ACTIVE FAULTS MAPPING USING REMOTE SENSING AND GIS TECHNIQUE: A CASE STUDY OF BUKIT TINGGI AND BENTONG-KARAK AREA, MALAYSIA

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ABSTRACT: Active faults are the most common source of earthquakes and tectonic movements. About more than 50 local earthquake occurrences were recorded in Bukit Tinggi and Bentong-Karak areas in Peninsula Malaysia. Therefore this study was carried out to identify active faults in these areas and to locate strategic sites for establishing monitoring stations. The application of topographic maps, aerial photographs, Shuttle Radar Topographic Map (SRTM) images and Interferometric Synthetic Aperture Radar (IFSAR) for the study areas was utilized to identify fault zones or fault traces. In addition ground surveys were conducted to verify potential active faults. This study shows that in Bukit Tinggi area the well-known NW-SE trending left lateral strike-slip fault Bukit Tinggi Fault Zone have been further refined comprising of four active fault segments, trending NW-SE, NNW-SSE, E-W and NE-SW. Meanwhile in the Bentong-Karak area two N-S trending right lateral strike-slip fault zones have been identified, named the Karak Fault Zone and Benus Fault Zone. Some of the geomorphic features picked up on remotely-sensed data and in the field shows several primary and secondary neotectonic features or landforms, such as steep-sided Quaternary alluvium, triangular facet, fault scarp, stream off-sets, stream shifting and beheaded streams. At least 10 monitoring stations have been proposed for the Bukit Tinggi and Bentong-Karak area. These stations are located where there are settlements for easy deployment and monitoring. Result of this study can be used as reference for future studies which focus on detailed characterization of critical active fault lines identified using geophysical methods, trenching and high resolution Digital Elevation Model of LiDAR that cover a larger geographical area.

1. INTRODUCTION

An active fault is defined as a fault which had manifestation of activity during the geologically period of Holocene (< 10 ka), and late Pleistocene (the past 100-130 ka) (Trifonov and Machette, 1993). Active fault segments are the most potential earthquakes sources (Kuria et al, 2010), tectonic movements and considered to be a geologic hazard. The location of active faults in Malaysia is still not clearly defined and established due to the limited number of studies carried out (Rahim et al., 2015). Shuib (2009) found that the seismic epicentres appear to coincide with reactivation of the N-S faults and NW-SE trending Bukit Tinggi and Kuala Lumpur fault zones. Meanwhile the seismic activities in the Bukit Tinggi area attributed the tremors to reactivation of ancient faults in the area (JMG, 2012). According to Lat and Ibrahim (2009), these may resulted in numerous minor and micro earthquakes in Bukit Tinggi area, with no ground motion or major disasters were recorded.

Generally, Malaysia is considered as tectonically stable with low seismicity profile (Wah, 2011) except for the state of Sabah. Peninsular Malaysia is situated close to the most active plate boundary between the Indian-Australian Plate and the Eurasian Plate. Peninsular Malaysia sitting on the Sunda Shelf lies passively behind the active Sumatra Fault Zone and Sunda Trench Subduction Zone. GPS measurements indicate rates of movements of between 2-5 cm/yr. along the Sumatra Fault Zone. Major large earthquakes that originated along the Sumatra fault and the subduction fault offshore of Sumatra have resulted in tremors being felt in Malay Peninsula (Balendra et al., 2001) with maximum intensity up to VII on the Modified Mercalli Intensity (MMI) scale.

In Peninsular Malaysia, consists of several major fault lines such as Bok Bak Fault, Lebir Fault, Terengganu Fault, Bukit Tinggi Fault, Kuala Lumpur Fault, Lepar Fault and Mersing Fault with the NW-SE trending faults (JMG, 2006). They are mainly sinistral strike-slip with significant dip-slip components as shown by quartz dykes along their length with the ages of faulting are not younger than 43 - 45 million years, or Eocene (Harun, 2002).

Generally, the major fault in the Malay Peninsula appeared to be inactive. About more than 50 local earthquake occurrences were recorded in Bukit Tinggi and Bentong-Karak areas in Peninsula Malaysia. According to MMD (2011), Peninsular Malaysia has felt tremors from local origin earthquakes (e.g., Bukit Tinggi Earthquakes, Kuala Pilah Earthquakes, Manjung Earthquake, Jerantut Earthquake and Terengganu Earthquake). The series of seismic activities is believed as preliminary indications of the reactivation of major faults in Peninsular Malaysia. Based on the associated seismic activities it is believed that major faults like the Bukit Tinggi Fault, Lepar Fault and Seremban Fault zone have been reactivated and can be reclassified as active faults (Rahim et al., 2015).

The objective of this study is to identify active faults in tectonically active area, determine critical active fault for monitoring and determine location monitoring stations.

2. METHODOLOGY

The study was carried out in Bukit Tinggi and Bentong-Karak is in the district of Bentong in Pahang state, Malaysia. It is located 50 km from the capital city of Kuala Lumpur which accessible by the expressway. The Bukit Tinggi town is famous with the cool weather and its serenity. The location of study area is shown in Figure 1. The geology of the study area consists of granite, schist, phyllite, slate, limestone, interbedded sandstone and alluvium. The granites are predominantly light grey to grey, coarse to medium grained biotite with porphyritic texture (JMG, 2014).

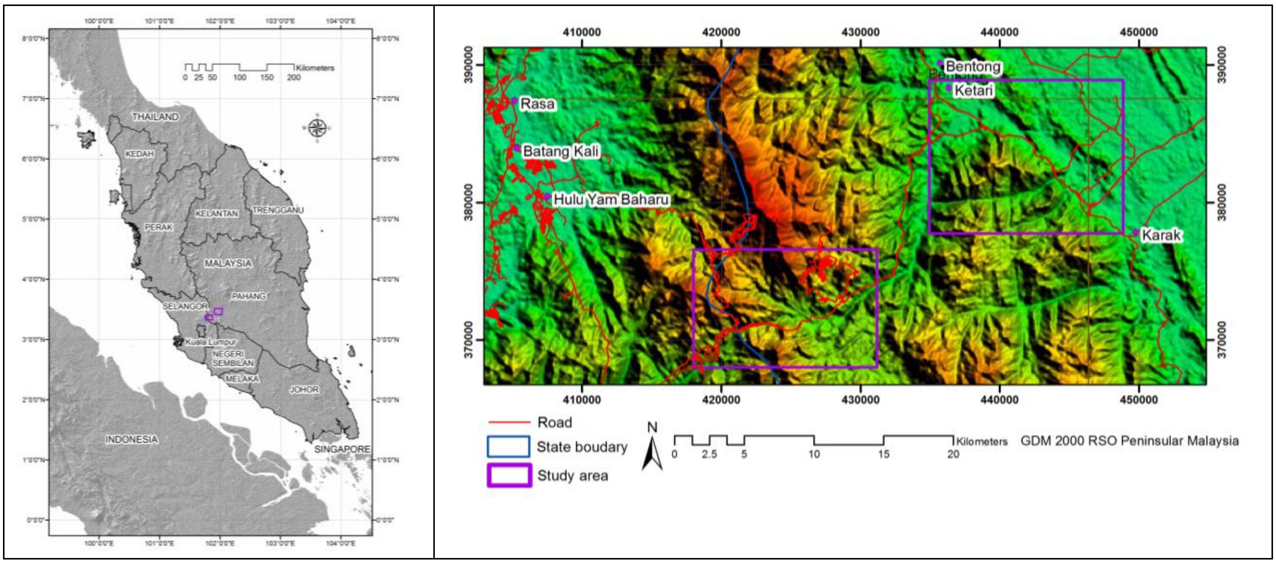

Figure 1: Location of the study area

This study integrates multi-disciplinary approach using geomorphological, structural and neotectonism in evaluation of active tectonics. Active faults can be recognized by using geomorphic evidence (Figure 2). Remote sensing plays a significant role in providing spatial information needed for the analysis. Remote sensing approach also is the most common and inexpensive approach for fault studies (Songmuang et al., 2007). Remotely sensed data sets include Landsat TM and SPOT-5 was used to understand geological setting as well as mapping water bodies of study area. Additionally, evidence of active fault which can only be seen from detail investigation of land surface was derived from medium and fine resolution of satellite imagery.

Digital Elevation Model (DEM) of 90m grid from Shuttle Radar Topographic Map (SRTM) data and 5m grid from Interferometric Synthetic Aperture Radar (IFSAR) data therefore were utilised to develop hill shading (Oguchi et al., 2003) using ArcGIS software for completing the identification of an active faults.

IFSAR Ortho-Rectified Image (ORI) with 0.62 m spatial resolution and SPOT-5 with 2.5 m spatial resolution were the main data used for detailed interpretation of fine geological features including river polar, triangular facet and sigmoid shape valley. All these features give strong indication that active faults are present within the study area. Field verification was carried out to observe field evidence of the active faults (e.g. recent earth movements such as scarps, damaged roads, landslides, mud volcanoes, hot springs etc.) and to locate potential monitoring sites.

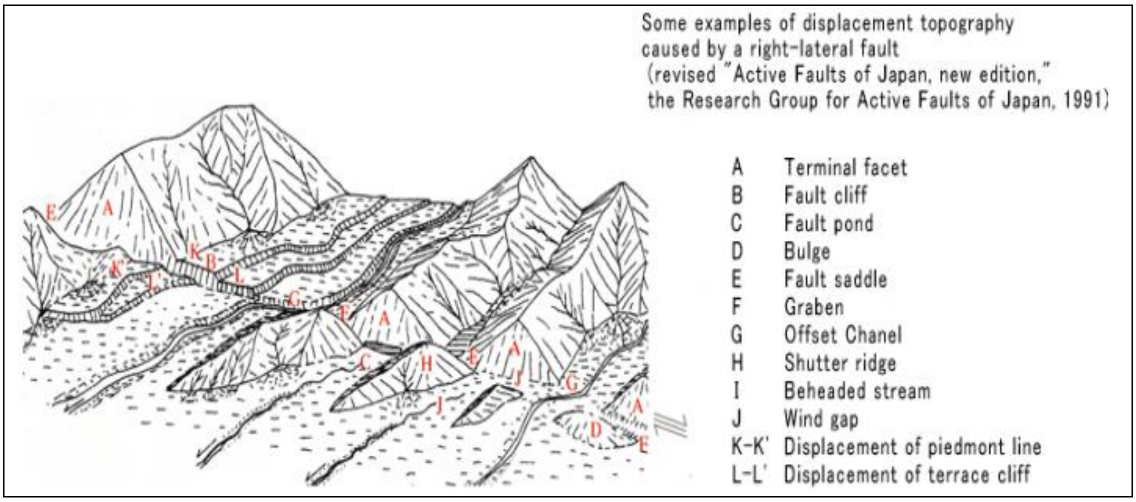

Figure 2: Geomorphic evidence for active faults

3. RESULTS AND DISCUSSION

Based on the SRTM data interpretation shows that Bukit Tinggi fault zone forms a fault zone about 7 km wide with the fault strikes 310^{O} to 325^{O}. Major faults trending NW-SE, NE-SW and N-S in the Bukit Tinggi area. In addition several of the earthquake epicentres are aligned parallel to the orientation of the Bukit Tinggi fault zone, which is northwest, and other epicentres follow the northerly Karak fault trend and NE smaller lineaments (Figures 3).

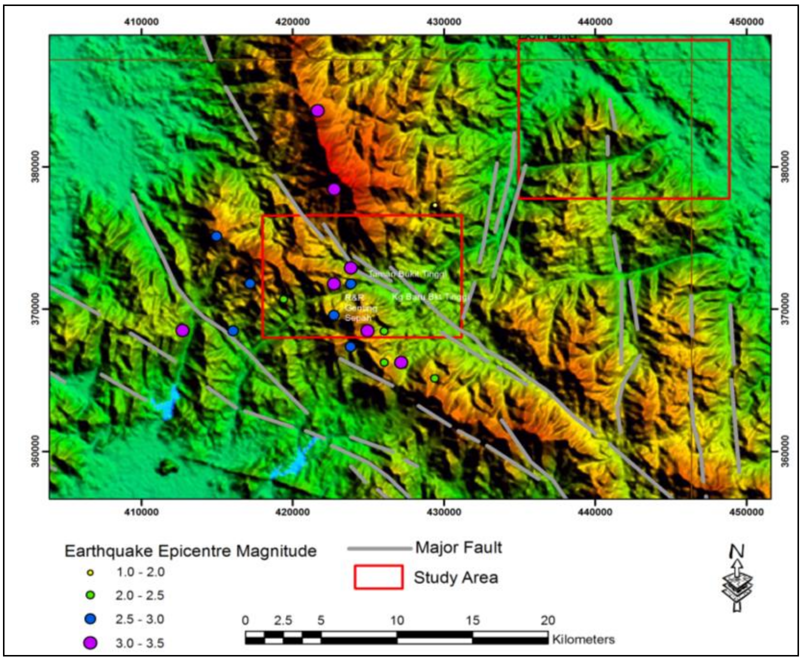

Figure 3: Major faults trending NW-SE, NE-SW and N-S in the Bukit Tinggi area.

IFSAR image interpretation shows several well defined morphotectonic landforms such as steep-sided Quaternary alluvium, stream off-sets, stream shifting and beheaded streams (Figure 4). In Bukit Tinggi area the Quaternary alluvium basins trend NW along the Bukit Tinggi Fault Zone. Stream off-sets occur at several places along Sg. Tanglir. The stream has been shifted for about 500 m to form the dog-leg pattern. The offset line is generally extended on both sides along negative lineaments of about 5 km long, bounded by triangular facets with hour glass geometry, typical of active faulting. The offset pattern shows sinistral strike-slip active faulting. The beheaded streams are defined as several distributaries streams that were offset along an offset line and shifted into a single major stream.

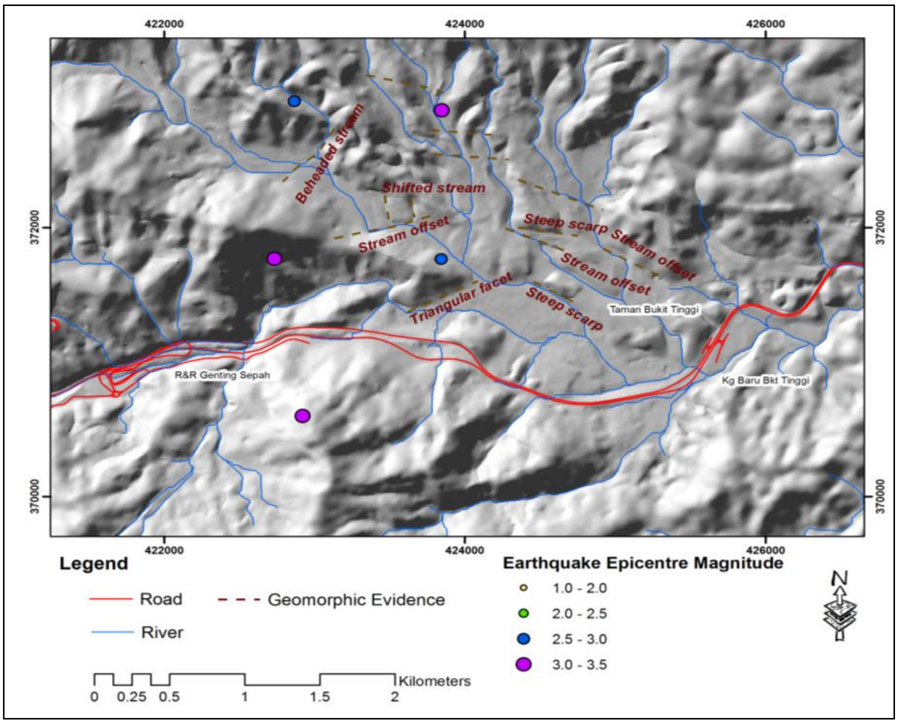

Figure 4: The distribution of geomorphic evidence along the Bukit Tinggi fault zone.

The presence of active NW-SE trending faults has been observed near Bukit Tinggi town associated with steep escarpment, deformed Quaternary deposit, abandoned sigmoidal stream and linear scarp. The steep escarpment and deformed alluvium occur along Sg. Tanglir near Taman Bukit Tinggi. A sigmoid-shape stream (Figure 5) occurs further west of Bukit Tinggi town indicating some form of drag due to NW-SE shearing along the Bukit Tinggi Fault Zone.

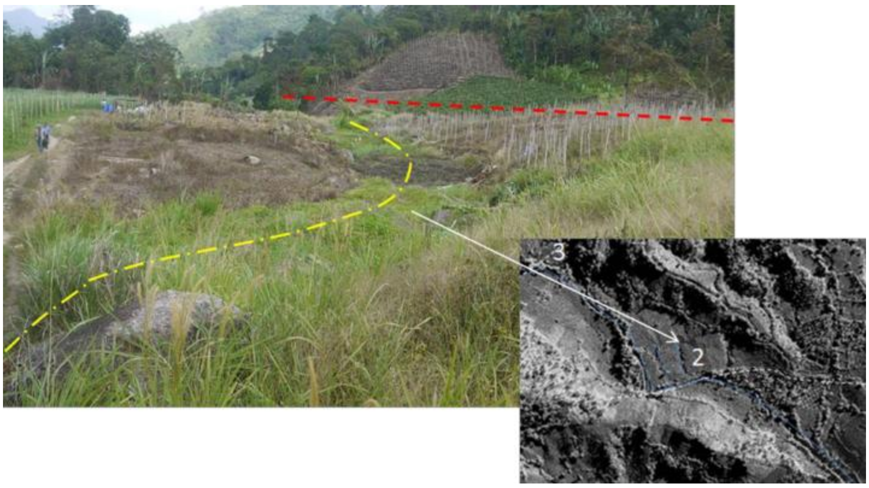

Figure 5: Sigmoid shape stream.

Remote sensing interpretation together with ground truth field survey indicate that the Bukit Tinggi Fault Zone is an active NW-SE strike-slip fault showing sinistral (left lateral) movement comprising of at least four segments, trending NW-SE, ENE-WSW, NNESSW and E-W. Meanwhile both the N-S trending Benus Fault and Karak Fault within the Bentong-Karak area fault zones are also active. A minimum of 10 monitoring stations are proposed for the Bukit Tinggi and Bentong-Karak area. These stations are located where there are settlements for easy deployment and monitoring (Rahim et al., 2015).

4. CONCLUSION

In conclusion, this study demonstrate the suitability of modern remote sensing images coupling with field surveys analysis for better understanding of active faults in tectonically active areas in Malaysia. In addition, result of this study can be used as reference for future studies which focus on detailed characterization of critical active fault lines identified using geophysical methods, trenching and high resolution Digital Elevation Model of LiDAR that cover a larger geographical area.

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