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Monitoring Active Faults in Ranau, Sabah Using GPS *

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Monitoring Active Faults in Ranau, Sabah Using GPS

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Summary

Natural hazards such as earthquakes, tsunamis, and volcanic eruptions endanger the lives of many people in tectonically active areas. Within the south east asia region, the convergence and collision of the Indo-Australian, Philippines and Eurasian plates are moving at rates of up to 10cm/year. Although Malaysia is considered as a country with relatively low seismicity, for the state of Sabah, earthquakes of local origin are known to occur from time to time. Between 1923 and 2007, it has been reported that a total of 65 earthquakes with magnitudes ranging from 3.3 to 6.5 on Richter scale had occurred. In an effort to better understand the geodynamic process in Sabah, the Department of Survey and Mapping Malaysia (JUPEM) and the Department of Minerals and Geoscience (JMG) cooperated in the establishment of a GPS network in Ranau. Both government agencies are members of the Geodetic Working Group (GWG) that was established under the auspices of the National Committee on Mapping and Spatial Data (JPDSN), chaired by the Director-General of Survey and Mapping.

The Ranau GPS Campaign 2010 was conducted in three epochs for the purpose of studying the tectonic behaviour of the area by determining the magnitudes and directions of the movement of active faults. The network comprises 19 new stations and five Malaysian continuously operating reference stations. This paper describes the GPS campaigns that had been carried out by the Geodesy Section of JUPEM. The study is based on the station coordinate changes between three epochs estimated in terms of the ITRF2008 coordinates.

The complete processing and analysis of the GPS observations were performed using Trimble Total Control software and also version 5.0 of the Bernese GPS software by the three independent analysis groups. Comparison between the three sets of final coordinates of the Ranau GPS Campaign 2010 suggests that displacements at a few mm level to up to 3-5cm occurring in stations located in the Mendasan and Lobou-Lobou fault zones. There is indication from the results that the displacements are caused by either the surface motion, active faults or a combination of both. This paper concludes that more GPS observations involving additional stations are needed in order to verify station motions and obtain a better understanding of the tectonic behaviour, thus paving the way in mitigating seismic hazards in Ranau.

Monitoring Active Faults in Ranau, Sabah Using GPS

[1]Azhari bin Mohamed

Introduction

Natural hazards such as earthquakes, tsunamis, and volcanic eruptions endanger the lives of many people in tectonically active areas. Within the south east asia region, the convergence and collision of the Indo-Australian, Philippines and Eurasian plates are moving at rates of up to 10cm/year. Using GPS data collected at 17 Malaysian continuous operating reference stations and 11 IGS stations from the year 1999 to 2002, it has been shown that the block is moving approximately 3 cm/year in a south-east direction (Figure 1).

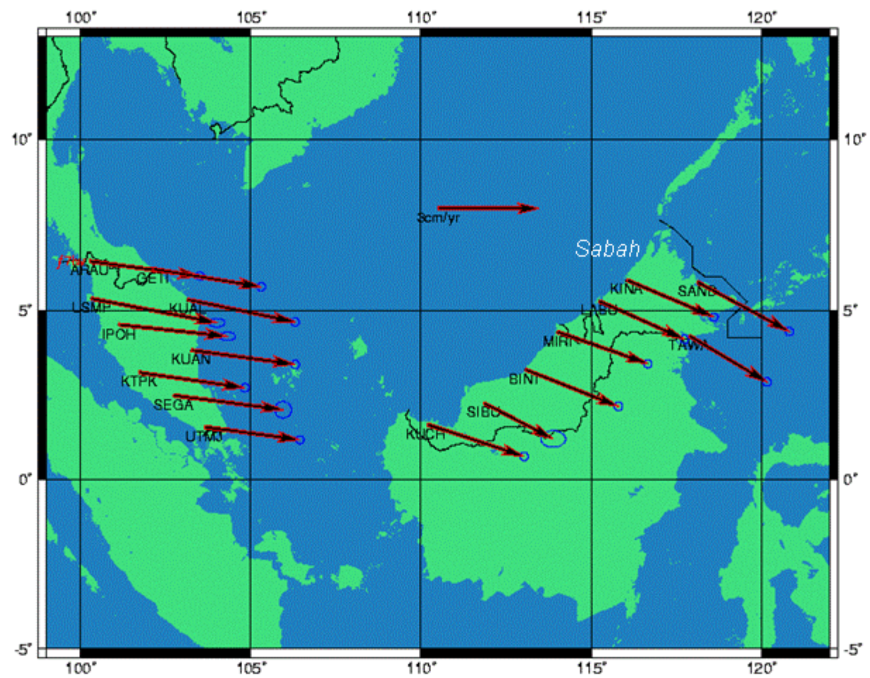

Figure 1: Computed motion vectors of Malaysian CORS stations (1999 - 2002)

Malaysia is considered as a country with relatively low seismicity. However, for the state of Sabah, earthquakes of local origin are known to occur from time to time. It was reported that between 1923 and 2007, Sabah had experienced a total of 65 earthquakes, with magnitudes ranging from 3.3 to 6.5 on a Richter scale. Although the motion of the Sundaland block is currently known in the global context relatively well, the differential movements along the differential fault lines have not been charted in a consistent way. In an effort to better understand the geodynamic process in Sabah, the Department of Survey and Mapping Malaysia (JUPEM) and the Department of Minerals and Geoscience (JMG) cooperated in the establishment of a GPS network in Ranau. Both government agencies are members of the Geodetic

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[1] Department of Survey and Mapping Malaysia (JUPEM)

Working Group (GWG) that was established under the auspices of the National Committee on Mapping and Spatial Data (JPDSN), chaired by the Director-General of Survey and Mapping.

The Ranau GPS Campaign was carried out for the purpose of studying the tectonic behaviour of the area by determining the magnitudes and directions of the movement of active faults. The network comprises 19 new stations and five permanent GPS stations. This paper describes the GPS campaigns that had been performed in 2010 by the Geodesy Section of JUPEM and the associated results. The complete processing and analysis of the GPS observations were performed by the Geodetic Working Group. The study is based on the station coordinate changes between three epochs estimated in terms of the ITRF2008 coordinates.

Tectonic Setting of Sabah

Malaysia is located on a relatively stable Sundaland block which forms the southern edge of the Eurasian plate. Sundaland block is affected by the continental collision between India and Asia. This block includes not only Vietnam, Thailand and Malaysia but also the Sunda shelf, Borneo, Sumatra and Jawa. Of particular interest is the triple junction area where the convergence of the Eurasia and Australia continental plates with the Philippine Sea/Caroline/Pacific oceanic plates occurs.

Figure 2 shows some of the major faults that can be found in western Sabah (MOSTI, 2009). Sabah is located in the north of the isle of Borneo. Ranau is one of the major tourist town in Sabah where Mount Kinabalu, the highest mountain in south east asia, stands. In the area between Ranau and Mount Kinabalu, there exist at least two active regional fault zones that intersect each other. The Mensaban fault system in

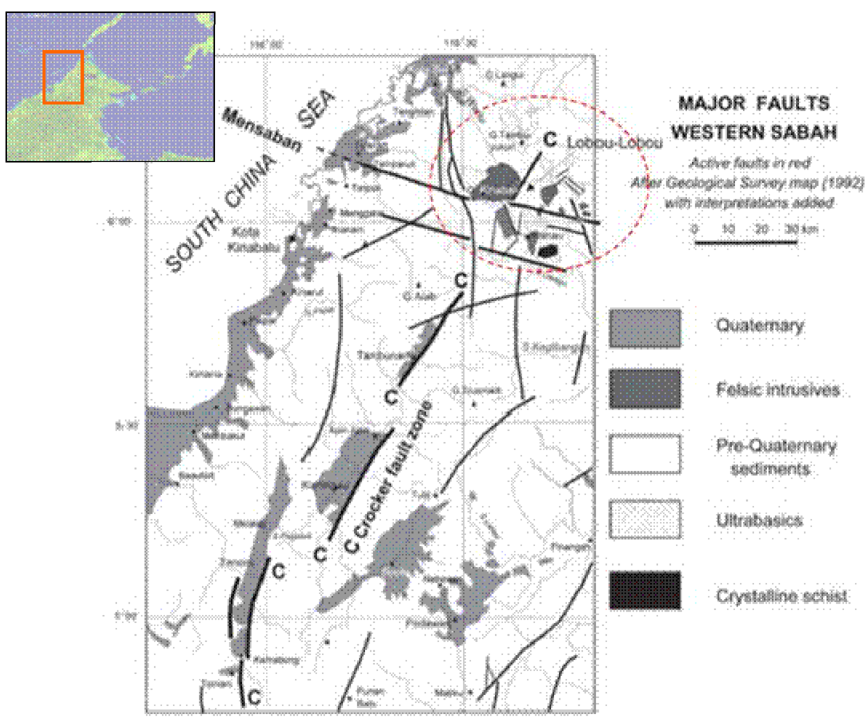

Figure 2: Major faults in western Sabah (MOSTI, 2009)

Kundasang, Ranau runs generally in the west-north-west to east-south-east direction and it is 12 km wide over a distance of 110 km from Tuaran towards east and into the interior of Sabah.

Recent studies have shown that earthquakes in Ranau area are attributable to the two intersecting faults i.e. Mensaban and Lobou-Lobou. These fault zones are active and past earthquakes and ground deformation have resulted in extensive damage to infrastructures in the area, specifically to schools and teachers' quarters (Figure 3).

Figure 3: Infrastructures affected by active faults in Kundasang, Ranau

Station Selection, Monumentation and Network Design

Station selection and monumentation were carried out after consultation with geologists from the JMG. The choice of site and monumentation is of particular importance as the stations will be used periodically. The design of the network is a compromise between the length of observation, accessibility, geological conditions, stability, security and logistics. The final locations of the new stations were carefully selected so that they cover the main geological features and active fault systems in the area.

The Sabah Topographical Section contributed the majority of the field crews in the operational activities during the monumentation stage. Auger instrument was used to bore the ground and measure the depth to the bedrock below the ground surface. A concrete monument was then prepared to mark the new station for GPS observation (see Figure 4). The monumentation for 19 new stations was carried out from 11 - 20 October 2009.

Figure 4: The process of monumentation

Description of GPS Campaign

It would be desirable to have a full network of continuously operating GPS stations established in the area of interest to obtain the best results. However, this may prove not only to be an expensive option, but also difficult to operate especially in areas lacking in the necessary infrastructure. As such, campaign style GPS observation is a reasonable alternative.

In the Ranau GPS Campaign 2010, the GPS observations were performed by the joint teams from the Geodesy Section and Sabah Topographical Section in three epochs, i.e. from 19 - 20 February, 22 - 23 June and 16 - 22 December (Figure 5). The GPS observational periods of 24 hours ran simultaneously at all stations during the first and third epochs, whilst for the second epoch, the observational period was 8 hours.

All daily sessions commenced at 0.00 hours UTC with a short break for data downloading, transfer and back-up at the end of each session. All stations were occupied with dual frequency GPS receivers with data recorded at an elevation cut-off angle of 10 degrees and a sampling rate of 15 seconds.

Overall, the GPS campaign had been highly successful, providing three unique sets of observations. The time intervals between epochs were four and six months which should be able to give an initial indication of the estimates of the tectonic motions in the area.

Figure 5: GPS observation at one of the station

Data Processing and Results

The complete processing and analysis of the GPS observations were performed using Trimble Total Control software and also version 5.0 of the Bernese GPS software by the Geodetic Working Group (GWG). The softwares form baselines from pairs of stations based on the shortest distance, as shown in Figure 6.

It was decided that GWG adopt an approach by which each different groups as listed below would compute its own independent solutions, using its favoured GPS processing softwares and different analysis strategies. This approach would provide an excellent basis for a reliable quality assessment for the independent results. In total, the following three groups participated in the data processing and analysis:

- Geodesy Section, Department of Survey and Mapping Malaysia (JUPEM)
- Faculty of Geoinformation Engineering and Sciences, Universiti Teknologi Malaysia (UTM)

- o Department of Infrastructure and Geomatic Engineering, Universiti Tun Hussein Onn Malaysia (UTHM)

JUPEM was appointed as the coordinating geodetic analysis group. It also assumed responsibility for the GPS data distribution and the overall data analysis effort. A point of concern was the use of different strategies by the three groups during the GPS data processing that have given rise to principal differences between the results obtained. Each group applies different data reduction algorithms and modelling techniques. As such, a technical workshop involving the three groups was held on 8 - 11 December 2010 to discuss a common strategy to be adopted.

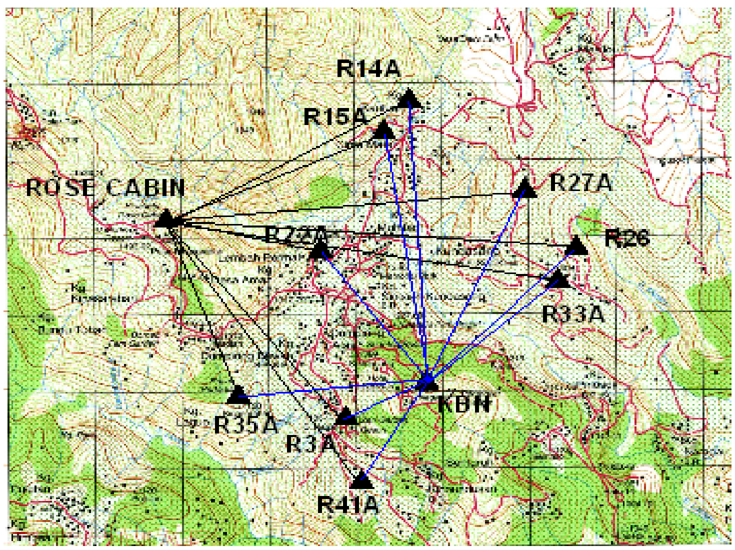

Figure 6: Baselines observed on 23 June 2010

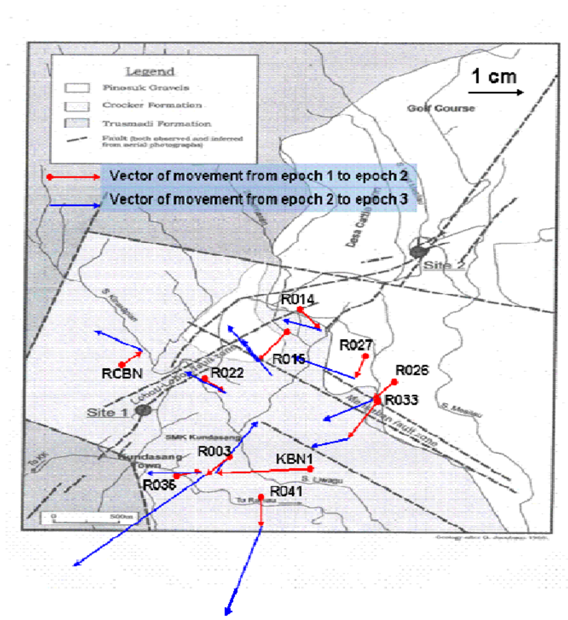

Figure 7: Computed vectors for each two epochs

As shown in Figure 7, comparison between the three sets of final coordinates of the Ranau GPS Campaign 2010 suggests that displacements at few mm level to up to 3-5cm occurring in stations located in the Mendasan and Lobou-Lobou fault zones. There is indication from the results that the displacements are caused by either the surface motion, active faults or a combination or both.

Conclusions

Natural hazards such as earthquakes, tsunamis, and volcanic eruptions endanger the lives of many people in tectonically active areas. Within the south east asia region, the convergence and collision of the Indo-Australian, Philippines and Eurasian plates are moving at rates of up to 10cm/year. Although the motion of those plates are currently well known in the global context, the differential movements along the local fault lines have not been measured in a consistent way.

The Ranau GPS Campaign 2010 was successfully carried out by observing a 24-station GPS network in three separate epochs to study the tectonic behaviour of the area. In this paper, the conduct of the GPS campaign and the geodetic results have been highlighted. Comparison between the three sets of final station coordinates suggests that displacements at few mm level to up to 3-5cm occurring in stations located in the Mendasan and Lobou-Lobou fault zones.

It is recommended that additional GPS observations be conducted on the network with additional new stations in order to not only maintain and monitor the evolution of the network but also to better understand its tectonic behaviour, thus paving the way in mitigating seismic hazards in Ranau.

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