the second place, it is essential to show the distribution of the details of subject phenomena on a basic map, one on which rivers, contours, railroads, principal highways and administrative boundaries are drawn.

Difficulties in map expression are much greater in this case than in that of the simple base map, but nevertheless the following advantages are to be found.

For instance, when the distribution of orchards is considered with the help of contours on the map, it can easily be seen whether the orchard is located on a mountain slope which is good for little else, or on a plain which could also be used as a paddy field or an ordinary field—that is, whether or not the distribution of the orchard plays a negative role from the viewpoint of grain production. In the case of the paddy field, too, contours will clarify whether it is located on flood plains where water supply is plentiful or on an upland not favoured with water supply, a fact which helps to evaluate the paddy field. Also, the distribution of the population is shown in relation to the types of plains, cities and communication lines.

Furthermore, the representation on the base map will give a more pertinent clarification of the mutual regional relationship between subject phenomena on a series of maps than in the case of the simple base map.

By reading the map through such perspectives, it is possible to perceive the regional differences concerning every subject phenomenon in its relation to the physical features of the land, thus obtaining the regional characteristics of every area as a composite result. Such regional differences or characteristics are the first consideration in deciding upon the investigation methods or in drawing up plans related to economic development. The investigation methods as well as the various plans should be established in accordance with regional conditions. If regional characteristics are neglected, it will be impossible to make the methods and plans outlined above conform to reality.

The following are worth mentioning as main examples of special maps: geological map, climatological map, map of mines, irrigation map, land use map, land classification map, agricultural map, industrial map, population map, commercial map and transportation map. In Japan, a map series on the 1 : 800,000-scale, including such maps as the land use map, agricultural map, traffic map, electric power map, labour

population and urban employment map, demographic map and land classification map, has been prepared.

With regard to the land use and population maps, world-wide preparation of such maps is being promoted by the special committee of the International Geographical Union and a committee of the Economic Commission for Asia and the Far East is responsible for the compilation of the world-wide geological map.

Both committees play important roles in economic development of underdeveloped areas. In this connexion, it is desirable to establish a similar global committee to further the preparation of land classification maps.

THE ECONOMIC MAP (GENERAL LAND USE MAP) OF SWEDEN [1]

Technical paper by Fredy Jonasson,
Head of the Economic Map Division of the Geographical Survey Office of Sweden

History

Economic maps of Sweden have been drawn up since the middle of the nineteenth century. At first the scale was 1 : 50,000, and these maps were used principally for statistical purposes. A description was separately published, containing among other things the areas of arable land, hayfields, pastures and the like, and of villages. In the early part of the twentieth century, when Sweden began to maintain registers of real estate, it was requested that real estate divisions should be inserted in the map. For reasons of cost it was not intended to make a cadastral survey proper. The scale of the map was then increased to 1 : 20,000 so that most of the real estate limits could be inserted. The map then became usable for many other purposes—in the first place, as a basis for planning in the fields of agriculture and forestry.

It gradually became apparent that the scale of the map was too small to allow for a fairly complete insertion of the real estate divisions and for the use of the map for planning purposes. About 1930 photogrammetric methods were initiated for the production of the map, which permitted another change of the scale to 1 : 10,000 at a reasonable cost.

The Economic Map of Sweden on the Scale of 1 : 10,000 was the beginning of a modern series of maps, produced by the Geographical Survey Office; at present this series comprises the following maps:

(1) The Photo Map of Sweden on the Scale of 1 : 10,000. This map is not printed separately but is included in (2);

(2) The Economic Map (General land use map) of Sweden on the Scale of 1 : 10,000;

(3) The Military Map of Sweden on the Scale of 1 : 20,000;

(4) The Topographic Map of Sweden on the Scale of 1 : 50,000;

(5) The General Map of Sweden on the Scale of 1 : 250,000;

(6) The General Map of Sweden on the Scale of 1 : 1,000,000.

The preparation of these maps has been organized as a typical series production in which the individual operations, both as to method and sequence, have been selected to suit the technique of combined production in the most favourable manner. With respect to methods of compilation, projection system, division of sheets and the like, co-ordination has been achieved as far as possible, taking into account the differences in scale and purpose of the maps; one map is used as the basis for another map on a smaller scale.

Technical features of the economic map on the scale of 1 : 10,000

Projection : Hanoverian projection of Gauss.

Projection system : 2°, 5 W medial meridian (2°15'W from the old observatory of Stockholm 15° 48' 29"8 east of Greenwich). By using one sole projection system for the whole of Sweden the distortion in the presentation is comparatively large in some parts of the country. As the Economic Map is used extensively for calculations of areas of real estate, each sheet indicates clearly the actual size of the ground covered by the image surface.

Division of sheets : Square co-ordinate sheets with an image surface of 50 by 50 centimetres. (The sheet lines are parallel to the axes of the co-ordinate system.)

Printing : Offset in three colours.

Contents :

(1) In green: photographic picture of the ground;

(2) In black:

- (*a*) Administrative divisions;
- (*b*) Division of real estate;
- (*c*) Outlines of and symbols for arable land, gardens, building sites, parks, lakes, watercourses, shores, islands, roads, railways, power lines, buildings, national parks, protected objects and areas, ancient monuments, etc.;
- (*d*) Names;
- (*e*) Height data (one spot height per square kilometre);

(3) In yellow: cultivated ground.

Editions

(1) Black printing;

(2) Black and yellow printing;

(3) Complete Economic Map in three colours.

Production

(1) Aerial photography, as a rule, from 4,000 metres altitude with a wide-angle camera Zeiss RMK 20/30 by 30 (photographing scale 1 : 20,000) or from the same altitude with a wide-angle camera Wild RC5a 15.3/23 (photographing scale

[1] The original text of this paper, submitted by Sweden, appeared as document E/CONF.25/L.7.

1 : 26,000). This camera may also be used at 5,000 metres altitude (photographing scale 1 : 33,000). Overlapping in flying direction 60 per cent, laterally 40 per cent, but 70 per cent for more hilly ground.

(2) Aerotriangulation in the multiplex (scale 1 : 10,000) with the aid of from three to four geodetically determined points and approximatively ten height points per hundred square kilometres. Approximately one passpoint per square kilometre is plotted. The heights of a number of points are also determined in the multiplex.

(3) Rectification of the aerial photographs in the Zeiss SEG I to the scale of 1 : 10,000 with the aid of the passpoints. This rectification is not done rigorously to a horizontal plane of reference but to the best possible agreement with the passpoints.

(4) Assembling of the rectified images on to a photo map (controlled mosaic) on a base on which the passpoints have been plotted. The assembling is done by gluing and a wet method is used to permit the stretching and shrinking of the images in order to give the passpoints their correct position with respect to their co-ordinates, to obtain as correct as possible orthogonal positions for the details in areas between the passpoints and to eliminate as far as possible the discrepancies at the image joints.

(5) A red-toned photographic copy of the photo map is made on an unshrinkable base (correctostat).

(6) The estate boundaries are inserted on the red-toned copy with the aid of land-surveying maps, reduced to the scale of 1 : 10,000 on transparent material.

(7) The division of real estate is completed in the field and other details of the map are obtained by photo-interpretation. The map shows other features such as roads, railways, power lines, settlements, shore lines, ancient monuments, contours for arable land, and gardens. Furthermore, material for the place names on the map is collected by a special staff. Generally, one India ink drawing is made per day.

(8) After the field work, the final stage of preparation includes pasting on of printed names, figures and symbols, examination of the division of real estate, cartographic control and a final inspection; then the black drawing is ready for reproduction and no new drawing is necessary.

(9) Printing from four plates, one for the black drawing made by photolitho (the red-toned image of the terrain filtered away), one made lithographically for the yellow colour of the cultivated ground, two made by autolitho from the photo map.

Map production programme

The Economic Map on the Scale of 1 : 10,000 is planned for 60 per cent of the area of Sweden. It is estimated that all 12,000 sheets of the map will be ready by 1970. The production programme is set up by provinces and follows a fixed sequence. At present about 5,000 sheets are already printed and the production rate is 400 to 500 sheets per year.

The Photo Map is produced at the Photogrammetric Division, which has a staff of fifty; the office also undertakes other work.

The Economic Map based on the Photographic Map is produced by the Economic Map Division, which has a staff of 140. The field work represents a good 20 per cent of the economic mapping proper. For this purpose, some ninety men are engaged during four to five months every year, and one man completes one to three square kilometres per working day in the field. About 40 per cent of the work of the Economic Map has reference to the division of real estate, due to the fact that Sweden has no cadastral survey. Thus, the Economic Map is a beginning of a cadastral survey of Sweden, as yet without judicial standing.

Use of the economic map

As already implied, the primary object of the Economic Map, which shows the division of real estate and the economic utilization of the land, is to furnish basic cartographic data for planning in the field of agriculture and forestry. Furthermore, this map is used to effect the measures designed to promote the practical application of such planning. It is the authorities concerned with those measures—the land-surveying offices, agricultural boards, forestry boards and the like—which need the map in the first place, but individual farmers and timber companies also derive great benefit from it in their daily work and their general planning. It enables landowners to have a detailed survey of their estates and to determine easily their acreage.

In addition, the map is used by the administrative authorities and regional and general plan investigation committees in various projects. With regard to technical projects, mention may be made of road-building projects and electric power distribution projects.

Because of its large scale, its richness of detail and its ease of reading, the Economic Map has proved practical for school instruction in local geography.

Finally, another principal use of the map is to serve as a base for other map series, primarily for the Topographic Map of Sweden on the Scale of 1 : 50,000. Further consideration to this question is given below.

The Economic Map as a basic map for the Topographic Map

The new Topographic Map on the Scale of 1 : 50,000, which passed from proof stage to production stage in 1954, is intended to replace the older Topographic Map on the Scale of 1 : 100,000. In this undertaking the use of the Economic Map, as a basic map, has helped to produce a modern topographical map with rich contents and has offered the further advantage of starting from a map on a larger scale. Efforts have been made to adapt the contents and the classification of detailed features of the two maps so that the Economic Map can furnish to the greatest extent information for the Topographic Map, with due regard to the differences of the two maps in scale and purpose. The image surface of one sheet of the Topographic Map is the same as that of one sheet of the Economic Map, but one topographic sheet covers twenty-five sheets of the Economic Map.

The following comparison is given of the contents of the two maps; variations due to differences of scale are not mentioned.

Roads. In the Economic Map public roads are classified in three classes according to the width of the road, and private roads in three classes according to trafficability. In the Topographic Map the same classification was adopted but the

lowest class of private roads was eliminated. (Some of these roads are drawn with the symbol for a footpath.)

Railroads. For both maps, classification is made according to the gauge of track and whether or not the railroad is electrified.

Hydrography. Certain cross ditches drawn on the Economic Map are not included in the Topographic Map, but in the sea areas the latter contains marine depth contours taken from hydrographic charts.

Buildings. In the Economic Map distinction is made between dwelling-houses and other houses and the drawing is made to true size. Only close settlement in communities is schematized. In the Topographic Map certain other habitations in communities are also schematized and the buildings are classified according to the size of the farms and the dwelling-houses.

Power lines. In the Economic Map two classes of power lines are shown: high-voltage and low-voltage lines. The Topographic Map carries only the high-voltage lines.

Kinds of land. The Economic Map shows arable land, gardens, building sites and parks, while the photographic picture of the ground is intended to give sufficient information on other features. During the past few years marshy ground has also been inserted on the Economic Map so that it can be used directly for the preparation of the Topographic Map, which shows marshy ground and forests.

Height data. The Economic Map shows generally one spot height per square kilometre, while the Topographic Map shows contour lines obtained by photogrammetric plotting.

Administrative divisions. The administrative divisions are identical for the two maps. However, the limits of real estate shown on the Economic Map are not to be found on the Topographic Map.

* * *

In sum, it appears that, although most of the contents of the Topographic Map can be taken directly from the Economic Map, some technical selection is still necessary in certain cases. When the selection or completion involves field work, it would be more economical if this work were carried out together with the field work for the Economic Map. For the past few years information required for the topographical plotting has been collected during the field work for the Economic Map. Thus, the field work for the Topographic Map can be limited to a quick checking after the completion of the draft map and the insertion of additional details on the plotting of the Economic Map. To complete both the Topographic Draft Map and the Economic Map at the same time would naturally present an advantage in certain respects, but experience has proved that difficulties of a practical nature have been encountered.

REGIONAL GEOLOGICAL AND MINERAL MAPS FOR ASIA AND THE FAR EAST [1]

Note by the ECAFE secretariat

The Regional Conference on Mineral Resources Development, held under the sponsorship of the United Nations Economic Commission for Asia and the Far East (ECAFE) in Tokyo, Japan, in April 1953, considered that, although the current geological knowledge of the region was by no means adequate, certain valuable information was already available, and that this region could not be considered as a geologically unknown area. As Asia and the Far East was the only area in the world for which no regional geological map existed, the Conference felt that a beginning should be made for the preparation of such a map, which, when completed, would not only bring out geological structures of the region, but would also assist in the discovery of mineral-bearing areas. Further, the Conference recommended that close contact should be maintained with the International Geological Congress regarding the standard scale, colour schemes, symbols and other technical matters.[2]

It was evident that such a task could not be undertaken without the co-ordinated efforts of the appropriate authorities of countries of the region. The Commission, at its tenth session, approved, therefore, a recommendation of the then Committee on Industry and Trade that the senior geologists of countries of the region should meet, under the auspices of ECAFE, to discuss problems involved in the preparation of the map.

Three meetings of the Working Party of Senior Geologists have since been held.[3] The working party reached agreement on technical specifications governing the preparation of the map. In addition, it has undertaken the preparation of regional mineral maps and studies for preparing a regional tectonic map.[4]

Regional geological map for Asia and the Far East

The working party nominated the Director of the Geological Survey of India as the co-ordinator for the preparation of the regional geological map. The Governments of the region extended full co-operation by furnishing their country geological maps, by conducting joint field surveys along border areas in order to obtain adequate correlation of geological data and by making contributions towards the cost of the publication of the map.

To fulfil the immediate need for country maps, several countries had to speed up the completion of their geological maps in cases where such maps were not available. For instance, in Afghanistan, a Geological Survey Department

[1] The original text of this paper, submitted by the secretariat of the Economic Commission for Asia and the Far East, appeared as document E/CONF.25/L.23.

[2] United Nations, *Development of Mineral Resources in Asia and the Far East* (Sales No.: 53.II.F.5), part one.

[3] The first session of the working party was held in Bangkok, Thailand, in November 1954, the second session in Tokyo, Japan, in June 1956, and the third session in Calcutta, India, in November 1957.

[4] *See* documents E/CN.11/I and NR/4.

was established shortly after the first meeting of the working party with the primary object of completing the first geological map of the country.

Several joint surveys are in the course of implementation. The Governments of the Federation of Malaya and Thailand have conducted a joint geological survey along border areas and the work is being continued. The joint survey of the border areas between Indonesia and British Borneo is expected to commence shortly, and joint studies in regard to correlation of sedimentary rocks northward from Malaya through Thailand into Burma are being considered.

The preparation of the map being a co-operative effort of the countries of the region, the working party decided that they should contribute towards the expenses for the map and that the contributions should be sent to the President of the Commission for the Geological Map of the World, which was established by the International Geological Congress specifically for this purpose. Over £8,000 have already been received from the Governments of Burma, the British Territories in Borneo, the Republic of China, India, Japan, the Federation of Malaya, Pakistan and Thailand.

The map is now ready for printing. Its technical specifications are outlined below.

Map scale. 1 : 5,000,000.

Map projection. Lambert conical projection.

Stratigraphic scale. Stratigraphic divisions shown on the map follow generally the standard scale adopted by the International Geological Congress. Several alterations have been made when subdivisions do not coincide with the standard scale. Precise age determination is given for rocks and minerals from different stratigraphic units, particularly in the pre-Cambrian formations. Distinction is made between intrusive and effusive rocks and, wherever possible, between marine formations and those of other facies. In addition lavas and pyroclastics of active volcanoes [5] are distinguished from other Quarternary effusives in the map. When the rocks of active volcanoes cannot be shown due to their limited area distribution, locations of active volcanoes are indicated by a special symbol.

Index map. An index map showing the degree of reliability or precision of the information obtained is inserted on each of the nine sheets of the regional geological map.

Topographic features. Railways, main highways, cities and major towns, main rivers, navigable canals and lakes are shown on the map together with bathymetric contours and marine contours.

Blank areas. Areas where no geological information is available will be shown in blank—thus drawing attention to the need for early action by the countries concerned.

Printed copies of the map are expected to be distributed early in 1959.

Regional mineral maps for Asia and the Far East

Three types of mineral maps on the same scale as that of the regional geological map are to be prepared.

(1) Regional maps showing the distribution of known mineral deposits.

(2) Regional " metallogenetic " maps—maps showing mineralization epochs and provinces.

(3) Regional " prognosis " maps—provisional maps showing potential mineral areas.

At present attention is being given to the preparation of the first type of map. The working party nominated the Director of the Geological Survey of India as co-ordinator and the Director of the Geological Survey of Japan as joint co-ordinator of this work. Countries of the region have been requested to prepare and forward to the ECAFE secretariat country mineral maps on a scale of 1 : 2,000,000 as base material for compilation. The decision with regard to the number of minerals to be selected and the amount of information—such as names of mines, types of deposits, production and reserves, and stage of development—to be included in the country maps is left to the country concerned when preparing them. However, international mineral symbols, as adopted by the Commission for the Geological Map of the World, will be used in drafting the mineral distribution maps of the region. The draft maps will be submitted to the next session of the Working Party of Senior Geologists scheduled to meet early in 1960.

Regional tectonic map for Asia and the Far East

Considering that many countries of the region have only a small number of competent technicians and limited technical facilities with which to meet the requirements for various maps in the field, the working party decided to postpone the preparation of a regional tectonic map until the work on the regional mineral maps is well advanced. However, it recommended that when resources permit these countries should start preparatory work on the tectonic maps of their respective territories on a scale of 1 : 500,000 to 1 : 2,000,000 and, in due time, transmit the final material to the ECAFE secretariat.

[5] Active volcano means a volcano which is known to have been in eruption within historical times or which displays solfataric activity at present.

INTERNATIONAL CO-OPERATION IN PREPARATION AND PUBLICATION OF TOPICAL MAPS [1]

Background paper submitted by Japan

With the demand for greater efficiency and certainty in projects of economic development, the need for adequate topical maps at appropriate scales in planning and technical work is essential and increasing. The list of topical maps has been extended to include more and more subjects, each of which becomes an individual mapping activity with its own procedures and techniques. For instance, land use maps

[1] The original text of this paper appeared as document E/CONF. 25/L.2.

which are the basic special maps for increasing food production and for other agricultural development, land classification maps which are essential for the preparation of land use maps and for land evaluation purposes, hydrographical charts which provide invaluable information for water resources development, and geological maps which are indispensable for investigation and development of mineral deposits are all of prime importance to countries of this region. Although some technical agreement has been reached with regard to the preparation of geological maps, the practice followed in the case of other topical maps varies greatly with each country.

Concerning land use maps, it is true that the Committee of the World Land Use Survey [2] has achieved some results in its attempt to standardize the legend and related material, but some of the legends thus far adopted cannot be considered as suitable for this region where, in many areas, farming is mostly practised on paddy-rice fields and where, in other areas, so-called " intensive farming " also prevails. As for land classification maps, no international system has been adopted and each country employs a system of its own. These conditions are approximately the same for the various other kinds of special maps.

The United Nations Regional Cartographic Conference, which brings together responsible officials and experts in the field from many countries, will afford a golden opportunity not only for exchanging knowledge and technique and promoting development in special mapping through mutual encouragement and assistance, but also for studying common methods of investigation and presentation, including standardization of the conventional signs and symbols.

The standardization of the signs and symbols will facilitate mutual assistance between countries with regard to technical methods and specialized personnel. Common procedures and specifications will result in greater efficiency of production in terms of time, cost and quality of work. In view of the fact that topical maps are newly developed techniques required by intensive economic development, standardization in this field could be even more effective than in topographical mapping.

[2] Of the International Geographical Union.

AGENDA ITEM 13

International Map of the World on the Millionth Scale (IMW)

STATUS OF WORK ON THE MILLIONTH SCALE MAP SERIES IN CHINA [1]

Background paper by Chi-Chi Chow,
Director, Chinese Society of Survey Engineering

Past publications programme

The provisional edition of eighty-five maps of China, 1 : 1,000,000, was published in 1947, on the following bases.

Projection. All on the modified polyconic projection.

Area of each sheet. Four degrees in latitude by six degrees in longitude.

Type of map. Hypsography shown by contours; printed mostly in black and white, partly in polychrome; simple notes and legends shown in the margin.

Source material used for compilation

Horizontal control. The astronomical and triangulation points established by the Chinese General Land Survey Bureau and other mapping agencies were used as the basic control. In the areas where no basic control was available, the evaluated values of the minor control established by various geographers were provisionally accepted.

Vertical control. The vertical control shown on the map was based on the mean sea level. Contour lines were compiled mainly from the published topographic maps on scales 1 : 50,000 and 1 : 100,000. In the areas where no such large-scale topographic maps were available, the contour lines were compiled from smaller hydrographic charts.

Basic topographic source material. The 1 : 50,000 and 1 : 100,000 topographic maps published by the land survey bureaux of various provinces were used as the basic material for the compilation. In the areas where no topographic maps were available at these scales, smaller-scale maps were used. Administration boundaries, communication lines, coastlines, islets and airways were compiled from the source material furnished by various Ministries—Interior, Communications, Foreign Affairs and Navy Hydrographic Survey Bureau.

In order to meet the standard of the International Map of the World on the Millionth Scale, a programme was set up in 1955 to revise the provisional edition of the 1 : 1,000,000 maps of China. The items of revision included not only topographic information, but also the specifications and symbols. The revised map was printed in polychrome; hypsography is shown by layered tints. Unfortunately, this revision was discontinued shortly after publishing the first sheet of Shanghai, NG-51, owing to inadequate source material.

Current programme for recompiling the maps of China on the Millionth Scale

A new programme has been set up recently to recompile the eighty-five maps of China, 1 : 1,000,000. The work is expected to be completed in 1963, and will be based on the following.

Projection. Modified polyconic projection of IMW.

Specifications. The specifications of the International Map of the World on the Millionth Scale will be adopted, except for a few points which will be modified to suit the conditions of China. The new sheet of NG-50, Fuchow, will be presented to this Conference.

Horizontal control

Astronomical data. Seventy-three first-order and 590 second-order astronomical points now available in various parts of China.

Triangulation data. The first-order and second-order triangulation data available in various provinces of China, except Suiyuan, Ningsia, Shansi, Chahar and Tibet. Reliable third-order triangulation data in various provinces will also also be used.

Vertical control. The existing vertical control data have been reduced to the mean sea level of the tidal station at Kammen, Chekiang Province.

Basic topographic source material. The 1 : 50,000 and 1 : 100,000 topographic maps and aerial photographs. For the areas where no such scale maps are available, the 1 : 250,000 or smaller-scale maps will be used. Communication lines, administrative boundaries, coastlines, hydrographic data and the like will be compiled from other available source material.

[1] The original text of this paper, submitted by China, appeared as document E/CONF.25/L.29.

PROMOTION OF THE PUBLICATION OF THE INTERNATIONAL MAP OF THE WORLD ON THE MILLIONTH SCALE [1]

Background paper submitted by Japan

Nowadays, the International Map of the World on the Millionth Scale (IMW), which is used as a basic map for the study of integrated projects in this region, constitutes not only a requisite for the development of economic enterprises but also a tool for the promotion of mutual understanding and cultural exchange among the nations. The increasing need for IMW sheets by governmental agencies, scientific societies and private organizations has required the speeding up of the preparation and publication of the Map so that an adequate number of copies can be made available to all those calling for this Map for their work.

It would appear that furthering the publication of the Map depends upon the solution of some principal problems such as the revision of the existing specifications governing the production of the Map and the relation of this Map to the World Aeronautical Chart 1 : 1,000,000. In so far as this region is concerned, a great number of IMW sheets have already been published though some of them are of early date. The remaining works include the preparation of a limited number of sheets to complete the coverage of the region and the revision of some of the existing sheets to bring them up to date. It is highly desirable that the work be carried out as soon as possible. Another issue of particular importance is the distribution of the published sheets. Simplified procedures are necessary to enable all the users to obtain sufficient copies promptly and without difficulty.

The adoption of proposals for revision of the specifications will probably be decided by the Economic and Social Council either directly or through a special technical conference on the subject. In either event, it would be helpful if the countries of this region concerned with this question could exchange their views on the various issues and work out co-ordinated views and action, taking into account the proposals submitted by cartographic agencies to the United Nations. Such co-ordinated views and action would facilitate the work of the United Nations in this particular field.

With respect to the major items of the specifications, Japan is of the opinion that no drastic change should be made, while the detail features could be left to the discretion of the respective countries publishing the sheets so that they might be allowed to adopt suitable substitutes to meet their particular topographical requirements as well as other special conditions.

[1] The original text of this paper appeared as document E/CONF. 25/L.1.

REPORT ON THE PROGRESS MADE CONCERNING AMENDMENTS TO EXISTING IMW SPECIFICATIONS [1]

Note by the Secretariat

In order to provide a factual base for drafting amendments to the existing specifications which govern the preparation and publication of the IMW sheets, a survey of the published sheets was made with regard to their conformity with the specifications. Furthermore, a study was made on the application of the IMW sheet reference system to other map series. The results of these two studies were outlined in the annual report on the International Map of the World on the Millionth Scale for the year 1957.[2]

On 15 October 1958, the Secretary-General of the United Nations submitted to all Governments of countries adhering to the International Map of the World on the Millionth Scale, for their comments, a paper entitled " Draft Proposals for Amendments to the Existing Specifications Governing the Preparation and Publication of the Sheets of the International Map of the World on the Millionth Scale ". The full text is reproduced below.

Draft Proposals for Amendments to the Existing Specifications Governing the Preparation and Publication of the Sheets of the International Map of the World on the Millionth Scale

The present paper is prepared in accordance with paragraph 4 (b) of resolution 600 (XXI) of the Economic and Social Council, which reads as follows:

> (*b*) *To prepare*, on the basis of proposals already received, draft amendments to the existing specifications of the International Map of the World on the Millionth Scale designed to allow the greatest possible flexibility, bearing in mind the need to maintain both the World Aeronautical Chart series of the International Civil Aviation Organization and the International Map, to submit the draft amendments to Governments of Member States concerned for their comments, and to report to the Council at a subsequent session; "

[1] The original text of this paper, entitled " Report on the progress made with respect to paragraph 4 (b) of resolution 600 (XXI), adopted by the Economic and Social Council on 2 May 1956, concerning amendments to existing IMW specifications, keeping in mind the need for maintaining both the ICAO World Aeronautical Chart Series and the IMW Series " appeared as document E/CONF. 25/L.22.

[2] See *International Map of the World on the Millionth Scale (1957)* (Sales No : 58.I.11), pages 2 to 9.

This resolution was adopted after consideration of the Secretary-General's report [3] on consultations with responsible national cartographic agencies regarding the revision of the specifications [4] for the International Map of the World on the Millionth Scale (IMW).

In the preparation of this document, account has been taken of the following: (*a*) the relevant resolutions adopted by the first United Nations Regional Cartographic Conference for Asia and the Far East, the Seventh General Assembly of the International Geographical Union, the Sixth Pan-American Consultation on Cartography, and the Specialists Meeting on Maps and Surveys of the Scientific Council for Africa South of the Sahara; (*b*) the views expressed by national agencies, and (*c*) two studies made by the Secretariat of the United Nations—one on conformity of the published sheets [5] with IMW specifications, and the other on the application of the IMW sheet reference system to other map series.[6]

The primary purpose of the revision is to accelerate the publication of the IMW sheets, and this cannot be achieved without an international agreement on important issues involved. Agreement has already been reached with regard to the need for flexibility in the application of the specifications, so that "no change in the existing sheets will be required and no country would be prevented from producing this series of maps due to specifications they could not meet".[7]

A major part of the land area of the world is already covered by IMW sheets which conform largely to existing specifications. Taking into consideration the sheets now in production, this coverage will be much broader next year. Several countries have reported, however, that in view of the current lack of enough technical facilities to carry out urgent cartographic work required for economic development, they are unable to produce both IMW sheets and ICAO World Aeronautical Charts following different compilation procedures. The major difficulty is the difference in projections and sheet lines. Two opposite points of view have been expressed: (1) that IMW projection and sheet lines are mandatory, and (2) that projection and sheet lines should be shifted from the IMW system to the ICAO WAC system.

Until the time when a definite choice can be made, a tentative intermediary solution may be envisaged to deal with the present situation.

Map projection

At present three projections are being used for international mapping projects on the scale 1 : 1,000,000: (*a*) the Modified Polyconic Projection (by IMW); (*b*) the Lambert Conformal Conic Projection (by WAC); and (*c*) the Universal Transverse Mercator Projection (by IUGG). In addition, the Stereographic Polar Projection is being envisaged for the proposed international map of Antarctica. As the IMW sheets are designed for assembling only a few sheets on a flat base, the comparison of the various projections from this point of view should be made on the basis of individual sheets. The differences between the above-mentioned projections are for practical purposes very small and, in some cases, hardly noticeable; therefore, the utilization of a comparable projection in place of the Modified Polyconic projection for IMW sheets would not result in significant discrepancies among the sheets and would enable several countries to publish their topographical sheets on the scale 1 : 1,000,000 immediately.

Sheet lines

With respect to sheet lines, both the IMW and the WAC series use the four degree bands starting from the equator. The differences lie only in the longitudinal limits—in some cases the WAC sheet is larger than the IMW sheet. In view of the fact that an extension of coverage has already been used in several published IMW sheets, a deviation from the standard IMW sheet lines which would enable the agencies concerned to speed up the production of IMW sheets by using the WAC plates could be considered as an extension of existing practice. Nevertheless, in order to maintain the general appearance of the International Map, the IMW sheet reference should be continued.

If these two tentative measures are agreed upon, the inclusion of the following paragraph in the existing specifications is proposed:

Paragraph 15 : parallel edition

In order to meet the present urgent need for topographic maps at the scale 1 : 1,000,000, a sheet plotted on a projection comparable to the Modified Polyconic Projection or showing slightly different coverage can be issued as a *parallel edition* of the IMW sheets.

Detailed cartographic features

No divergent opinions were expressed on the principle of bringing detailed technical features of the International Map up to date to meet modern methods and present-day requirements. A redrafting of specifications regarding numerous detailed items—including simplified symbols and lettering—would have to meet the desiderata of all agencies concerned. If the preparation of a revised style sheet is requested, the interested agencies will have to submit to the Secretariat precise proposals to that effect.

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[3] *Official Records of the Economic and Social Council, Twenty-first Session*, Annexes, agenda item 6, document E/2823.

[4] For the full text of the specifications, see *World Cartography*, vol IV (Sales No.: 56.I.9), pages 33 to 57.

[5] See *International Map of the World on the Millionth Scale (1957)*, pages 2 to 8.

[6] *Ibid.*, pages 8 to 9.

[7] See *Official Records of the Economic and Social Council, Twenty-first Session*, Annexes, agenda item 6, page 13.

INTERNATIONAL STANDARDIZATION OF SHEET LINES AND PROJECTIONS FOR THE LAND AND AIR SERIES OF 1 : 1 MILLIONTH SCALE [1]

Background paper submitted by the United Kingdom

There are at the present time two separate international agreements for 1 : 1,000,000 scale cover of the world—the International Map of the World on the Millionth Scale (IMW) and the ICAO World Aeronautical Chart 1 : 1,000,000 (WAC).

It is submitted that, whereas in well developed areas such as Europe it is necessary to have two different specifications, in desert areas such as Arabia it should be possible to prepare a single specification which would go a long way to meeting the dual requirement. Furthermore, even in well developed areas, where it is possible to justify having two different specifications, there is no fundamental reason, other than historical, why common sheet lines and a common projection system should not be adopted.

It is noteworthy that a number of nations including the United Kingdom are unable to devote sufficient cartographic resources to maintain the two separate series in the form called for by present specifications; in the case of the United Kingdom, national priorities are such that the ICAO chart is being maintained, whereas the IMW map is being left unrevised. It is probable that this is also the position for a number of other nations.

The United Kingdom, recognizing that there is a dual requirement for land and air series at the 1 : 1,000,000 scale, and realizing that in practice it will often not be possible to maintain both series unless the cartographic effort required is somehow reduced, recommends that the specifications should be brought more closely into line by the adoption of common sheet lines and a common projection for the two series. This would have the effect of reducing the cartographic effort required to maintain both series.

With regard to the projection, the difference between the modified polyconic projection prescribed for the IMW and the Lambert conformal conic projection prescribed for the ICAO WAC is scarcely plottable at the 1 : 1,000,000 scale. Hence there appears to be no fundamental reason why any nation should object to the adoption of the Lambert conformal conic projection for both series.

With regard to the sheet lines, there is already agreement in the northern and southern limits of the sheets which are at every four degrees of latitude in both series. The ICAO WAC sheets are larger than the IMW sheets, and their incidence on the land masses is on the whole considered to be preferable to that of the IMW sheets. For these reasons, the United Kingdom would recommend the adoption of the ICAO WAC sheet lines as a basis for discussion of a common sheet line system for both series. There are other factors to be considered, such as the differences that have grown up between the sheet lines in use by civil aviation and military aviation.

In the view of the United Kingdom, the ultimate aim should be to have one single sheet line system for mapping and charting at the 1 : 1,000,000 scale for all purposes—land, air, civil, military and so on.

[1] The original text of this paper appeared as document E/CONF. 25/L.8.

REPORT ON PROGRESS MADE IN DRAFTING THE GENERAL FRAMEWORK OF A PROGRAMME LOOKING TOWARDS UNIFORMITY IN THE WRITING OF GEOGRAPHIC NAMES [1]

Note by the Secretariat

1. On 26 June 1958 the Secretary-General of the United Nations submitted to all Governments, Members of the United Nations or members of the specialized agencies, for their comments, a paper entitled: " Draft Programme for Achieving International Uniformity in the Writing of Geographic Names ". This paper, with its Annex, is reproduced immediately below; the response of Governments to the Secretary-General's request for comments is dealt with in paragraphs 2 and 3.

Draft Programme for Achieving International Uniformity in the Writing of Geographic Names

Introduction

The present paper is prepared in pursuance of paragraph 4 (*a*) of resolution 600 (XXI) of the Economic and Social Council which reads as follows:

" *The Economic and Social Council,*

" . . . .

" 4. *Requests* the Secretary-General:

" (*a*) to draft, in co-operation with interested international organizations and such experts as he may wish to consult within the limits of budgetary availability, the general framework of a programme looking towards maximum international uniformity in the writing of geographical names, to submit it to Governments of States Members of the United Nations or members of the specialized agencies for their comments, and to report to the Council at a subsequent session; ".

In the preparation of this document, the debates in the Council have been taken into account, together with the Report of the Secretary-General on International Co-operation in Cartography of 2 February 1956 (E/2823) which contained views expressed by Governments and the deliberations of regional inter-governmental cartographic conferences re-

[1] The original text of this paper appeared as document E/CONF. 25/L.10 and Add.1 and 2.

garding this subject. Consultations were held with several experts in this field. A report by one of these experts is reproduced, for purposes of information, as an annex.

International uniform standard methods of writing geographic names

The adoption of a uniform standard method of writing geographic names involves two basic questions, namely, the standardization in one form of a geographic name by the country concerned and the adoption of standard methods of transliteration or transcription of the accepted form into other languages. Although the first question is a domestic matter and the concern of the Government itself, appropriate international co-operation in this field could promote common methods and procedures and, subsequently, might facilitate the development of an international uniform method of transliteration or transcription. As to the second question, obviously any issue would involve more than one language group.

(*a*) *Standardization at national level*

To achieve standardization of geographic names at the national level, several Governments have set up special bodies to study the problem, to co-ordinate national effort and to make decisions in specific cases. These bodies are also concerned with transliteration of foreign names into their own language for official publications. Moreover, the International Congress of Onomastic Sciences studied the question from the linguistic point of view. A systematic exchange between countries of technical information on the subject—special studies, technical decisions, gazetteers and the like—should prove helpful. Such an exchange could be arranged either through bilateral arrangements between Governments or through a central clearing centre

(*b*) *Adoption of general principles for international standard methods*

With regard to the adoption of international uniform standard methods of transliteration or transcription of geographic names, account must be taken of the work already carried out in this field by national agencies and international organizations in connexion with their geographical studies and cartographic publications. To speed up international uniformity two fundamental problems must be solved at an early stage, and the decisions taken should serve as guiding principles in formulating rules for transliteration or transcription when dealing individually with different languages.

One of these problems is the selection of the element in any particular geographic name by which it can be converted into various systems of writing. This selection may be determined by the sound of the name, its written form, or its meaning. The other problem is the acceptance for international use of a system of writing. Such a system could be based on an existing or new alphabet, or on phonetic symbols.

The above two problems are closely related and should be studied together, taking into account not only present but also future needs. It would be useful if Governments, when commenting on the present draft programme, could make known their views on them, both from a national and an international point of view. The replies received may indicate that the possibility exists of international agreement being reached on these two questions and that fruitful co-operation may be expected in the future in dealing with detailed issues. They may, on the other hand, reveal that further preliminary studies are required before such possibility can be contemplated. In any event, the information provided by these replies would facilitate the work of the Economic and Social Council in considering the proposal made by the first United Nations Regional Cartographic Conference for Asia and the Far East and the Seventh Panamerican Consultation on Cartography for convening an international conference on geographic names.

(c) *Preparation of international transliteration methods*

The writing systems now in use can be divided generally into two groups: alphabetical and non-alphabetical. In alphabetical writing, the Roman alphabet is used in most European languages. Considerable work has already been done in the romanization of certain non-alphabetical systems.

In view of the numerous systems of writing and their complexities, which no one expert could be expected to master, it would not seem practicable to attempt a solution of the detailed problems of a universal system for the writing of geographic names until a study had first been made of the results already achieved in this regard in the different languages. Small working committees might be set up of representatives of countries using the same system of writing to study common problems and to develop guiding principles for a systematic conversion of the written geographic names. Experts in the other systems of writing and languages involved could be invited to participate in the work. The work of such committees might also deal with detailed questions, including draft rules for international adoption.

It would not be necessary to organize simultaneously committees to deal with all systems of writing. At the first stage, efforts could be concentrated on those systems which are of most general international concern. However, a sufficient number of languages must be studied to ensure that adequate consideration is given to the problems involved. When a sufficient number of these committees have completed their work, it may be found useful to arrange for a small group to review the various experts' reports and make recommendations to the Economic and Social Council.

(d) *International co-ordination and liaison*

International uniformity in writing geographic names, which has to be achieved gradually in accordance with world progress and needs, is obviously a long-range undertaking. Lack of international co-operation in this field would tend to result not only in duplication of work in individual countries, but also in uncoordinated development which would make international uniformity more and more difficult of attainment. The possibility might therefore be considered of arranging for information on work undertaken and achieved to be received at and to be made available from some central point.

ANNEX

Suggested Programme for International Standardization of Geographic Names

by Dr. Meredith F. Burrill,
Executive Secretary of the United States Board on Geographic Names

Many of the Member States of the United Nations have come to agree that international standardization of the writing of geographic

names, or at least a greater degree than now obtained, is highly desirable. Several countries have responded to the Economic and Social Council request for ideas on such international standardization with interesting and helpful replies. Two principal methods of obtaining standardization have been proposed: (1) standardization on the forms used by the nation of sovereignty and (2) the use of an international alphabet for all geographic names.

Several international alphabets have been devised in the past. One, the IPA (International Phonetic Alphabet), has rendered good service for many years in linguistic and pedagogic circles. Evaluation of the possible role of an international alphabet in geographic name standardization requires a clear distinction between standardized writing and standardized pronunciation. Uniform writing is here the objective; such aid to pronunciation as is feasible and compatible with uniform writing is desirable but over-emphasis on pronunciation should not be allowed either to defeat or obscure the objective.

Fully uniform pronunciation is impossible. Every language has its own unique sound system, never shared with any other language completely if at all. Speakers of one language cannot react to and produce at will all the sound features of another language without intensive linguistic training. Especially will speakers of languages with few sound distinctions (phonemes) be at a loss to reproduce sounds they have never heard before from languages with a greater number of phonemes. Mere symbols will not help one to pronounce strange sounds. Furthermore, although an " international alphabet" is usually thought of as representing with a different symbol every different significant sound in all the principal languages of the world, one that fully covered only the principal languages would be so enormously complicated and cumbersome as to defeat its purpose. It is in point that almost all writing systems employ conventions, since few alphabets represent, in a completely systematic way, the sounds of even the language or languages which they are regularly used to write.

Replacement of writing systems in present general use by an international alphabet is most unlikely. Judging from resistance in various countries in modern times to proposed orthographic reforms, proposals to introduce completely new alphabetic symbols (in contradistinction to modifications of present symbols) for supplementary special use in writing geographic names would also be unlikely to receive ready acceptance.

Written names are generally more widely recognizable within a writing system than are spoken names. Dialectical variations in pronunciation do not negate visual recognition by literate people. Written forms of unfamiliar names that invoke pronunciations that do not approximate local pronunciations closely are still acceptable; written forms containing sequences of symbols that appear unpronounceable will be acceptable if the user can learn how to pronounce them in some fashion or rarely has to say them at all.

A practical programme looking towards international standardization must take full account of the linguistic and cultural limits set by present-day conditions. In the last few years it has been generally recognized that the practical impossibility of uniformity in spoken rendition of geographic names does not preclude a high degree of uniformity in writing them. People all over the world now have occasion to refer to, identify, or even go to places that their ancestors either never heard of or considered so far away and inaccessible as to be of no concern. It has become increasingly evident that the old gradual process of bending names from other sound systems into written forms compatible with the system of the receiver language, producing what we call " conventional " names, was consistent with the ideas, attitudes and limited geographic needs of earlier times. That process is inconsistent with today's concepts of international co-operation and of respect for people who speak other languages, and inconsistent with the enormously greater number of geographic names with which people must deal.

It has also become apparent in recent years that the toponymic problems of one country commonly recur in other countries. This suggests that each country has something to gain from comparison of such problems and of the efficacy of efforts to solve them, since the experience of each country is relevant to comparable problems in other countries. Such experience means individual efforts as well as collective efforts by groups or governments. A sharing of this experience and comparison of problems would be highly profitable.

In light of the facts and conditions mentioned above, the following steps appear practical, feasible and internationally acceptable. They would bring about a much higher degree of international standardization than exists today.

I. It is proposed that an international conference be held under appropriate United Nations auspices on the problems of the international standardization of geographic names and that this conference refer back its findings to the Economic and Social Council for use in further planning and for reference to the regional conferences mentioned below.

II. It is proposed that the regional conferences be based on the following writing-systems:

1. Roman alphabet
2. Cyrillic alphabet
3. Greek alphabet
4. Hebrew alphabet
5. Amharic alphabet
6. Arabic alphabet
7. Indic alphabet
8. Tibetan alphabet
9. Burmese alphabet
10. Siamese (Thai) alphabet
11. Chinese alphabet
12. Japanese alphabet
13. Korean alphabet

Several of the writing systems are used to write more than one language. The Roman, Cyrillic, Arabic and Siamese alphabets are used with extra symbols in addition to the basic ones in some languages, and with different sound values for at least some symbols within an alphabet group. However, in the main, the principles operating within an alphabet group are the same and are the basis of classification. Although the Indic alphabet group actually includes many alphabets, all are ultimately based on the Sanscrit alphabet and operate on the same principle.

It is further proposed that regional working group conferences be set up under appropriate United Nations auspices, at which the nations in each writing system group involving more than one country would discuss the place name problems of the group. It would probably be helpful for observers from other writing systems to attend such working conferences. It sometimes happens that transcription or transliteration draws attention in a useful way to inadequacies in the donor languages for the writing of geographic names. Such attendance would also serve as a reminder that each working conference is part of a larger plan. It is suggested that, in the interest of international standardization, each nation in each writing system group should establish the names and spellings of its own place names and make them available to other nations, particularly to other nations within its writing system group. If each nation in the group would accept the place name spellings of the other nations in the group, standardization within one writing system would automatically result. Within each writing system each nation would have to decide for itself, or in concert with other nations using the same language, whether to retain the diacritical marks and modified letters used in writing other languages of the group but not by themselves, or to " transliterate " such symbols; for example, Roman alphabet nations would decide either to reproduce Icelandic ð and þ or to transliterate them, for instance, by *dh* and *th* respectively.

Each nation would have to decide which conventional spellings or names for places outside its own jurisdiction it wishes to retain in addition to the proper spelling in the area where the place is. Each nation would also have to decide many problems relating to place names within its jurisdiction, including its possessions, such as which language or languages are official in the country or possession as a whole or in specified parts, and how to treat names from minority languages within its boundaries.

Users of each writing system should transcribe or transliterate, whichever is linguistically appropriate, the place names of other writing systems. Agreements on transcription and transliteration systems between the nation of origin and the nations into whose writing system names are taken is highly desirable and to be encouraged in the interest of international co-operation, but the needs of the receiver nations should be regarded as paramount. Here again the nations in each writing system should at least consider transcribing or transliterating uniformly the names from other writing systems.

Changes in the orthography of a language, on either a national or an international basis, should be respected and be reflected in international usage wherever feasible. It is recommended that orthographic reforms be made in the direction of improvement in the relationship between sound and symbol.

It is recommended that the United Nations make linguistic geographic and other technical toponymic advice available, as desired, to the personnel of regional conferences mentioned above.

Geographic names are known to be subject to change, but it would be possible to make the nomenclature of every area of the world more stable and to achieve a higher degree of standardization if the groundwork in the compilation of place names by each nation is carefully done. It is therefore recommended that advice, such as that described in the preceding paragraph, be made available by the United Nations to nations that request it.

The proposed steps would not accomplish international standardization of geographic names overnight, but each would lead in that direction and the initial steps are all feasible.

2. Several Governments have made known their comments on the above paper, while others have informed the Secretary-General that the matter is being studied by the appropriate organs. The texts of the substantive comments received so far are given below in the order in which they were received.

3. *Excerpts from communications received*

(*a*) **Ireland**

" The terms of resolution 600 (XXI) of the Economic and Social Council have been referred to the Irish Ordnance Survey Office which has replied that it has no observations to offer. It states that in general it endeavours to follow as far as possible such decisions as may be reached in matters of this kind and in this particular regard its policy is adequately reflected by the methods followed in national maps as published from time to time. The matter of transliteration of names from Gaelic to the Roman alphabet raises no special difficulties in this connexion as cartographical procedure is the same as the literary and the latter already in this respect is a matter of common occurrence and practice."

(*b*) **The Netherlands**

The Government of the Netherlands submitted a list of geographic names for the Netherlands Antilles,[2] compiled by a committee appointed for this purpose and stated: " In this connexion reference is also made to the Secretary-General's note of June 26, 1958, EC 821, submitting, under the provisions of resolution 600 (XXI) of the Economic and Social Council, a draft programme for achieving international uniformity in the writing of geographic names. The attached list can be considered to constitute a first reaction to the draft programme's paragraph dealing with ' standardization at national level '. The comments of the Netherlands Government on the draft programme which were requested in paragraph 5 of Council resolution 600 (XXI) will be submitted at a future date."

(*c*) **Luxembourg** [3]

" The Government of Luxembourg has examined with great interest the Draft Programme in question and expresses its agreement to co-operate in committees with the objectives to achieve international uniformity in the transcription of geographic names."

(*d*) **Costa Rica** [4]

" The draft programme mentioned above is an attempt to reduce to a reasonable minimum the difficulties which in the spelling and pronunciation of geographical names are a result of the different languages and alphabets used throughout the world. It can be said that in our continent there is no problem, as only one alphabet is used, and the phonetic differences between the officially recognized European languages are relatively small. It would consequently be simple to find a common denominator that would eliminate these differences. The problem is serious in Eurasia, as that area is the cradle of cultures which developed in response to different environments and were stimulated by economic needs and philosophic trends which varied from time to time and from place to place.

" Page 3 of the annex to the draft programme includes a recommendation for the establishment of regional working group conferences under United Nations auspices; on page 4 of the annex, there is a recommendation that the United Nations should make technical advice available to the regional working groups. Costa Rica accepts this plan in principle; its execution and financing would be the responsibility of the Costa Rican committee of the Pan-American Institute of Geography and History.

" We can offer but little to solve the problems of peoples separated from ourselves by different cultural traditions. We shall confine ourselves at present to offering our co-operation in the American regional community in order to achieve ' international uniformity in the writing of geographical names ', while leaving to the great Powers the task of achieving what is possible in other continents."

(*e*) **Nicaragua** [5]

" This matter, which has been widely discussed at all the meetings of the Pan-American Institute of Geography and History and on the occasion of the Central American Cartographic Week, is considered by the Government of Nicaragua to be entirely feasible from the cartographic point of view.

" The problem is purely linguistic and, thus, once the draft programme has been approved by the various countries, the solution of the problem will have to be left to their linguistic experts. After that, each country will decide whether the system of writing which has been chosen should be accepted and, if so, how that system should be applied to its official language and to geographic publications, charts, maps, etc."

(*f*) **New Zealand**

" Geographic names in New Zealand are written in the Roman alphabet and are derived from English, other European and Maori language sources. The assignment of new place names and the amendment of existing place names are the responsibility of the New Zealand Geographic Board. A copy of the New Zealand Geographic Board Act 1946 [6] is enclosed.

[2] The list is available for consultation at the Secretariat.

[3] Translated from the French.

[4] Translated from the Spanish.

[5] Translated from the Spanish.

[6] The Act is available for consultation at the Secretariat.

" The following rules of nomenclature have been adopted by this Board:

" 1. An original name where suitable should be given preference.

" 2. (*a*) Where the original name has been changed by publication or by local usage the original name should be restored in the correct form.

" (*b*) Where, however, the incorrect name has become established by local usage over a long period the Board may in its discretion retain such incorrect form.

" (*c*) Where the choice lies between two or more names all sanctioned by local usage then that which is most appropriate and euphonious should be adopted.

" 3. The publishing of a name in any work which in the opinion of the Board is authoritative should be taken into consideration, but the publishing of any name shall not necessarily establish that name.

" 4. The possessive form should be avoided whenever possible without destroying the euphony of the name or changing its descriptive application.

" 5. The use of hyphens to connect parts of names should in most cases be avoided and the name written either as one word or as separate words where established by usage.

" 6. Geographic names in a foreign language should be rendered in the form adopted by that country, except where there are English equivalents already fixed by usage.

" 7. Where the name for a single feature has been published in both Maori and English forms, both of which forms are in general use, the Board may retain both forms, either of which may be used officially. The use of alternative names should, however, as a general rule be discontinued.

" 8. In the case of new names for alpine and other features the mountaineers or explorers first climbing, traversing or discovering such features shall have the right to submit names for the approval of the Board.

" In collaboration with the Antarctic place names authorities in Australia, Great Britain and the United States of America, the New Zealand Geographic Board acts as an Antarctic place names committee in the assignment and amendment of place names in the Ross Dependency.

" Lists of names approved by the Board from time to time are published in the New Zealand Gazette, copies of which are made available to other international place name authorities."

(*g*) Iran

" There are two problems to be considered: The first is a problem of a different sort and relative to the transliteration of names of countries (Deutschland-Allemagne-Germany) or cities (Den Haag-The Hague-La Haye) and of common geographic names.

" This linguistic problem can be solved only in the case of general maps (for instance IMW or similar maps).

" The second problem is the selection of alphabetical letters to define exactly the pronunciation of geographic names. Each country has selected certain letters or combinations of letters, accents, indexes, etc., for the pronunciation of the letters of its alphabet. As, on one side, the letters of the Latin alphabet are pronounced differently in each language, and, on the other side, certain sounds existing in one language do not exist in another, a standardization of alphabetical letters and symbols is imperative.

" As the proposal of Brigadier General H. A. Razmara, former chief of the Army Map Service of the Imperial Army of Iran, made to the Economic and Social Council of the United Nations on 1 May 1950, is simpler and more complete than the letters selected for instance by the United States Board on Geographic Names (see special publication No. 78: The transliteration of Arabic and Persian), we are in favour of the said proposal ..."

This proposal is reproduced below as it was presented in annex IV to document E/2362 submitted to the Economic and Social Council at its fifteenth session:

" (1) All geographical names, names of countries, towns or natural features, in all countries, on all published maps and in all textbooks in use, especially international 1/1,000,000 maps, should be written uniformly according to the current local name (of course, excluding historical maps);

" (2) In order that names on maps may be written and pronounced uniformly, a single special alphabet should be drawn up and published by decision of the United Nations.

I add the following notes by way of brief explanation:

" (*a*) Generally speaking, geographical proper names are written differently in each country and bear no resemblance to the local names. For example, the name adopted by the English, French or Egyptians for the capital of their respective countries is given different interpretations in other countries. Again, the country which we Iranians call Tchine (*çin*) [7] and the French call Chine (*cin*), the English China (*çâynâ*), and the Russians Kitaï (*kitây*), is called by the Chinese themselves Tchungo (*çungo*). This diversification is as inadmissible as the changing of a person's proper name. This age of great discoveries, with its plans for the conquest of interplanetary space and its grandiose schemes for utilizing the extraordinary advances to be made in the near future, unfortunately has not succeeded in adopting a common universal language; but at least agreement should be reached to ensure that for geographical names, which are not infinite in number, all nations should adopt a uniform spelling, conforming to that established by usage in the country concerned. Such standardization would not only facilitate the teaching of geography and the everyday use of maps and similar documents but would also make international maps truly international, so that all nations would really be able to accept them as such and each nation would recognize them as conforming to its own conceptions.

" (*b*) With a view to attaining a uniform spelling for geographical names on maps, I think it would be desirable for the United Nations to consider compiling a uniform alphabet, which should be as simple as possible but should include all the essential sounds.

" In March 1950 several publications of the Geographical Section of the General Staff of the Imperial Iranian Army, together with the first and second volumes of our geographical dictionary, were sent to the United Nations through the Iranian Ministry of Foreign Affairs.

" As perusal of the dictionary will show, the Iranian alphabet does not have separate signs for vowels but has instead additional consonants written differently but similar in sound, and therefore, in order to indicate the exact pronunciation of the vowels we have had to use the alphabetic signs already given in the large NAFICY Iranian dictionary.

" The resulting alphabet, the key of which is contained in the attached annex, was considered adequate to indicate the exact pronunciation of Iranian names. However, for the proposed international alphabet, the adoption of which depends upon the decision of the United Nations, it will probably be necessary to add a number of additional signs.

" I believe that disinterested co-operation, together with the goodwill of the services concerned, cannot fail to achieve the desired result, which will represent a notable contribution to international progress."

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[7] *See* pronunciation key reproduced in figure 65.

Signs	Iranian Equivalents	French Pronunciation	English Pronunciation
a	آ	**i**mprimer	**a**nswer
e	اِ	mod**e**l	ann**e**x
o	اُ	**O**range	**O**rder
ow	کشش صدای ضمه مانند (دولت)	—	l**ow**
â	آ	**a**ge	h**a**rd
i	ی	t**i**r	**i**ll
u	او	**ou**vrage	p**u**t
b	ب	**b**ord	**b**ad
p	پ	**p**orte	**p**ark
t	ت - ط	**t**able	**t**able
s	ث - س - ص	**S**ang	**S**ong
j	ج	**dj**	**j**apan
ç	چ	**tch**	**ch**ange
h	ح - ه	**h**auteur	**h**orn
x	خ	**kh**	**kh**
d	د	**d**rapeau	**d**ash
z	ذ - ز - ض - ظ	**Z**inc	**Z**one
r	ر	**r**endre	**r**ail
j	ژ	**j**ardin	—
c	ش	**ch**apeau	**sh**oe
'	ع و همزه ساکن	—	—
q	غ - ق	**gh**	**gh**
f	ف	**f**roid	**f**ar
k	ك	**K**ilometre	**K**ind
g	گ	**G**roupe	**G**uess
l	ل	**l**ambert	**l**ondon
m	م	**M**onde	**M**ad
n	ن	**N**oire	**N**oise
v	و	**V**oix	**V**alue
y	ی	**Y**acht	**Y**ear

Figure 65. Pronunciation key used in the Iranian Geographical Dictionary

(*h*) United Kingdom

" Her Majesty's Government are in general agreement with the views expressed in this paper and in its Annex. In regard to the two questions raised in Section B of the document it is the view of Her Majesty's Government that the most satisfactory basis for standardization of geographical names is the written form rather than the sound of the name or its meaning, and that the Roman alphabet, supplemented by diacritical marks as necessary, would provide the most effective means of standardizing the writing of such names."

(*i*) Panama [8]

" . . .

III. Comments on the United Nations Draft Programme

" With regard to the initial problems raised in the interesting draft programme prepared by the United Nations—such as the

possibility of expressing the elements of geographic names in different writing systems, and of obtaining international acceptance and application of a particular writing system through the establishment of a new alphabet, the adoption of an existing alphabet or the use of phonetic symbols—it has been argued that international agreement on these questions is unlikely to be achieved. It is proposed not to refer to other preliminary matters but to turn at once to the problem of uniformity in the writing of geographic names.

" No proposal to establish or adopt an international phonetic alphabet has any hope of acceptance at present or in the immediate, and possibly relatively distant future. It would complicate matters and would moreover conflict with the respect due to the various different cultures as a basis of international understanding and co-operation.

" There is some merit in the idea, referred to in the programme, of creating a central organization, provided the central body has broader functions than the mere collection and distribution of information and of the results of past and current work, as suggested in the programme.

" The idea of convening an international conference on geographic names, under the auspices of the United Nations, is acceptable in principle provided the conference is preceded by a period of preparatory work designed to give a sense of direction to the discussions with a view to securing more positive results than a collection of theoretical recommendations that may lack coherence. In order to carry out the preparatory work it seems essential that some central body or unit should be set up within the United Nations, whose aid and support would enable it to work effectively and smoothly.

" Similar considerations apply to the convening of regional conferences of groups of States and peoples using the same writing systems. The results are likely to be more positive if they are guided and co-ordinated by a central body.

" The final recommendations contained in the Annex to the programme, prepared by Dr. Meredith F. Burrill, geographer and Executive Secretary of the United States Board on Geographic Names, incorporate valuable suggestions which are worthy of support.

IV. Recommendations

" The writer ventures to make the following recommendations in the light of the foregoing.

General principles

" (1) Each geographic name or toponym is the product of a culture and as such belongs to the people in whose area and within whose culture (or series of past cultures) it arose and evolved until it reached the form in which it is written at the present time.

" (2) Toponyms are subject to permanent change, as a result of natural evolution or Government decisions; they also undergo changes when they are converted into other languages and systems of writing.

" (3) Changes in geographic names and the increase in their number form a continuing process and permanent arrangements must be made to deal with them.

" (4) From the point of view of international understanding and co-operation, the problem of uniformity in the writing of geographic names (though not in their pronunciation) is of world-wide importance. It needs to be tackled immediately and, in view of its complexity, it needs to be solved progressively, by stages. This can only be done successfully in and through the United Nations.

" (5) For practical purposes, it would appear to be necessary to establish categories of geographic names based on the frequency with which they are used: (*a*) names in common international use; (*b*) names in frequent use within a given country; (*c*) names used locally and to a limited extent.

" (6) States using the same writing system should standardize the writing of their toponyms as soon as possible.

" (7) The conventional forms of foreign place-names, or translations of place-names into other languages using the same system of writing, should be progressively eliminated. At all events, the use of such forms should be limited, until such time as they are eradicated, to the country which created and uses them.

" (8) Transliterations and transcriptions should be standardized in States using the same writing system.

Proposed plan

" The following course of action is proposed; it would be divided up into phases or stages and undertaken and developed within the United Nations.

A. *Initial phase*

" (1) The establishment by the United Nations of a central international body which might be called the International Committee on Geographic Names.

" In the initial phase, the character and function of the body would be as follows:

" (*a*) It would be the central, official United Nations body responsible for the examination and solution of the problem of uniformity in the writing of geographic names.

" (*b*) It would promote and stimulate the interest of Governments in the establishment of national committees on geographic names and advise such committees in carrying out the functions assigned to them.

" (*c*) It would collect, collate, publish and circulate the results achieved by the private organizations concerned with the problems of transliteration and transcription of toponyms.

" (*d*) It would prepare, with such expert advice as might be necessary, basic documentation for the discussion and formulation of rules for transliteration and transcription.

" (*e*) It would collect, compile and publish lists or nomenclatures of geographic names in common international use, and lists of geographic names in frequent national use prepared by the national committees; and ensure that they received the widest possible dissemination.

" (*f*) It would prepare, at the earliest possible date and with such expert advice as might be necessary, a provisional list or nomenclature of geographic names in common international use, in the form in which they are written in the Roman, Cyrillic, Arabic and Indic systems of writing. The list would be used as a basis of discussion in regional conferences and in an international conference on geographic names.

" (*g*) It would recommend to the Secretary-General of the United Nations the convening, as appropriate, of regional working groups and regional conferences of States using the same writing system with a view to the standardization of the writing of place-names within that system. It would arrange for them to be provided with the necessary expert advice.

" (*h*) It would consider, and make recommendations on, the desirability of convening an international conference on geographic names, and would organize and make preparations for the conference if it was decided to convene it.

" (*i*) It would lay the foundations for the compilation of a nomenclature or list of geographic names in common inter-

[8] Memorandum prepared by Professor Angel Rubio, Chief Geographical Adviser to the Ministry of Foreign Affairs of Panama. Translated from the Spanish.

national use and in frequent national use, together with the standard methods of writing them in each writing system.

"(*j*) It would answer questions submitted to it by States and interested institutions on matters concerning the international spelling of place-names.

"*Constitution*. This would be similar to that of other United Nations bodies, such as the International Law Commission. Initially it would consist of a permanent secretariat at a seat to be selected and three members representing the Roman, Cyrillic, Chinese, Arabic and Indic writing systems. The members would attend annual sessions lasting three or four months. They would be chosen from experts in geography with special knowledge of toponymy, geographic dictionaries etc., or experts in cartography, communications etc. Financial assistance in meeting expenditure might be obtained through the co-operation of organizations interested in the problem of writing geographic names (postal, radio, transport and travel organizations and the like).

"*Headquarters*. Geneva is recommended, in view of the availability of the Palais des Nations and the proximity of Berne, the seat of the Universal Postal Union. Failing Geneva, London would, if possible, be a suitable headquarters, as it is the seat of the Royal Geographical Society, whose Permanent Committee on Geographic Names has taken a leading part in the study of transliterations and transcriptions.

"(2) *The institution by States of national committees on geographic names*, with firm official backing and sufficient funds to discharge their duties quickly and efficiently.

"The duties and membership of these committees might be as follows:

"(*a*) They would be national bodies qualified to establish the way of writing geographical names within the State and its dependencies, in its own writing system, and the usual manner of writing the geographic names of other countries, including those which use the same writing system and those whose names must undergo transliteration and transcription;

"(*b*) They would be agents of, and work in co-operation with, the United Nations international committee on geographic names;

"(*c*) They would prepare nomenclatures or lists of those geographic names (toponyms, oronyms and hydronyms) which they consider to be in common international use, in frequent national use, or in limited local use;

"(*d*) They would record and publish the official changes of names within their State and communicate them to the international committee on geographic names;

"(*e*) They would settle the numerous practical problems raised by national toponymy;

"(*f*) They would promote and lay the groundwork for the preparation of national geographic dictionaries and the development of the scientific study of toponymy;

"(*g*) They would act as advisers to the cartographic, statistical and communications services of their countries in questions of the writing of geographic names;

"(*h*) They would consider and settle questions on transliteration and transcription submitted to them by the international committee on geographical names or other institutions concerned.

"This first stage, if carried out expeditiously, might be completed within five or six years.

B. *The later phase*

"Activities and functions would largely depend on experience in the first phase. With that proviso, they could be as follows:

"(*a*) The definitive establishment of the international committee on geographic names;

"(*b*) The widening of the committee's activities to include the question of the standard writing of place-names in writing systems not considered during the first phase;

"(*c*) The formulation of international rules for transliteration and transcription from one writing system to another on the basis of discussions in regional conferences, regional working groups, consultative meetings of experts or any other procedure considered appropriate. Publication and dissemination of the rules adopted.

"(*d*) The preparation and publication of nomenclature or list of geographic names showing the standard form of each writing system and the conventional forms used by various countries employing the same writing systems;

"(*e*) The centralization and circulation of documentation concerning the writing of geographic names and methods for transferring them from one writing system to another;

"(*f*) The dissemination of official changes in geographic names, and suggestions for their transliteration or transcription;

"(*g*) The preparation and periodic revision of a Universal Geographic Dictionary after establishment of the criteria to be followed in compiling a dictionary of this type;

"(*h*) The centralization and encouragement of the study of scientific toponymy at the international level."

(*j*) Spain [9]

"... the *Instituto Geográfico y Catastral de España* considers the topics mentioned therein of real interest and would wish to take part in the proposed work and meetings and to be kept advised at frequent intervals about any decisions which may be taken and how the problems in question are viewed and solved in other countries.

"The Institute's point of view is summarized in the four subparagraphs below:

"1. Need for an exchange between countries of technical information on the subject, as indicated on page 2 of the draft programme.

"2. Desirability of holding regional conferences, as indicated on page 4 of the draft programme. Great difficulty is being experienced in working out a special system for the writing of geographic names.

"3. Desirability of agreeing to standardization in respect of languages using the Roman alphabet through the adoption of special symbols.

"4. The Geographic Institute is endeavouring to standardize the toponymy of Spanish geography and it is doing this in the *Atlas Geográfico de España* (Spanish Geographical Atlas) now in preparation."

(*k*) Canada

"It is recognized that the adoption of a uniform method of writing geographic names involves two basic questions, viz: the standardization in one form of a geographic name by the country concerned and the selection of standard methods of transliteration or transcription of the accepted form into other languages. It is agreed that the first question is a domestic matter, but that international co-operation could lead to common methods and procedures and might assist the development of a uniform method of transliteration or transcription. It is, however, suggested that experts in systems of writing and in languages rather than cartographers could best undertake this co-operative work.

[9] Translated from the Spanish.

" If there is evidence of sufficient international interest in this problem, the Economic and Social Council might encourage the setting-up of regional committees of experts to study the possibility of achieving uniformity in the writing of geographic names among the language groups of their regions. The finding of these committees might be reported through the Economic and Social Council to future cartographic conferences."

(*l*) United States of America

" . . .

" The United States is in general agreement with the draft programme for achieving international uniformity in the writing of geographic names.

" The United States is confident that the Secretary-General in the implementation of the programme will present for consideration by the Economic and Social Council detailed concrete proposals and the United States is hopeful that these proposals will include the following elements:

" (1) Provide encouragement and guidance to those nations which do not have a national organization for the standardization and co-ordination of geographic names to establish such an organization and to produce national gazetteers at an early date;

" (2) The Secretariat act as a central clearing office for geographic names with the following functions:

" (*a*) Collection of gazetteers and information concerning the technical procedures that each Member nation has adopted for standardization of domestic names;

" (*b*) Collection of information on the techniques and systems used by each Member nation in the transliteration of the geographic names of other countries;

" (*c*) Dissemination among Member Nations of all documents and information collected, utilizing existing United Nations periodicals wherever feasible; and

" (3) Within the limits of budgetary availability to sponsor conferences of regional working groups representing countries which use the same system of name writing, to develop guiding principles for attaining uniformity in domestic name procedures and for standardization of methods used in the transliteration of foreign names.

" It is believed that the actions outlined would be desirable and necessary as initial steps towards international name standardization and would be deserving of emphasis at this time."

INTERNATIONAL STANDARDIZATION OF NAMES, SPELLING AND TRANSLITERATION [1]

Background paper by Professor Meynen

The question of spelling geographical names has occupied geographers and cartographers in Germany since the second half of the past century. This question was officially raised by the German Hydrographic Office in 1888. The discussion of this problem was reopened with the preparation of hydrographic maps and with German co-operation in the International Map of the World on the Millionth Scale and resulted in the issuing of *Richtlinien für die Schreibweise von Orts- und Landschaftsnamen in deutschen Karten- und Textveröffentlichungen* (Directions for the spelling of place and geographical names in German maps and publications). These directions, published in 1952, are mandatory on all official publications in the Federal Republic of Germany.

For further examination of the problems relative to the spelling of names, it is now planned to constitute a Permanent Committee for German Spelling of Geographical Names (*Ständiger Ausschuss für die deutsche Rechtschreibung geographischer Namen*), inviting the co-operation of linguists. Thus, an institution for the spelling of names will be established in Germany which will be competent to prepare uniform regulations for the spelling of geographical names in the German language in accordance with the " Draft Programme for Achieving International Uniformity in the Writing of Geographic Names ".

In the Federal Republic of Germany it is maintained that the geographic name is a part of the living language; therefore, it seems quite natural and justifiable, from the linguistic point of view, for the name of the same place to be different in different languages. Within this concept, the following names belong to place names spelled as is customary in the German language:

1. All officially prescribed place names within the territory of the German-speaking States of Central Europe, that is, those of Germany (within the 1937 boundaries), Austria, and the German-speaking regions of Switzerland;

2. The names of places in German-speaking territories other than those mentioned above, according to the authorized local spelling in the German language;

3. The names of places located outside of countries where the German language is spoken but for which customary names exist in German in the form of exonyms.

On the other hand, in view of the increase in relations and co-operation among nations, it is necessary to meet the requirements of the map user desirous of obtaining information about the official names used in the country concerned, in addition to the conventional names used in his mother tongue.

The official name is defined as the name used in official indexes of place names (gazetteers) and official maps, in brief, the name used in the official correspondence of the country concerned. If a country is officially bilingual, and two equivalent place names actually exist, both names are acknowledged as official.

In all areas using the Roman alphabet with diacritical signs, the spelling of the official place names should be in its autochthonic form, that is, with all diacritical signs. Where a conventional German spelling of such names does not exist, this official spelling should be used as the spelling for German purposes.

To overcome the difficulties in spelling official names in languages not using the Roman alphabet, it seems advisable to seek official standards for romanized transliteration and

[1] The original text of this paper, submitted by the Federal Republic of Germany, appeared as document E/CONF.25/L.59.

transcription, to be created in areas where such languages are spoken, and internationally approved.

If a country whose language does not use the Roman alphabet has officially adopted a standard for romanized transliteration or transcription, the spelling in this form should be approved as official spelling, as far as it is acceptable to languages using that alphabet.

In cases where no official transliteration and transcription keys are available, an attempt is made in the Federal Republic of Germany to realize, as far as feasible, a phonetic spelling of geographic names by means of the German alphabet, a system which may be used in other regions where the German language is spoken. In such cases, reference should also be made to the name as given by the international postal service and indicated in the *Dictionnaire des Bureaux de Poste*.

As more countries achieve independence changes in names and spellings will take place which will need to be considered according to the above-mentioned principles.

As to the standardization of individual place names for international spelling, the spelling of names as officially adopted in the State concerned should be used. In this case, from the German point of view, which is in accordance with the conception of the International Congress on Toponymy which held meetings at Salamanca in 1955 and at Munich in 1958, one has to proceed from the *de jure*—not from the *de facto*—regulation for the region under consideration.

The exchange of results obtained by the international institutions for the spelling of geographic names would be greatly appreciated by German experts.

Dr. Meredith Burrill, United States Board on Geographic Names, made the following suggestions: (1) to approach step-by-step towards a solution of international standardization, and first to promote the official adoption of geographic names in the different countries; (2) to constitute national and international committees to be charged with the preparation of official standards for transliteration and transcription from one group of characters into another, and especially from languages which do not use Roman characters into those which do.

These suggestions deserve wide support.

INTERNATIONAL STANDARDIZATION OF NAMES, SPELLING AND TRANSLITERATION [1]

Background paper submitted by the United Kingdom

The search for a standard, internationally acceptable method of writing geographical names on maps represents a very old problem. One of the earliest modern attempts to solve it was made in 1820 by the Institut de France, which offered the Volney Prize for the best *alphabet transcriptif universel*. The prize was awarded posthumously to Christian Garnier in 1899 for a very ingenious alphabet. Meanwhile, Köppen had proposed the use of a special alphabet for the writing of geographical names (1893), and in 1913 Esserky offered an interesting alternative. Geographers have tacitly rejected these schemes. The various " missionary " alphabets for the writing of native languages (Schomburgk, 1949; Max Müller, 1854; Lepsius, 1855; P. W. Schmidt, 1907), though also applicable to the writing of geographical names, have similarly been rejected. Geographers resist the use of unfamiliar symbols and of diacritical marks because they detract from the clarity of maps.

The first steps towards a solution of the problem was made by the Union Postale Universelle (founded 1874) when it accepted the Roman alphabet for international use in the writing of the names of post offices. The names are accepted by the Union in the romanized forms preferred, presumably, by the postal authorities of the respective countries, and without any attempt to standardize them internationally. The First International Geographical Congress (Antwerp, 1871) had already decided to recognize the national official spellings of all geographical names in countries which officially use the Roman alphabet, and the International Geographical Union has ever since upheld the " Roman alphabet rule ", to the extent of recommending (Amsterdam, 1938) the acceptance of the forms of names appearing in the *Dictionnaire des Bureaux de Poste*.

The names of natural features of the earth's surface which have to be given on maps are, however, far more numerous than those of inhabited places where there are post offices. The problem of rendering the former still awaits international solution. It has been solved nationally by the application of various schemes of transcription and transliteration to names written in non-Roman alphabets and scripts. British efforts to render foreign names in an orderly manner go back to Astley's *New General Collection of Voyages and Travels* (London, 1745-47), and the growth of a British official system is traceable to a principle applied to the transliteration of Indian languages by Sir William Jones in 1788: that of using the vowel-symbols of the English alphabet to carry the Italian values while the consonants retain their English values. Between 1836 and 1885, the Royal Geographical Society developed this principle, until the " R.G.S. System " was officially accepted for use on British maps and charts. Since 1919, the Permanent Committee on Geographical Names for British Official Use has further developed the system in its *Principles of Geographical Nomenclature*, a copy of which is reproduced as an annex to the present paper.

The main technical difficulties in the treatment of geographical names are:

(I) The use in every language of conventional forms of foreign names rather than their " native " forms, in particular the names of countries, of certain towns and of geographical features which are international in character and cannot therefore be standardized in any one language;

(II) The conflict between the values assigned to the individual letters by countries which use the Roman alphabet; and in consequence the impossibility of any one existing form of the Roman alphabet in current use serving for international use in the rendering of geographical names;

[1] The original text of this paper appeared as document E/CONF. 25/L.12 and Add.1.

(III) The difficulty of determining which is the preferred name in countries in which two or more languages are current or where varying forms of names are used for different administrative or linguistic purposes;

(IV) The fact that national orthographies and the names of places change from time to time;

(V) The fact that many geographical names, including those of inhabited places, have never been adequately recorded.

The first of these difficulties can be overcome only by modifying well-established customs in speech and writing. If place names existed only as written words on maps, and were never spoken or recorded in other documents, the question of dropping conventional forms of names and adopting the official " native " form would be easier, but these names are part of the habit of speech, and tradition in matters of this kind dies slowly. A complete abandonment of conventional names is hardly possible or, perhaps, desirable. The names of countries, oceans and similar international features appear to present an insuperable obstacle. The practice normally adopted on British maps and charts is set forth in sections (1), (2) and (3) of the *Principles of Geographical Nomenclature* of the Permanent Committee on Geographical Names for British Official Use

The second can only be resolved when systems of transliteration and transcription have been devised which will gain international approval, but the successful application of these systems, when devised, depends upon the satisfactory solution of the problems defined in III, IV and V, of which the more pressing are III and V.

There is at present only the smallest measure of international agreement on transliteration except between the English-speaking peoples. In the United Kingdom, official map and chart makers adopt the system in the *Principles of Geographical Nomenclature* already mentioned. Many of the practices devised by the United Kingdom for the treatment of geographical names and methods of treating individual languages are accepted for official use in the United States and similarly the United Kingdom uses officially many systems devised originally for United States use. For some mapping purposes certain western European nations have agreed to follow identical procedures in the treatment of geographical names. That these measures of international agreement have been attained leads one to suppose that still wider international agreement could be achieved.

While the maximum use should be made of the systems and principles already evolved and in use on maps and charts, the whole question of geographical names merits wider consideration if complete international standardization is sought. It may well prove impossible to devise a single set of rules and principles to cover all linguistic groups. If this should prove to be so, a number of parallel systems may need to be devised, each meeting the requirement of the largest possible number of countries interested in each linguistic group.

It is considered that, if the problem is to be pursued, separate attention must be given in the first instance to the basic linguistic and topographical difficulties. The large amount of research already carried out in various countries should be taken into account. The best national authorities should be ascertained and their advice sought. In particular it is considered that:

(1) The use of conventional forms of names should be reduced to the minimum, while acknowledging the fact that their complete abolition is neither possible nor desirable;

(2) The Roman alphabet (supplemented by diacritical signs) should serve as a basis for any international orthography devised for the transliteration or transcription of geographical names;

(3) Subject to (1) above, where the Roman alphabet is the official national alphabet, the geographical names of a country should be taken complete with their modified letters and diacritical signs. This has been generally approved by the International Geographical Union and other geographical authorities, for example, the International Committee of Onomastic Sciences, which is affiliated to the International Council for Philosophy and Humanistic Sciences created by the United Nations Educational, Scientific and Cultural Organization (UNESCO);

(4) Should experience show that international acceptance of any given existing system of romanization cannot be achieved, a series of parallel systems might be devised each suiting the requirements of the maximum possible number of nations within each linguistic group for a means of transcribing a given language;

(5) In order to help resolve the basic problem and ensure the certain identification of places by name, each nation should be urged to:

(*a*) eliminate unnecessary names; (*b*) eliminate, for international use, variant forms and spellings of the same name; (*c*) set down its names in writing with full pointing, in scripts other than Roman, for the indication of vowels, length, tone and stress; (*d*) make all information on place names freely available to other nations;

(6) The most suitable agent for the implementation of these measures is the United Nations acting perhaps by way of a parent body composed of national representatives and free to confer with appropriate authorities, official and academic, through subordinate study groups concerned with regional problems.

ANNEX

Permanent Committee on Geographical Names for British Official Use

Principles of Geographical Nomenclature ("P.C.G.N. Principles")

(1) The spelling of the names of (*a*) regions and geographical features of continental or international extension, (*b*) water areas extending beyond the territorial limits of recognized government, and (*c*) countries, shall be in accordance with English conventional usage, for example, (*a*) Sahara, Alps, Danube, (*b*) Bay of Biscay, (*c*) Italy.

(2) In the case of oceanographical features lying outside territorial waters, the descriptive terms entering into their names shall be in English, for example, Challenger Bank, Dogger Bank, Walfisch Ridge (*not* Walfisch Rücken).

(3) The approved name of any administrative division of a State,[a] or federation of States, or of any natural or artificial geographical feature or of any place lying wholly within one State, or

[a] For the purpose of applying these principles, the term "State" shall be taken to include an independent country, or colonial territory, or protectorate, protected State, or trust territory.

federation of States, shall be that adopted by the supreme administering authority concerned with that State or federation of States, for example, Uttar Pradesh (*not* United Provinces), Kaliningrad (*not* Königsberg); *but*, should a different name be current in English conventional usage, the latter may be given subordinate recognition, for example, Cabo de Hornos (Cape Horn), Dhiórix Korinthou (Corinth Canal), Moskva (Moscow).

(4) Where any name of the kinds referred to in section (3) above contains a descriptive term in a foreign language, that term shall not be translated into English, for example, Cabo de Hornos (*not* Cape de Hornos), Schloss Bellinghoven (*not* Bellinghoven Castle), Isola d'Ischia (*not* Island of Ischia); *but*, where a geographical term on a foreign map or chart stands in isolation and is neither a geographical proper name nor is attached to such a name, it may be translated, for example, "bridge" (*not* German "Brücke"), "ford" (*not* Russian "brod").

(5) The names of places and of geographical features in countries which officially use varieties of the Roman alphabet shall be accepted in their official spelling, including the accents and diacritical marks used in the respective alphabets.

(6) The non-Roman letters in the official names of places and geographical features in countries which use partly-Roman alphabets may be transliterated into Roman letters in accordance with the conventions of the respective partly-Roman alphabets.

(7) In countries where the official alphabet of the administering authority is not Roman:

(*a*) Where an official romanization acceptable to the Committee is in current use, the spelling of names shall be in accordance with it;

(*b*) Where no official national romanization exists but a system of Roman transliteration has been accepted by the Committee for the country under consideration, the official forms of names shall be transliterated in accordance with it;

(*c*) Where there is no system of romanization, or none acceptable to the Committee, the official forms of names shall be transliterated into the conventional alphabet given below.

(8) In countries where the official script is not alphabetical, the official forms of names shall be rendered in Roman letters in accordance with systems of transcription adopted by the Committee, for example,

China: the Wade-Giles system as modified in 1942;

Japan: the Hepburn system as recommended in 1942;

Korea: the McCune-Reischauer system.

(9) In those territories where the foregoing principles may prove to be inapplicable, geographical names should, whenever possible, be recorded in the alphabet officially used for the languages concerned, or be collected in the field by the scientific methods employed for the phonetic recording of speech. Only when these means fail should they be recorded in the conventional alphabet given below.

Conventional alphabet

Range of sound represented

Symbol

Vowels

a = *a* in *father*; all the sounds represented by *a* in the French words *patte*, *pas*, *page*, *pâle*; *o* in English *son* or *u* in *cut*; also a shade of the unstressed neutral vowel (see under *ö* below).

e = The first part of the diphthong in *day*, *e* in French *thé*; *ai* in *fair*, *è* in French *père*; *e* in *bet*; a shade of the unstressed neutral vowel (see under *ö* below).

i = *ee* in *fee*, *i* in French *si*; *i* in Italian *via*; *i* in *sit*.

o = *ou* in *bought*, *aw* in *law*, *o* in *not*; *eau* in French *beau*, *o* in *rotund*.

ö = *ö* in German *schön*, *eu* in French *peu*; *eu* in French *peur*; *œ* in French *œuf*; *ea* in *earth* (the last is the stressed neutral vowel in English). The unstressed neutral vowel (the sound of *a* in *marine*, *e* in *often*, *u* in *difficult*) is better represented, according to its nearest approximation, by *a* or *e*.

u = *oo* in *boot*; *oo* in *foot* or *u* in *put* (but not in *but*).

ü = *ü* in German *über*, *u* in French *lune*.

y = The cavernous vowel, unknown in standard English, represented by *bl* in Russian and by *r* in Turkish. Note that *y* is also used for a consonant-symbol (see below).

Diphthongs

Diphthongs may be represented by combinations of the vowel-symbols given above.

Consonants

b = English *b*, any other sound recognized as a kind of *b* by English ears, as *b* in Spanish *saber*.

ch *or* c [b] (=tsh) = *ch* in *church*. *c* is established with this value in parts of Africa.

d = Any sound recognized as a kind of *d*.

dh = The soft sound of English *th* in *this*, *they*, etc.

f = Any kind of *f*.

g = *g* in *got* or *gift*.

gh = The soft guttural sound represented by غ (ghain) in Arabic, which resembles that of Parisian *r*.

h = (*i*) The aspiration of vowels (the sounds preceding the vowels in *her hat*);

hh = (*ii*) the aspiration of consonants (emphatic *k*, *t* and *p* are aspirated in English; *b* is often aspirated in Irish English).

In a conventional alphabet it is possible to distinguish between the digraphs (pairs of letters standing for single sounds) *dh*, *gh*, *kh*, *sh*, *th* and *zh*, and aspirated *d*, *g*, *k*, *s*, *t* and *z*, respectively, only by means of elaborate devices.

j (=dzh) = In *jib* or *g* in *gem*.

k = Any kind of k-sound, as *c* in *cat*.

kh = *ch* in Scottish *loch* or German *ach*.

l = *l* in *leave*; *ll* in *wall*; *ll* in Welsh *llan*.

m = English *m*.

n = English *n*.

ñ *or* ny = As in Spanish *cañón*. Established in many parts of Africa.

ng = *ng* in *singer*; *ng* in *finger*.

p = Any kind of *p*.

q = The guttural sound represented by ق (*qaf*) in Arabic.

r = As sounded in Scotland; any other clearly rolled or trilled r-sound, like *r* in Spanish *pero*.

s = *ss* in *hiss* (but not *s* in *his*)

sh *or* š [b] = *sh* in *fish*.

t = Any kind of *t*.

th = Hard English *th* as in *thistle*.

v = English *v*.

w = English *w*.

x (=ks) = *x* in *extra* (not *x* in *exact*).

y = *y* in *yet*. Note that *y* is also used as a vowel-symbol (see above).

z = English *z* or the *s* in *was*.

[b] *See* instruction 6, below.

zh or ž [b] = *j* in French *je*; *s* in *measure*.

(') = (inverted comma) The Semitic sound represented by ع (*'ain*) in Arabic; the glottal stop. (In practice the two will not conflict.)

Instructions for spelling in the conventional alphabet

1. Standard native pronunciation is to be taken as the basis for spelling.

2. Each sound is to be represented by its closest corresponding symbol, and a symbol may be doubled only to indicate a clear repetition of the same sound.

3 If their representation be indispensable, a vowel-symbol may be marked with:

   (*a*) an acute accent (') for *stress* (*Kórinthos*—Greece);

   (*b*) a macron (¯) for *length* (Tōkyō—Japan);

   (*c*) a tilde (˜) for *nasalization* (*Eggã*-Nigeria, *unofficial*).

4. Retroflex, emphatic, implosive or ejective consonants may be indicated by dots beneath the symbols representing them.

5 Palatalization of consonants as in Russian may be indicated by an apostrophe (') after the symbol affected.

6. If it be imperative to distinguish between *sh* and *zh* (the symbols given above) and aspirated *s* and *z* respectively, the alternative symbols š and ž may be used for the former pair. Similarly, *c* and *ch* could stand for the unaspirated " ch " sounds respectively.

7. In the narrow rendering of names in, and their close transliteration into, the conventional alphabet, recommended for textual documents and particularly for gazetteers, the diacritical marks listed in 3, 4, 5 and 6 above should be used. From the broad rendering in, and broad transliteration into the conventional alphabet, appropriate to maps and charts, these marks may be omitted. This instruction applies only to the conventional alphabet and has no bearing whatever on No. (5) of the principles of nomenclature.

Alphabetical order

The full conventional alphabet consists of the following thirty-seven symbols: a, b, ch *or* c, d, dh, e, f, g, gh, h, i, j, k, kh, l, m, n, ñ *or* ny, ng, o, ö, p, q, r, sh *or* š, t, th, u, ü, v, w, x, y, z, zh *or* ž ('); but names written in it should be filed or arranged in common English alphabetical order disregarding (').

AGENDA ITEM 14

Aeronautical Charts

PROPOSALS FOR THE COMPILATION OF AERONAUTICAL CHARTS [1]

by Karl-Heinz Meine

Introduction

The bases for discussion of aviation cartography are the Standards and Recommended Practices of the International Civil Aviation Organization (ICAO). Seventy-four States are members of this organization and the following fourteen member States participate in the Regional Cartographic Conference: Afghanistan (since 4 April 1947), Burma (since 8 July 1948), Cambodia (since 16 January 1956), Ceylon (since 1 June 1948), China (since 2 December 1953), India (since 1 March 1947), Indonesia (since 27 April 1950), Japan (since 8 September 1953), Korea (Republic of) (since 11 November 1952), Laos (since 13 June 1955), Pakistan (since 6 November 1947), Philippines (since 1 March 1947), Thailand (since 4 April 1947), Viet-Nam (Republic of) (since 19 October 1954).

According to ICAO decisions, a number of chart series are to be produced to meet the requirements of civil aviation; priorities have to be established with regard to the politico-economic needs as well as to the current air traffic problems of the responsible States. The following chart types should be mentioned:

(1) Topographical maps—scale: 1 : 1,000,000; 1 : 500,000; 1 : 250,000 (for visual navigation);

(2) Charts for instrument navigation:

(*a*) Approach and landing charts;

(*b*) Radio facility charts;

(*c*) Special charts (Decca, Loran, Consol);

(3) Planning and plotting charts.

The basic ICAO series is the World Aeronautical Chart 1 : 1,000,000 (WAC) which is to provide world-wide coverage.

According to the ICAO Chart Catalogue, issued May 1958, of the 165 sheets covering Asia and its islands, twenty-three sheets (13.5 per cent) have been completed and forty-nine sheets (28.8 per cent) are being prepared. Burma, India, Japan and Thailand co-operate in producing this part of the WAC and Japan has obtained entire coverage of its territory.

Production responsibility for the WAC sheets is as follows: Burma, 3; Ceylon, 1; China, 39; India, 23; Indonesia, 21; Japan, 8; Korea (Republic of), 1; Pakistan, 4; Philippines, 8; Thailand, 3.

Thirty-four more sheets are being produced by the United Kingdom and twenty by France. Moreover, according to ICAO information, the following aeronautical charts are produced or published, or both, by Asian countries: Burma, instrument approach charts; Ceylon, instrument approach charts and aerodrome obstruction plans and profiles; China, instrument approach charts and radio and navigational aids facilities chart; Federation of Malaya, instrument approach and landing chart; Hong Kong, instrument approach charts; India, long-range plotting charts, 1 : 3,000,000 (eighteen sheets provided) and radio facility chart; Indonesia, approach charts; Japan, route charts, 1 : 1,000,000 (two sheets); Pakistan, instrument holding approach chart and radio facility chart; Philippines, instrument approach and landing charts; Thailand, instrument approach and landing charts.

Nearly all Asian countries give elevation data in feet; only Japan takes as a basis the metric system used by the majority of European countries.

Japan also has a complete 1 : 500,000 ICAO series, composed of seventeen sheets.

The following aeronautical charts, providing partial or entire coverage of Asia, are produced by countries outside of Asia.

(1) Carte générale aéronautique du monde (France), consisting of twelve sheets of which the following ones cover Asia:

B II: Europe–Asie Nord-ouest

A II: Afrique Nord–Asie Ouest

B III: Asie Nord-ouest

A III: Asie Est.

Scale: 1 : 10,000,000; projection: Mercator.

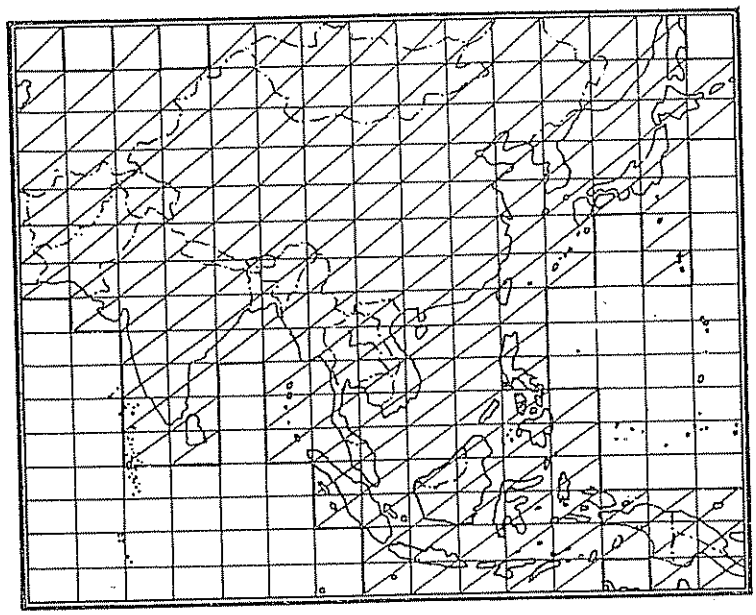
(2) 1 : 500,000 Aeronautical Planning Chart (United States), with the sheets: AP-6, AP-7, AP-12, AP-13, AP-20, AP-21.

(3) United States World Aeronautical Chart, 1 : 1,000,000.

(4) Strip Chart (United Kingdom), from Portreath, England to Kunming and Rangoon.

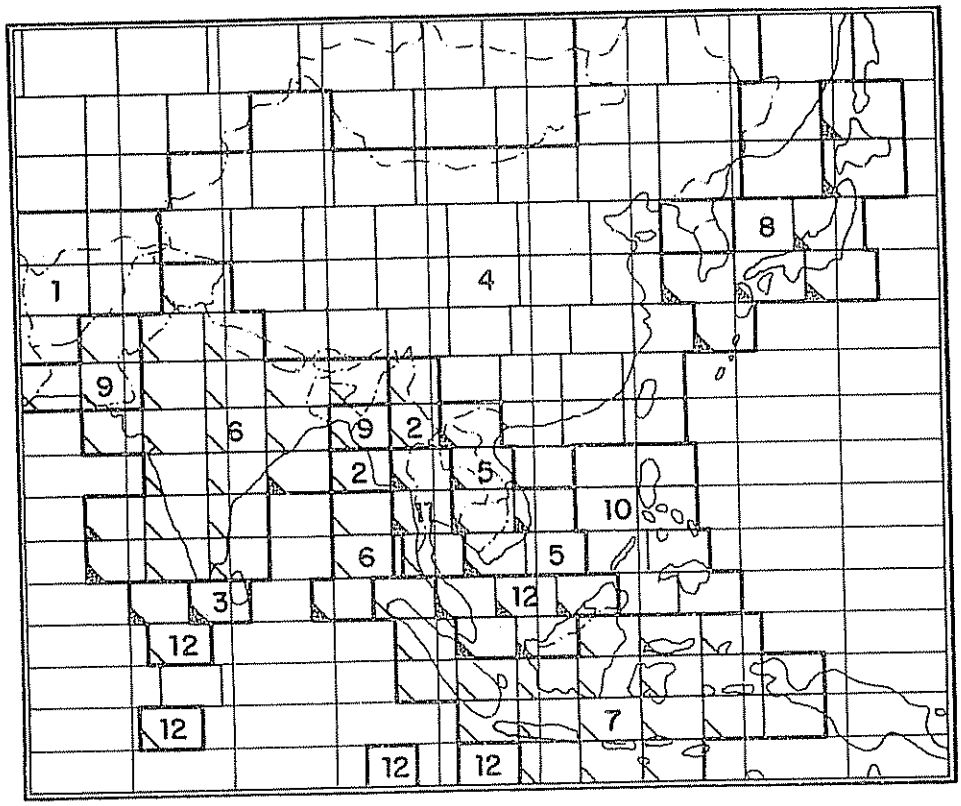
(5) Aircraft Position Charts (United States), sheet 3094 (Japan/Alaska).

[1] The original text of this paper, submitted by the Federal Republic of Germany under the title " Proposals for the Design of Aeronautical Charts ", appeared as document E/CONF.25/L.41.



Present coverage of the International Map of the World 1:1,000,000 (IMW)

Figure 66



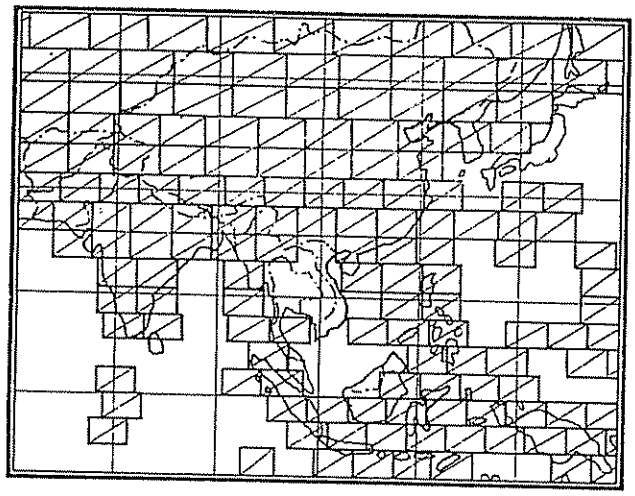
Index of the World Aeronautical Chart ICAO 1:1,000,000 (WAC)

Present coverage

Sheets in preparation

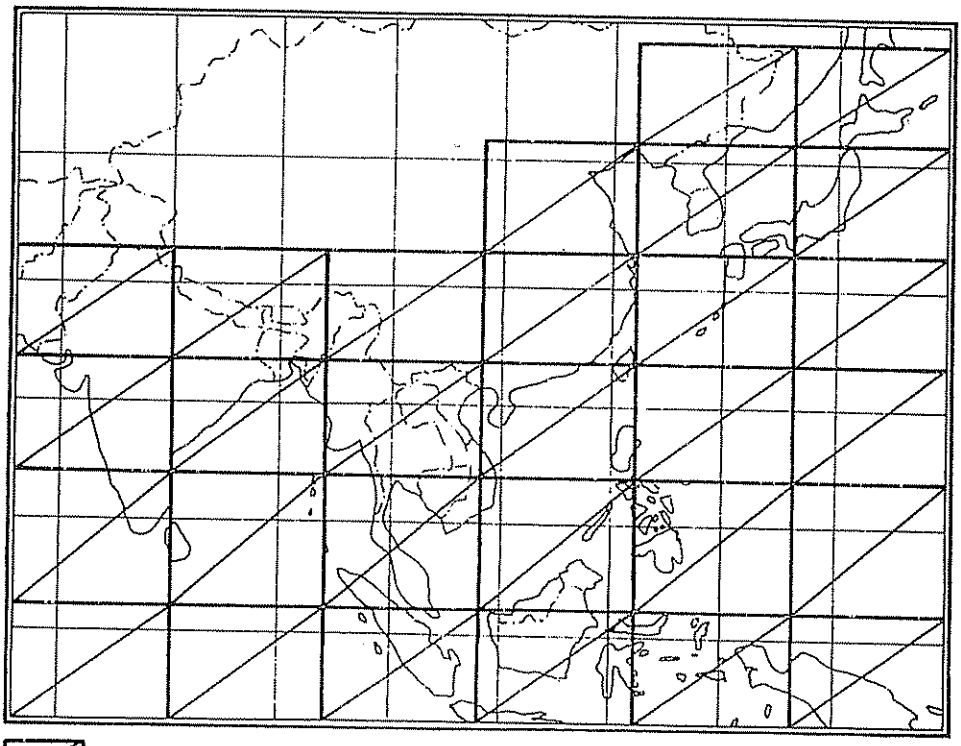
1 Afghanistan	4 China	7 Indonesia	10 Philippines
2 Burma	5 France	8 Japan	11 Thailand
3 Ceylon	6 India	9 Pakistan	12 United Kingdom

Figure 67



Present coverage of the World Aeronautical Chart 1:1,000,000 by the United States

Figure 68



Present coverage of the 1:1,000,000 Plotting Series (GSGS), on Mercator projection, by the United Kingdom

Figure 69

(6) 1 : 5,107,200 Long-range Air Navigation Chart on Mercator projection (United States), with sheets 1, 2, 3, 5, 16.

(7) 1 : 2,188,800 Air Navigation Chart on Mercator projection (United States), providing nearly full coverage of Asia.

(8) 1 : 7,500,000 Carte de navigation OACI pour avions long-courriers, on Mercator projection (United Kingdom).

(9) 1 : 1,000,000 Plotting Series on Mercator projection (United Kingdom).

(10) 1 : 5,107,200 Loran Air Navigation Chart on Mercator projection (United States), on three sheets; also at the scale of 1 : 2,188,800, on three sheets.

Figures 66 to 69 show the status of four 1 : 1,000,000 chart series of Asia.

Considerations on the Structure of Aviation Cartography

In any case, the individual governmental or topographical cartography of each country provides the basis from which aeronautical charts are systematically derived. This is obtained by reduction of scale and selection of details. Generally speaking, aviation cartography, like communication cartography, belongs to special-subject, or applied, cartography. Moreover, in the terminology, a " map " is a geographical map, while a " chart " is designed for navigation purposes.

It is impossible to establish standard principles for the structure of aviation cartography; principal programmes will differ according to the techniques available.

With an organized structure of chart series for special purposes and availability of suitable topographical bases, aeronautical charts might be ranked as follows:

(1) World Aeronautical Chart ICAO 1 : 1,000,000, or 1 : 500,000 for areas with great density of industrial features or for those with dense communications patterns;

(2) Charts at the scale 1 : 250,000 for highly developed areas and for the immediate vicinity of international airports;

(3) Planning and plotting charts at very small scales.

Depending on the importance of current air traffic, the following charts should, in any case, be produced simultaneously with the above-mentioned series: (*a*) approach charts; (*b*) landing charts; (*c*) radio facility charts.

The preparation of special charts for Decca (hyperbolic cartography), Consol, Loran (Long-range navigation), Radar or other special navigation procedures must be the last step in the total field of aviation cartography.

The following chart types particularly are of basic importance:

(1) *Charts for visual navigation (up to twelve colours)* Scale 1 : 250,000 (produced only by the United Kingdom, the United States, Chile and the Netherlands).

Scale 1 : 500,000. Charts at this scale are used for training purposes, scheduled air services, sport flying, visual navigation and flight planning purposes. This scale is ideal for medium to low speed aircraft.

Scale 1 : 1,000,000 (World Aeronautical Chart, also usable by higher speed aircraft).

Scale 1 : 2,000,000. The production of charts at this scale will increase with scheduled operation of jet aircraft. They are destined for approximate orientation in the upper airspace.

Scales 1 : 500,000 to 1 : 2,000,000 use the Lambert conformal conical projection.

(2) *Charts for technical navigation* (instrument navigation) show only a topographical skeleton, often in three colours (hydrography blue, built-up areas, graticules and communication pattern black, contour lines sepia), together with the aeronautical information overprint (magenta or dark blue).

(*a*) *Approach charts*. According to international agreement, these shall be at a scale not smaller than 1 : 250,000. They serve as an aid to changing over from general maps or navigation charts used during flight to the landing charts used in terminal approaches. The presentation emphasizes the data of the special approach procedure with supplementary profiles.

(*b*) *Landing charts*. These cover the runway area within a radius of one nautical mile. Usually their scale is larger than 1 : 50,000. They show primarily the landing area, obstructions, reference levels, aerodrome beacons, approach aids, built-up areas, ground aids and radio facilities.

(*c*) *Radio facility charts*. These are preferably at scales of 1 : 1,000,000 or 1 : 2,000,000 and are designed for instrument navigation. They are preponderantly " mathematical " in type and show, in addition to graticules, technical air traffic control facilities and related data emphasizing the airways and thus stressing the representation of controlled air space, navigation aids and the like. Conical conformal projection is used.

Planning and plotting charts generally include graticules and graduations, outlines of continents, national boundaries, capitals, lines of equal magnetic variation and the like. They are mostly unicoloured. Mercator projection is preferred.

Design, Content and Production of Aeronautical Charts

Depending on its function, a chart has to meet three requirements: isometry, equal area projection or conformal projection. Conformity is the main requirement for air and sea navigation. Another problem is: what basic maps are especially suited for aeronautical charts, which must provide a significantly combined portrayal of topography and navigational aids invisible to the naked eye? For this purpose, reproduction of natural features by relief portrayal is of special importance, as was recently emphasized by two international meetings. At the meeting of the Ausschuss für Funkortung, held in Berlin in May 1958, as well as at the Second International Cartographic Conference, held at Shepard Hall, Evanston (Chicago), Illinois in June 1958, it was stated that the plasticity of aeronautical charts was preferable to an exaggerated abstraction of landscape. While this principle was formerly expounded in Europe, today it predominates in North American aviation cartography.

The representation of the contents of a chart results from the need to provide a means of orientation. Thus, the face of the chart is composed of two elements:

(1) *Topography*

(*a*) Culture (cities and towns, communications pattern, landmarks such as towers and the like);

(*b*) Hydrography (as the most conspicuous orientation mark);

(*c*) Relief (shaded relief and contour lines);

(*d*) Vegetation. The representation of wooded areas is more important for charts at scales of 1 : 1,000,000 and larger.

(2) *Special aeronautical information overprint (aeronautical chart symbols)*

Charts for visual navigation are to include, besides topography, detailed air traffic control information. This requires special preparation, generalization and selection of topography. Its clear and differentiated portrayal is to permit optimum comparison of the picture of the landscape with the chart. According to reports, the United States is trying to meet this requirement by flight-checking the sheets before printing in order to prove the accuracy of topographic and aeronautical data, a method at present impossible in Europe because of the expense involved. A symbol code on the back has facilitated interpretation of the chart. For instance, on the German 1 : 500,000 ICAO series, four languages (German, English, French, Spanish) are given.

Optimum chart production is obtained, doubtlessly, by precise comparison of aerial photo and basic topographical material in order to seize on characteristic features of conspicuous landmarks. This method, however, cannot replace the visual air survey but at best prepares for it. Today, air mapping and reconnaissance are no longer reserved for military purposes, but are the most important principles of any terrain reconnaissance. In particular, they facilitate the significant portrayal of the communications pattern and of conspicuous spot elevations.

There is another essential problem of chart production. While, on the one hand, a chart should include a maximum of aeronautical information, on the other, there is the danger that other chart details will be suppressed. In the history of aviation cartography new methods, successful or otherwise, are always being tried in order to find the most suitable compromise. Above all, revolutionary changes in radio navigation since 1945 have made new representation methods necessary.

The following design features for aeronautical charts are preferable:

Topographical bases

Drafting and scribing on glass and on transparent foils

Colour separation:

Black (graticules, railways, lettering, bridges, landmarks, lines (two-metre line) on shores, spot elevations and the like);

Blue (hydrography);

Sepia (contour lines and reference data);

Red (highways and roads and their names and numbers where not printed in broken half-tone, screened);

Green (wooded areas or hypsometric tints);

Yellow (built-up areas where a black screen is not used—large towns of 100,000 inhabitants and more);

Dark blue or magenta (aeronautical information).

For hypsometric tints the following colours should be used: blue-green or light grey (depressions), green or white, light brown, brown and sepia. The following contour intervals should be adhered to in the hypsometric tints (in metres): 0-100; 100-200; 200-300; 300-500; 500-1,000; 1,000-1,500 (up to 1 : 1,000,000).

Production procedures (mostly on glass):

(*a*) Separate drafting of graticules;

(*b*) Separate scribing of communication pattern and built-up areas;

(*c*) Composition of lettering;

(*d*) Strip-masking for hypsometric tints and other colour plates (Astralon, Astrafoil, Mylar and so on).

Plotting scale: 1 : 1 for all chart series for visual navigation (in Germany); for approach and landing charts, 2 : 1.

Aeronautical information overprint

(*a*) Drafting in accordance with given co-ordinates (combined situation and graticules) on blue print;

(*b*) Drafting on Astralon;

(*c*) Composition of lettering and symbols;

(*d*) Preparation of an original copy for printing.

The aeronautical information overprint and related symbols should be prepared according to ICAO specifications.

Problems of shaded relief done by photomechanical means and by other modern cartographic methods, such as the use of foils, printing procedures and scribing, which are increasingly coming to the fore, and of vignetting on coast lines, have been sufficiently discussed in the American and German literature. Detailed information concerning design and production of aeronautical charts at all scales may be obtained on request from the author of this report.

Summary and Outlook

Aeronautical charts at all scales are important aids to flight navigation as well as to air traffic control. Their contents vary and depend on (1) the special function to be fulfilled by the chart, (2) the scale, and (3) technical progress, the latter with regard to the changing locations of technical facilities, such as radio facilities, on the one hand, and the selection from the operational and cartographic point of view on the other. By its artistic technique of portrayal cartography generally forms a bridge between geodetic survey and interpretation of geography. It has to fulfil three functions in the important field of aviation.

First, it is not an end in itself but a means to an end; thus, it is only a "secondary field" of aeronautical technique. Secondly, it provides a safety device for air pilots and ground services. Thirdly—and this seems to be the chief point—its task is to give a map presentation of planning and operation of air traffic control for navigation and air traffic.

Finally, two of the manifold problems of aviation cartography will be discussed separately. These are (1) relief representation, and (2) a new scale, 1 : 2,000,000, for operations in the upper airspace (jet operations).

Relief representation

To indicate the third dimension on aeronautical charts various methods and combinations are possible.

(*a*) *Contour lines*

Advantage: relatively accurate means of measuring when of close linking or of short contour interval; of relatively sufficient plasticity for mountainous terrain.

Disadvantage: contour lines alone lack clarity; additional hill shading would be recommendable.

Application: possibly for charts at a scale of 1 : 250,000.

(*b*) *Hypsometric tints*

Advantage: more compact and clearer representation of the shape of the terrain.

Disadvantage: hypsometric tints are form lines rather than direct height delineations. The loss of accuracy in measuring must be compensated for by an increase in numbers of spot elevations.

Application: these tints should in any case be confined to the scales of 1 : 1,000,000, and 1 : 2,000,000. Photomechanical shading would possibly be preferable on charts at the scale of 1 : 500,000.

(*c*) *Manual shading*

Advantage: strong modulation effects, more clearly emphasizing terrain plasticity. A well-performed manual shading provides the best chart image, particularly when supported by a chamois tone.

Disadvantages: (1) useless without contour lines; (2) with hypsometric tints no clarity of the chart image; (3) requires long practice.

Application: satisfactory for charts at the scale of 1 : 500,000; less suitable for charts at smaller scales.

(*d*) *Photomechanical shading*

Advantage: possibility of detailed representation.

Disadvantage: this detailed representation may result in an overloading of the chart. The application of photomechanical shading should exclude the use of hypsometric tints.

Application: if possible, for charts at scales larger than 1 : 500,000.

(*e*) *Combination of shaded relief with screened wood plates*

The conventional overprints of wooded areas destroy the plastic effect of any relief shading. This can be avoided by combining the shaded relief with a screened wood plate by repro-masking.

(*f*) *The Swiss method*

The Swiss method of relief cartography renders by far the best image. Yet its use for aeronautical charts seems to be inappropriate for two reasons: (1) since up to four colour plates are necessary, it is uneconomical; (2) the artistic colour image would be much more impaired by requisite aeronautical overprints than is the case with present charts.

(*g*) *Method of the reduced colour scale*

Basic material: water colour base for all colours of the respective surface for entire terrain representation. Then photomechanical prime colour separation and production of printing plates for blue, red and yellow without manual retouch by masking.

A new scale—1 : 2,000,000

Introduction. For flights in the upper airspace, that is, above 20,000 feet, the creation of a new ICAO chart series is deemed necessary. For several reasons this series should not be derived from a scaling down of the WAC ICAO 1 : 1,000,000, since the 1 : 2,000,000 series should show the following characteristics: (1) little lettering; (2) no wooded areas; (3) rigid selection of built-up areas, of railroad, highway and road patterns; (4) light, readily identifiable, graduated hypsometric tints; (5) aeronautical information overprint of not too much emphasis; (6) drainage pattern optional.

Purpose of the series. (1) To permit approximate orientation when the earth's surface is in sight; (2) to facilitate navigation; (3) to guarantee flying safety; (4) to represent accurately the basic topography.

Problems. The following suggestions are made.

(1) *Design*

International boundaries: grey.

Boundaries of domestic states: may be omitted.

Shore lines: blue vignetting.

Hydrography: large-size to medium-size rivers and lakes optional.

Lettering: grey, strictly limited.

Railroads: multi-track and single-track only where of landmark prominence; black.

Cities and towns: separate plans, as on ICAO 1 : 1,000,000, but in graduated classification (additional circles for less prominent villages, names omitted).

Wooded areas: no representation.

Graticules: corresponding to those used on ICAO charts 1 : 1,000,000.

Aeronautical information overprint: exchange of views about data selection is necessary.

Contour intervals (in metres): 0-200; 200-500; 500-1,000; 1,000-1,500; 1,500-2,000; 2,500-3,000; 3,000-3,500; above 3,500.

Hypsometric tints: green, yellow, orange, light brown, sepia, red brown.

Sheet lines: overlaps are to be provided.

(2) *Sample chart.* Not later than the end of 1958 the Federal Republic of Germany will prepare a sample chart of a sheet size of 21 by 29.9 centimetres and submit it to ICAO member States. It will include three different map sections: (*a*) Hamburg (shore with lowlands); (*b*) Frankfurt am Main (with highlands); (*c*) South of Munich (with the Alps).

(3) *Sheet lines.* The Institute of Applied Geodesy in Frankfurt am Main is currently investigating the problem of a worldwide basic projection to be submitted by the Federal Republic of Germany together with the sample chart. Geodetic considerations are to be made as to: (*a*) the utility of the conformal conical projection with two isometric standard parallels between the equator and 80° latitude, and the polar stereographic projection between 80° latitude and the pole (corresponding to the projection of WAC 1 : 1,000,000); (*b*) which latitudinal spacing shall be provided for the two isometric standard parallels; by this the sheet size would be definable.

The above-mentioned projections are deemed necessary. A cone must be used which permits optimum sheet lines with a minimum of distortion and handy chart format.

The problem of which cartography technique is most appropriate to meet the requirements of aeronautical charts for special purposes has not been uniformly solved by all countries, since techniques of printing and reproduction vary from one State to another. The same problem exists in cartographic selection of map contents. The results of past co-operation, however, show worth-while ways of solving these problems. An example calling for more intense co-operation is the difference in contents, colours and sheet lines of the 1 : 1,000,000 scale International Map of the World, ICAO World Aeronautical Chart and United States World Aeronautical Chart, even though the first United Nations Regional Cartographic Conference for Asia and the Far East, held from 15 to 25 February 1955 in Mussoorie, India, stated that the IMW and the WAC series, though using as far as possible the same basic material, would serve different purposes according to their different individual characteristics.

In the age of jet operations the distance between the continents will in any case become smaller and smaller.

AERONAUTICAL CHARTS AND AERONAUTICAL INFORMATION PUBLICATIONS[1]

Information paper by United States Air Force,
Aeronautical Chart and Information Center

During the period which has elapsed since the first United Nations Regional Cartographic Conference for Asia and the Far East, held in Mussoorie, India, in 1955, the United States has keyed its aeronautical charting programme to meet the needs of expanding civil and military aviation. The specialized nature of aircraft and air missions, increased speed, greater air space available to the airman, and heavier air traffic have made necessary a constant review of cartographic requirements of aviation and have brought about significant modifications both in design and content of aeronautical charts. The trend has been towards a more simplified presentation of essential information for improved readability, particularly on those charts designed for instrument flight.

The most widely used series of aeronautical charts is the World Aeronautical Chart (WAC) Series, scale 1 : 1,000,000. During the past three years the United States Air Force has revised or recompiled 105 charts in this series in Asia and the Far East, using the best and most up-to-date source information available, including aerial photography. Also this series was subjected to intensive study and a new design was developed by the Air Force to fulfil the needs of military aviation. A number of charts reflecting the new design are being produced to meet military requirements. Also the new chart design is being examined to determined whether a single 1 : 1,000,000 scale navigation chart can fulfil all United States civil as well as military uses. The new series is intended to provide optimum portrayal of chart features, colours, terrain tints, symbols, shaded relief, and the like, and a more realistic and better balanced portrayal. Final design is still to be established.

Also, during the past three years the United States published a new series known as Jet Navigation Charts, scale 1 : 2,000,000. This series was designed to fulfil the requirements of high speed, long range, and high altitude flight and at the same time provide for radar, celestial, dead reckoning, and pilotage navigation. Fifty charts in this series have been published for complete coverage of the northern hemisphere. Charts are published on sheets 42 inches by 58.5 inches in size; strips of minimum width of 12 inches may be cut from them and may be used independently. Six of these charts covering Arctic areas have been published as Loran-Consol editions.

Development of a new series of Global Navigation and Planning Charts, scale 1 : 5,000,000, was carried out. It is envisioned that this series of twenty-six charts will provide world coverage and it is intended to replace several series of small-scale aeronautical planning charts produced by the United States Air Force. The proposed charts will be published on large-size sheets incorporating the latest portrayal refinements and are planned in such a way that many long flights, particularly over water areas, can be accomplished with the use of a single planning chart. Loran editions of nine of these charts are being contemplated.

In addition to the improvement in design, the United States Air Force has increased its effort to improve accuracy and completeness of chart content in all series of charts produced for military aviation.

A major redevelopment programme has been under way for the past year in connexion with the various aeronautical information publications of the United States Air Force. New flight information documents are being considered for the three basic phases of flight—planning, enroute, and terminal. The flight planning function is being viewed as requiring a loose-leaf book containing general information needed for flight planning, together with inserts containing supplementary flight information for specific areas. Enroute documents may consist of larger-size graphics showing radio facilities and similar data for high, mid-range and low altitude flights. This particular document is being given priority consideration for military and civil needs. The terminal documents will contain approach and letdown charts together with other terminal data for given areas.

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.31.

REQUIREMENTS FOR AERONAUTICAL CHARTS AND AERONAUTICAL PUBLICATIONS [1]

Background paper by Rear Admiral H. Arnold Karo,
Director, United States Coast and Geodetic Survey

Discussion

With a dynamic and expanding aviation industry throughout the world, the cartographer is hard-pressed to produce modern and up-to-date aeronautical charts to meet aviation's operational needs. Within the past decade we have seen aircraft crash the sound barrier and climb to tremendous altitudes. There has been an enormous expansion in the use of electronic navigational aids to permit all-weather flying and safe landing under minimum weather conditions. The steadily increasing density of air traffic requires greater control to prevent mid-air collisions. The United States will soon stratify the airspace into three layers with different airway and route structure for better control of traffic.

These forces influence the type of information portrayed on existing and projected series of aeronautical charts for the use of a pilot in flight. The trend is towards simplified presentation and greater legibility for rapid assessment of the aircraft's position.

Domestic civil requirements for charts and publications in the United States are determined from the needs of all types of users, such as the private pilot, operators of business aircraft, charter service and the scheduled air carriers. These requirements are co-ordinated and satisfied on the same charts where feasible. However, due to different types of operations, different speeds of travel and different methods of navigation, several series of charts are required.

The civil and military chart requirements are examined within the structure of the Air Co-ordinating Committee and, where the requirements are parallel, joint civil-military charts are produced. Special-purpose charts may be published solely for civil or military use.

The aeronautical chart and information publications requirements for international civil aviation are determined by the International Civil Aviation Organization (ICAO). The Standards and Recommended Practices for the production of aeronautical charts and the publication of aeronautical information are contained in annex 4 and annex 15 respectively to the Convention on International Civil Aviation. International meetings are held from time to time to keep the requirements current and the annexes up to date.

At the present time the Air Navigation Commission of ICAO is sponsoring a Map Panel to review the requirements for aeronautical charts. The first meeting of the Map Panel was held in Montreal, Canada, from 3 to 14 March 1958. At this meeting the operational requirements for aeronautical charts were determined, as well as the type of charts that will satisfy these requirements. Detailed specifications for the production of the charts are now being prepared by the Map Panel members. The next meeting of the Map Panel will be held on 1 December 1958, for final co-ordination of the specifications. The report and recommendations of the Map Panel will then be distributed to the ICAO member States for review.

On 28 April 1959, an ICAO Divisional Aeronautical Information Service and Map Meeting will be opened to act on the recommendations of the Map Panel and to bring annex 4 and annex 15 up to date.

It was the consensus of the Map Panel at the first meeting that the specifications for the production of aeronautical charts need not be rigid, so as to permit improvement in cartographic practices and to meet changing operational requirements. As an example, the introduction of transport jet aircraft will require some modification in the chart series because of the new operational requirement for higher flight altitudes and greater speeds. In the interests of safety, standardization of symbology should be kept at a maximum so that no matter what chart a pilot may be using he will readily recognize the symbols, whereas considerable latitude can be allowed in the choice of colours, style of type and other minor cartographic detail.

Conclusion

Since the International Civil Aviation Organization is continually working on the international aeronautical charting problem, it is recommended that the United Nations Cartographic Conference co-operate fully with that organization in determining the requirements for aeronautical charts and information publications.

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.73.

RECENT DEVELOPMENTS IN TECHNIQUES USED IN PRODUCTION OF AERONAUTICAL CHARTS [1]

Information paper by United States Air Force,
Aeronautical Chart and Information Center

An instrument for rectification of 9-inch by 18-inch photographs for use in preparation of aeronautical charts and photo maps was developed and placed in operation. The instrument accommodates tilts up to 30 degrees and provides reductions as small as 30 per cent and enlargements as great as 400 per cent. For tilts between 30 degrees and 65 degrees a special transformation printer was developed for use in first making a partially rectified print. Rectification is then completed with the basic auto-focus rectifier.

[1] The original text of this paper, submitted by the United States of America, appeared as document E/CONF.25/L.32.

Development has continued in the refinement of the process of negative engraving (etching) on resin-coated vinyl sheets. This process of preparing a reproduction negative by engraving directly from a compilation manuscript has eliminated many steps and has replaced the old hand drafting method in the United States agencies producing aeronautical charts. The initial red coating has been replaced by a green coating for more versatility and comfort. An orange opaque material has improved opaquing. Negative stick-up having a transparent coloured background instead of opaque black was developed for addition of type and symbols to film and scribecoat negatives. Two new engraving tools were developed—the Rectagraver, which facilitates the cutting out of rectangular windows of precise dimensions by simple pressure motion of the operator, and the Turretgraver, which is a circular engraving device containing several scribing needles of various sizes. A needle of the desired size can be placed in scribing position by merely rotating the instrument.

A new process known as "photoscribe" used in negative engraving makes possible the photomechanical etching of complex images, such as names, figures and certain symbols, prior to normal scribing operations. Names and other images are pre-etched on colour separation copy to eliminate re-scribing by hand.

A new process known as the "phantom transparency technique" makes possible the revision of reproduction negatives without recourse to other forms of copy. The area to be revised is rendered transparent by the application of a special solution, the negative is placed over guide copy for tracing of the new detail by scribing techniques, and the area is then restored to its original opacity by application of another solution. The obsolete detail is opaqued out. Application of screen, names and other stick-up is provided for.

AGENDA ITEM 15

Hydrography

REPORT ON THE PRESENT STATUS OF HYDROGRAPHIC WORK IN JAPAN [1]

Besides the mutual exchange of information on the status of ordinary hydrographic works, necessary in developing marine traffic, countries concerned with the seas in this region have a special need for further co-operation in this field on account of their economic relations and common concerns in connexion with geographic or oceanographic conditions. In recent years, hydrographic data have been widely used not only for navigation but also in various economic fields. Furthermore, they play an important role in human welfare activities, such as disaster prevention, exploitation of submarine resources, excavation of submarine tunnels and bridging work over channels. In all these undertakings, proper hydrographic investigations with high accuracies are required, as ordinary surveying methods are insufficient due to topographic and oceanographic particularities.

Therefore, it is highly desirable that countries which carry out surveys for these purposes and for ordinary navigation should inform each other of the status of their hydrographic work in order to improve efficiency and to reduce the expenses involved.

The Japanese Hydrographic Office has obtained the following results.

Ordinary works

Surveys

	Carried out 1956	*1957*	*To be carried out 1958*
Harbour survey	29	26	10
Coastal survey	9	11	9
Pelagic survey	10	8	8

Total of surveys hitherto completed (number of sheets)

Harbour survey	306
Coastal survey	89
Pelagic survey	7

Charts

	Nautical		*Special*	*Aero-nautical*	*Total*
	Coast of Japan	*Foreign coasts*			
New edition	20	5	22	2	49
Revised edition	31	24	8	—	63
Total	51	29	30	2	112
To be published in 1958:					
New edition	7	2	6		
Revised edition	11	9	9		
Total	18	11	15		

Total of charts hitherto published (available at present)

Nautical charts	1,688	(about two-thirds of these are charts of the coast of Japan)
Special charts	213	
Aeronautical charts	11	

Special works

Investigations of submarine topography and geology in Tugaru Strait (1954-1955). This survey was performed in order to obtain basic data for the excavation of a submarine tunnel under the western entrance to Tugaru Kaikyō connecting Honshu and Hokkaido. The surveying area extended over 20 kilometres offshore, where the rate of tidal current exceeded 6 knots. In order to cope with this condition, unfavourable to ordinary methods of surveying, the Decca Navigator System and Precise Echo Sounder for Shallow Water, developed by the Japanese Hydrographic Office, were used. Both instruments gave results with sufficient accuracy.

Outline of survey

Scale of charts prepared	1 : 5,000-1 : 20,000
Area surveyed	130 square kilometres
Device for sounding	J.H.O.-type Precise Echo Sounder for Shallow Water
Accuracy	± 0.1 metre
Device for position fixing	Decca Navigator
Accuracy	±10-15 metres
Interval between sounding lines	30-110 metres
Number of spots where bottom sediments were dredged	1,930
Density of spot	1/0.0877 square kilometre
Period	117 days
Number of persons engaged:	
In 1954	10
In 1955	48

Investigations of submarine topography and geology in Akashi and Naruto Channels (1956). Accurate surveys were carried out in two channels, Akashi Seto and Naruto Kaikyō, between Honshu and Shikoku, for the purpose of obtaining basic materials for planning the construction of the government railway connecting these two islands.

Since the rates of the tidal currents at these channels exceeded 7 to 8 and 10 knots, respectively, the Precise Echo Sounder for Shallow Water was used instead of sounding by hand lead.

[1] The original text of this paper, submitted by Japan, under the title "Reports by Governments on the Present Status of their Hydrographic Work", appeared as document E/CONF.25/L.25.

The resulting submarine geomorphological charts revealed in detail various features of the channels, including domes and valleys of modest size in the central part of Akashi Seto.

Investigations on submarine topography in the Japan Trench (1957). As a part of the systematic survey of Nippon Kaikō (Japan Trench), a precise investigation of the central part of this trench was initially made. Decca Navigator was used to fix positions of survey ships, and Precise Echo Sounder for Extreme Deep Sea of the type used by the Japanese Hydrographic Office (effective to 10,000 metres with accuracy of 10 metres) was used for sounding. Results of the survey reveal the existence of large sea mountains and crests rising from the base of the trench.

ACTIVITIES OF THE HYDROGRAPHIC DEPARTMENT, ROYAL THAI NAVY [1]

Report submitted by Thailand

Historical Background

Thailand, with its coastline extending to some 1,500 nautical miles, has, like the other maritime nations of the world, established a hydrographic service in order to procure and disseminate to the naval service all necessary hydrographic and oceanographic information, including charts, sailing directions and nautical instruments.

A century ago, in 1856, the British Admiralty sent one of their ships, the *Saracen*, to conduct a hydrographic survey in the Gulf of Thailand, with Master John Richards as chief of the party. This survey, which lasted for three years, might be recorded as the first hydrographic survey ever made in Thailand. The original working sheets of this survey, still in exceptional condition, are at present a valued record of the British Admiralty Hydrographic Department. During the following ten years, little, if any, surveying work was done.

By an agreement between the Governments of Thailand and the United Kingdom, in about 1871, the work was again started, using a Thai naval vessel under the command of Commander A. J. Loftus, who had accompanied Master John Richards on the first survey. A few years later the Government created the "Royal Survey Department" with Commander Loftus, who had been promoted to the rank of Captain, as the head of the department. The work of this department progressed for a period of fifteen years until the retirement of Captain Loftus. After a standstill of several years, the Royal Thai Navy established a Hydrographic Division. In 1906, a course in hydrography was included in the curriculum of the Royal Naval Academy.

It may be reckoned that an organized survey of Thai waters was introduced in the year 1912. The first systematic survey was carried out at the Bangkok Bar by Commander F. Thomsen, and Commander M. Bojesen of the Royal Danish Navy. After that, Thai naval officers made themselves familiar with the technique of hydrographic survey under the supervision of their chief.

In 1913, a surveying office was created under the administration of the Naval Science Department, with the aims of promoting the survey of Thai waters and procuring nautical charts, publications and instruments for the Royal Thai Navy. The office was later given the name of "Kong Utoksastr", which is equivalent to the Hydrographic Division.

During that period, the originals could not be drawn nor could the charts be reproduced. It was not until 1921 that the first chart, compiled and constructed by a Thai naval officer, was reproduced on a flat-bed press at the Royal Survey Department of the Royal Thai Army. In 1922, His Majesty the King was graciously pleased to proclaim the establishment of "Krom Utoksastr", or the Hydrographic Department, with Commander F. Thomsen as Director-General.

It is also worth mentioning that in June and July 1919 the first International Hydrographic Conference was held in London, resulting in the formation in 1921 of an International Hydrographic Bureau with its headquarters in the Principality of Monaco. Thailand (Siam at that time) was among the twenty-four founding States members. The prime object of the International Hydrographic Bureau may be stated briefly as attempting to stimulate co-operation and exchange of technical information leading to a more accurate survey and better charts for all mariners.

In 1935, the meteorological work was transferred from the Irrigation Department to the Hydrographic Department as a section under the Oceanographic Division. Owing to the rapid expansion of its work, in 1943, this section was raised to an independent department under the direct control of the Royal Thai Navy.

Present Organization

In 1929, two naval officers of the Hydrographic Department were sent to the United States for a period of three years for further studies in hydrography, cartography and related subjects. After their return the financial situation of the country was still in a serious condition and little could be done in this field. It was only in 1936 that the work was reorganized; this, after some modification, led to the present organization.

The function of the Hydrographic Department is to collect, evaluate, compile, produce and distribute hydrographic and oceanographic information, including nautical and aeronautical charts, sailing directions and aids to navigation calculated to afford maximum possible navigational safety and facility to vessels of the Navy and Merchant Marine. Its established policies are based on various technical agreements and are under the direction of the Royal Thai Navy. Close co-operation has been maintained with other governmental

[1] The original text of this paper appeared as document E/CONF. 25/L.72.

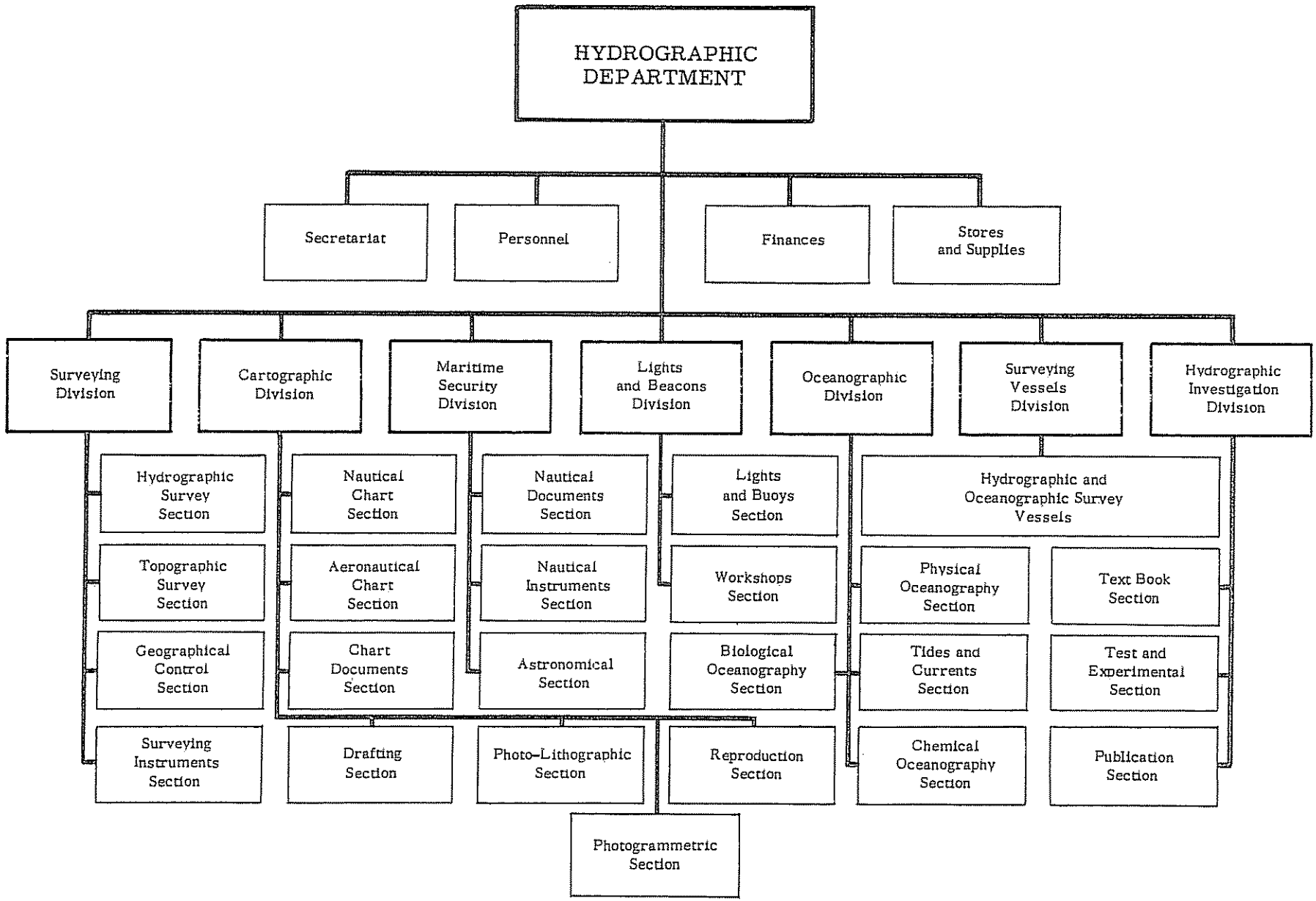


Figure 70. Royal Thai Navy, Hydrographic Department—organization chart

agencies and foreign hydrographic offices for exchange of information covering matters of mutual interest. To accomplish its task, the Hydrographic Department has several principal functions, namely:

To conduct hydrographic and oceanographic surveys in Thai waters;

To compile data thus obtained, including the computation of astronomic positions and geodetic adjustments, tidal computations, predictions, tabulations and the like;

To compile, construct and reproduce nautical and aeronautical charts;

To collect from all available sources all hydrographic, nautical and oceanographic information of value in promoting the navigational safety of vessels;

To maintain aids to navigation service;

To evaluate, compile, publish and disseminate timely information to mariners by means of sailing directions and Notices to Mariners;

To provide hydrographic and oceanographic materials for basic intelligence studies.

These functions lead to the following organization.

(1) *Surveying Division*

- Hydrographic survey
- Topographic survey
- Geographical control
- Surveying instruments

(2) *Cartographic Division*

- Nautical charts
- Aeronautical charts
- Chart documents
- Drafting
- Photo-lithography
- Photogrammetry
- Reproduction

(3) *Maritime Security Division*

- Nautical documents
- Nautical instruments
- Astronomy

(4) *Lights and Beacons Division*

- Lights and buoys
- Workshops

(5) *Oceanographic Division*

- Physical oceanography
- Chemical oceanography
- Biological oceanography
- Tides and currents

(6) *Surveying Vessels Division*

- Hydrographic survey vessel
- Oceanographic survey vessel

(7) *Hydrographic Investigation Division*

- Textbooks
- Tests and experiments
- Publications.

Hydrographic Survey

Hydrographic surveys along the coasts are carried out according to projects made in advance and approved by the Navy. These projects may be changed, modified or postponed according to the immediate requirement or the urgency of obtaining hydrographic information of any particular area as directed by the Navy. Special surveys, such as those for harbours and ports, are occasionally done.

Triangulation is based on geodetic points on the first-order or second-order already established along the coasts by the Royal Survey Department of the Royal Thai Army. Extension of the triangulation network for hydrographic survey is usually of the third-order and some control points for sounding purposes are of the fourth-order. Special care is exercised to achieve an accurate result. Precision instruments are used for triangulation, and sounding for depths is accomplished by the use of an echo-sounding machine. Lead line is also used for sounding in the shallower areas. Aerial photographs are utilized whenever available in obtaining coastal topography and coastline declination. One surveying season will last about six months, depending on the monsoon.

Two vessels, former naval transports, are provided for the purpose, but they are obsolete and do not justify the installation of modern surveying equipment.

The use of the electronic fixing system, Decca, has been initiated for off-shore sounding, which is still lacking in most parts of the Gulf of Thailand.

Chart Construction

Valuable information and various field data from hydrographic surveys are compiled and evaluated, and finally the originals of the nautical charts are constructed and photographed on glass plates from which zinc plates for offset reproduction are made. The procedure for the preparation of originals involves technical considerations and requires experienced cartographers. Some eight or nine months or even a whole year used to be spent before an original could be finished. At present, with modern techniques of chart construction, nautical charts can be reproduced within forty per cent of the time formerly required. A more rapid and flexible method of chart construction can be achieved by the use of plastic or vinylite sheet as a base for drafting, instead of drawing paper mounted on zinc plate.

Negatives of the originals are photographed by means of a precise camera which can accommodate any wet collodion plate, dry plate or sheet film up to the size of 40 by 40 inches. After the zinc plates are made, the two offset presses, one of them a double-colour printing press, take their turns in producing the charts to be distributed, after many careful and thorough inspections, for the use of mariners.

Besides the construction and reproduction of nautical charts, which are the prime object of this department, aeronautical charts are also being constructed and reproduced for the Ministry of Communications and the Royal Thai Air Force.

Photogrammetric work will be included in the near future. With adequate coverage of aerial photography along the coasts, aerial photographs could be fully utilized to give more facility in laying out a triangulation scheme of a hydrographic survey and also to obtain topographic details of the area.

Oceanographic Work

Oceanography is a composite science embodying the study of all processes which take place from high tide level to the abyssal depths of the sea. The physical oceanographic surveying work could not be started until two years ago. Two oceanographic boats of about ninety tons each, and one transport ship of about 400 tons are provided for the purpose. These vessels are working constantly to collect, by means of reversing thermometers and Nansen bottles, oceanographic data consisting of temperatures and sea-water samples at various depths for salinity and density determination. Bottom sediments are also collected and analysed for their physical properties. Data thus collected will be evaluated, compared and interpreted for the phenomena which are, needless to say, most important for fishing, harbour engineering and protection from coastal erosion, as well as for military application, especially to submarine warfare.

A laboratory is now under construction at Sattahib Naval Training Station with facilities for analysing the sea-water samples obtained during the course of the oceanographic survey. Mechanical analysis of bottom sediments collected will also be done in this laboratory. Future expansion of this laboratory will include complete equipment for submarine geological work and measurements of radio-activity of sea water and sediments.

Our biological oceanographic work at present is confined to maintaining a museum of marine animals and to making a preliminary study of sea turtles. New projects have been drawn up for studies of plankton, which is essential to many kinds of fish. An important part of the biological work consists of participation in co-operative field studies with the Department of Fisheries and the Marine Laboratory of the Chulalongkorn University on specific local ecological problems.

Observations of Tides and Currents

Soundings obtained during the course of a hydrographic survey, if plotted directly on to charts would not be useful to mariners without a datum establishing a reference to the depth of the water. Tidal observations at various locations are therefore necessary to yield a datum for reducing the soundings before they can be plotted on charts. Information on water level is also needed for harbour engineering work. Ten tidal stations have been established to operate continuously in the Gulf of Thailand and one on the west coast of the Malay Peninsula. The results of observations from these tidal stations will be tabulated, computed and harmonically analysed, after which various tidal constants will be determined; tide predictions at various places can then be made by the use of a tide-predicting machine. Preparation on the work of prediction has been made one year in advance so that tide tables can be published and be ready for distribution before the beginning of the following year.

Observations of currents by direct method are at present mostly incorporated in the hydrographic surveys along the coasts. The distribution of the chemical and physical properties of the sea water is also an indication of the movement of the water. It was only after adequate data had been collected that the chart showing currents could be produced.

Astronomy

As the astronomical work, which had been affiliated with the Nautical Instruments Section, has greatly increased, it was deemed proper in 1954 to raise its status to that of a section to be known as the Astronomical Section. The prime object of this section is to determine the time. In 1939 the Hydrographic Department bought a transit instrument of 100 mm objective and two Reifler pendulum clocks from Germany in order to form a time service for the ships of the Royal Thai Navy. These instruments have been serving as the time determination unit ever since. Nowadays, pendulum clocks are inferior to quartz crystal clocks in many respects. Moreover, the Hydrographic Department lacks personnel to handle this work; therefore, time determination has been temporarily discontinued for the past few years. We hope to have a sufficient number of observers and enough quartz crystal clocks to resume this work in the very near future.

Although the main task of this section has been temporarily suspended, it still computes astronomical data for the Royal Almanac every year with the aid of the advanced proofs of the British Nautical Almanac. Moreover, some information on local astronomical phenomena is furnished by this section.

On 14 December 1955, astronomers of the Hydrographic Department set an observation spot on the east coast of the Gulf of Thailand to observe the annular eclipse. The time of contacts was taken by a camera attached to a telescope of about 300 mm focal length, synchronized by chronometer.

This year the Navy has ordered a Coudé refractor of 150 mm objective from the Federal Republic of Germany to be installed at the observatory of the Naval Academy. This telescope will be used for teaching astronomy to the cadets. It will also be used for joint research work by the Academy and the Hydrographic Department.

Chart Revision

The Hydrographic Department produces nautical charts of Thai waters only, but it has maintained a supply of foreign charts for distribution to naval vessels operating in foreign waters. Charts of both categories are subject to frequent changes of nautical information. In an effort to keep those charts up to date, corrections have to be made in accordance with Notices to Mariners or any other reliable source prior to the next edition, if any. For Thai charts, revisions have to be made either on the zinc plates or on the negatives of the originals, or, in some cases, new originals must be prepared.

Nautical publications are treated in the same way.

Notices to Mariners

Notices to Mariners, issued monthly by this office, primarily serve to supply navigators with carefully prepared and printed information for use in navigation. The secondary objective of the Notices is to serve as a medium through which exact corrections to the charts and publications may be carried out on board.

Urgent Notices are broadcast following the weather report by the Government Broadcasting Stations.

Nautical Instruments

The Hydrographic Department is also responsible for the supply, testing, adjustment and repair of nautical instruments used on board naval vessels, including optical instruments such as binoculars and timepieces. Facilities for repairing and testing are inadequate, but plans have been made for the future expansion of the work in this field.

A nautical instrument school was established a few years ago for the purpose of giving instruction on the operation, care and maintenance of nautical instruments, but at present only two courses, in the use of the gyro-compass, are given. They are the operator's course and the technician's course, which take two and twelve weeks, respectively. The technician's course will be open only to electricians' mates.

Lights and Beacon Service

Submerged or partly visible rocks are menaces to navigation in all navigable areas, especially those located on traffic routes frequently used by merchant ships. To assist mariners in making landfalls when approaching from overseas, and also to assist them in identifying and distinguishing isolated dangers, several types of marks have been established. These marks or guides are commonly called aids to navigation. As all aids serve the same general purpose, such structural differences as those between an unlighted buoy or lighted beacon are solely for the purpose of meeting the conditions and requirements of the particular location at which the aid is to be established. Our department is responsible for the operation of many lighthouses, lighted and unlighted buoys, and beacons in the Gulf of Thailand. These aids are accurately charted and catalogued. Our List of Lights and Buoys contains all aids to navigation, with detailed descriptions and geographical positions of each. A small workshop is also maintained for some minor repair work.

The future programme will provide for the establishment of new lighted beacons and the building of a special ship for this service.

Hydrographic Investigation

To keep pace with new developments and techniques, investigation and research in both the theory and practice of hydrography, oceanography and related subjects are carried out to find new procedures and techniques. Studies of equipment and instruments, including experiments, are also included.

A library of technical books, instruction books, manuals and scientific papers is maintained and is always accessible to all officials. Any material of interest is translated and disseminated to the various divisions and sections directly concerned.

Communication with the International Hydrographic Bureau, as well as technical correspondence with other hydrographic offices or scientific institutions, will be handled by this Department and any recommendations from them will be submitted to the Director.

Our future programme includes the procurement of the necessary facilities and equipment for making photostatic copies and facsimiles of all kinds of illustrations, diagrams and charts. Extensive study on electronic equipment used in hydrography, oceanography and navigation will be started in the near future.

Surveying Vessels

Under the new organization, surveying vessels are assigned permanently to the Hydrographic Department. Care and maintenance of these vessels, including a refrigerating vessel and small fishing boats, must be undertaken by our own staff with an additional budget for the purpose. The list of vessels and boats under the direct control of this Department is as follows:

Name	*Tonnage*	*Used for*
H.M.S. *Suriya*	920	Hydrographic survey
H.M.S. *Kram*	450	Hydrographic survey
M.F.V. No. 9	490	Refrigerating vessel, used temporarily for oceanographic survey
H.V. No. 1	96	Oceanographic survey
H.V. No. 2	96	Oceanographic survey
29-foot launch	4	Sounding
F.V. No. 2	40	Sounding
F.V. No. 3	40	Sounding
F.V. No. 4	40	Sounding
F.V. No. 7	30	Sounding
F.V. No. 8	30	Sounding

Partial List of References

" Development of Hydrographic Work in Thailand ", by Rear-Admiral Luang Joldhan Brudhikrai, Director, Hydrographic Service (lecture delivered at the Fifth International Hydrographic Conference in April and May 1947, at Monaco).

Survey Work in Thai Waters, from its Beginning until the Erection of the Hydrographic Department in the year 1922, by F. Thomsen (Bangkok, 1925).

" Progress Achieved by the Hydrographic Department of the Royal Thai Navy During the Last Five Years (1952-1957)", by Rear-Admiral Vicharn Desakorn, Director, Hydrographic Department, Royal Thai Navy (address delivered at the Seventh International Hydrographic Conference in May 1957, at Monaco).

Historical Information and Regulations Governing the Organization of the Hydrographic Department, by Commander Luang Samruat Vithi Smudh, Director, Hydrographic Service (November 1933).

HYDROGRAPHIC CHARTING FOR NAVIGATION SAFETY [1]

Background paper submitted by Japan

In spite of resolution XIII adopted by the first United Nations Regional Cartographic Conference for Asia and the Far East, held at Mussoorie, India, many areas in the seas of this region, including several main ports and harbours, have not yet been adequately surveyed. Again, it should be stressed that it is desirable for each Government concerned to promote hydrographic surveys of sufficient accuracy in these areas as fast as possible and to make the data available to the public even in the case of a partial survey. Japan, being interested in this question, is ready to extend technical co-operation as far as conditions permit.

[1] The original text of this paper appeared as document E/CONF.25/L.26.

SPECIAL CHARTS FOR THE EXPLOITATION OF SEA RESOURCES AND FOR MARINE CONSTRUCTION WORKS [1]

Background paper submitted by Japan

Nowadays, hydrographic data are extensively utilized for economic and scientific research as well as for navigation. In this connexion, the Japanese Hydrographic Office has prepared several kinds of charts which will be studied below. It is desirable for all countries having equal interest to compile the same kinds of charts and to exchange them among themselves to their mutual benefit.

Fisheries charts

Three kinds of fisheries charts are published to meet the demands of fishery enterprises.

(1) Planning charts for pelagic fishery (1 : 4,500,000).

These cover, with three sheets, the sea areas east and south of Japan, in which most of the Japanese fishing vessels operate constantly.

(2) Pelagic fisheries charts (1 : 2,000,000, 1 : 1,500,000 and 1 : 1,200,000).

These cover, with ten sheets, the areas surrounding Japan.

(3) Coast fisheries charts (1 : 500,000), eight sheets.

The special features of these charts are:

(*a*) Polychromatic printing, which is easy to read;

(*b*) Detailed contents showing varied equipment and facilities for fishing, including harbours, bases, radio stations and prohibited areas;

(*c*) Currents and character of bottoms, together with isobathic contours for showing depth, so that existence of shallow waters is clearly discerned;

(*d*) Indication of great circle routes between main bases and fishing grounds.

The fisheries charts enable fishing vessels to operate much more easily than by ordinary nautical charts, and they are also utilized by administrative authorities and fishing enterprises for planning and investigation.

Bathymetric charts

Charts showing the depths of the seas adjacent to Japan (1 : 8,120,000), and other bathymetric charts with scales of 1 : 4,000,000, 1 : 500,000, 1 : 100,000, 1 : 50,000, 1 : 20,000, 1 : 10,000, 1 : 5,000, and so on have been published, facilitating perception of the conditions of the sea bottom. These charts are not only indispensable to sounding navigation but also supply basic data for the fishing industry, for the exploitation of submarine resources and for disaster prevention.

For countries concerned with this region, the preparation of bathymetric charts with scales of 1 : 8,000,000, 1 : 4,000,000 and 1 : 500,000 would be sufficient in the beginning and their standardization could be easily worked out if undertaken from the start.

Bottom sediments charts

Bottom sediments charts (1 : 1,200,000 and 1 : 200,000), in nine colours, show the distribution of bottom sediments, such as basement rock, gravel, sand, clay and mud. These charts provide additional information required in certain projects.

Bottom geomorphological charts

Bottom geomorphological charts of the seas adjacent to Japan (1 : 8,120,000) and of the sea off Shikoku and others (1 : 500,000) have been prepared. These charts show the principal features of the sea bottom, such as trench, ridge, basin, plateau, mount, crest and valley, providing the fundamental data for geological researches.

Geomorphological charts designed for sea construction works (1 : 50,000 to 1 : 20,000) have also been prepared.

Charts of equivalent-diameter contours of sediments

Charts showing equivalent-median diameter contour of sediments and others showing equivalent-sorting coefficient contour of sediments have been prepared, which supply fundamental data about sand and mud of the sea bottom. From them can be seen the effects of tidal currents and waves on the sea bottom, and these charts are indispensable for under-sea construction works such as protection of coasts, bridging and exploitation of submarine oilfields.

[1] The original text of this paper appeared as document E/CONF.25/L.27.

ANNEX

Resolution [1] adopted by the Economic and Social Council on international co-operation on cartography : question of convening a third United Nations regional cartographic conference for Asia and the Far East

" *The Economic and Social Council,*

" *Commending* the valuable work achieved by the Second United Nations Regional Cartographic Conference for Asia and the Far East,

" *Recalling* the recommendation of the Conference that a third United Nations regional cartographic conference for Asia and the Far East be convened not later than 1961,

" *Noting* the increasing interest of Governments in participating in the work of such conferences,

" *Requests* the Secretary-General to consult the Governments of the States Members of the United Nations and the specialized agencies concerned on the convening, not later than 1961, of the third United Nations regional cartographic conference for Asia and the Far East and on the date, place and agenda of the conference, and to report to the Economic and Social Council at its twenty-ninth session."

[1] Resolution 714 (XXVII).

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