Active Faults In Peninsular Malaysia With Emphasis On Active Geomorphic Features Of Bukit Tinggi Region

Mustaffa Kamal Shuib, Mohammad Abdul Manap, Felix Tongkul, Ismail Bin Abd Rahim, Tajul Anuar Jamaludin, Noraini Surip5, Kabie AB Bakar, Mohd Rozaidi Che Abas, Roziah Che Musa, Zahid Ahmad

1Department Of Geology, University of Malaya, 50603 Kuala Lumpur:Minerals and Geoscience Department Malaysia, Headquarters Bangunan Tabung Haji, Jalan Tun Razak, 50658 Kuala Lumpur:School of science and technology, Universiti Malaysia Sabah, 88999 Kota Kinabalu, Sabah:School of Science and Technology, UCSI University, 56600 Kuala Lumpur:Malayian remote Sensing Agency, Jalan7 Tun Ismail, 50480 Kuala Lumpur:Malaysian Meteorology Department. Jalan Sultan, 46667 Petaling Jaya, Selangor.

This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ARTICLE DETAILS

ABSTRACT

In this paper, we summarize the results of recent geomorphic investigations of active faults in Peninsular Malaysia with emphasize on Bukit Tinggi region using IFSAR and field verification. The evidences for active faulting, and their characteristics are discussed. Several fault segments within in the Bukit Tinggi fault zone are deemed active. The Bukit Tinggi fault zone is considered to be active and is a potential source of future earthquakes. Outside Bukit Tinggi area, the Benus and Karak faults are also deemed active. These fault zones show the following active neotectonic geomorphic features: 1) displays geomorphic features indicative of recent fault activity; 2) show evidence for displacement in young (Late Quaternary) deposits or surfaces; and/or 3) is associated with a pattern of microearthquakes suggestive of an active faults. They were ancient faults that were reactivated in the Quaternary period and continued into the present. The magnitude of palaeoearthquake estimated from the activity and stream offsets suggest a minimum of 6 magnitude on the Richter scale. In Peninsular Malaysia, recent studies (e.g., JMG, 2008 and 2012) concentrated on the relationship of earthquake epicentres to geomorphic lineament expression of faulting, and the comparison with the features observed along active faults. These factors result in a lack of recognizable, long-lived surface faulting geomorphic features. Despite these shortcomings, Quaternary deformation investigations in Peninsular Malaysia have been successful and indicate that it is ongoing and that these activity may pose a seismic hazard (e.g., JMG, 2008 and 2012). Lacking a well-defined Quaternary framework for Peninsular Malaysia, recent studies (e.g., JMG, 2008 and 2012) concentrated on the relationship of earthquake epicentres to geomorphic lineament expression of faulting, and the comparison with the features observed along active faults. These factors result in a lack of recognizable, long-lived surface faulting geomorphic features.
The fractures in the basalt are essentially vertical and are evident manifestations of reactivation of the older faults. In Southeast Johor at the edge of the Penyu basin, crustal uplift of 0.5 - 0.8 m during the past 5000 years is suggested by an abrasion platform that is much higher compared to the eustatic Holocene sea-level curve of the Peninsula which was established from almost a hundred radiometrically determined bio-shoreline indicators. In the northwest on the shores of Langkawi, a 2500-year old abrasion platform is cut by a long fault zone whose associated secondary structures suggest sinistral displacement.

**Active major faults**

Generally, major fault in the Malay Peninsula (Figure 1) appeared to be inactive. However, a series of large earthquakes in recent years had changed the tectonic scenario in the Southeast Asian region, including the Peninsular Malaysia. In spite of its crustal stability, the 2004 Sumatra earthquake had caused horizontal shifts of GPS monuments in the Peninsula in the order of up to 7 mm. There are also indications of co-seismic uplifts. In Langkawi, stacked doublets of recently live specimens barnacle-oyster bands suggest uplift in the order of half a meter by the same event. The Malay Basin region offshore the Peninsula is on stable crust, and yet seismic shows major, deep-reaching faults to approach the seabed to within 150 m, indicating activity on these structures to have persisted into the Pleistocene.

A series of seismic activities with local epicentres (Figure 1) occurred in the peninsular since 1978. From 1978 to 2006 Peninsular experienced local earthquakes up to 4.6 Mw (IRIS Earthquake Database). From 2007 to 2010 it experience earthquakes up to 4.2 Mw (MMD). The series of seismic activities is believed as preliminary indications of the reactivation of major faults in Peninsular Malaysia. Therefore, many believed that the reactivation of the faults system in Peninsular Malaysia was associated with the great Sumatra-Andaman Earthquake (26 December 2004), Nias Earthquake (28 March 2005) and Bengkulu Earthquake (12 September 2007). Subsequently, local earthquakes that had occurred in Bukit Tinggi (between 30 November 2007 to 25 May 2008), Jerantut (17 March 2009), Manjong (29 April 2009) and Kuala Pilah (29-30 November 2009) were associated with these events. Recently, the Southern Sumatra Earthquake that occurred on 30 September 2009 had reactivated the Bukit Tinggi Fault system, and caused a series of 7 weak local earthquakes around the Bukit Tinggi area (8 October and 4 December 2009). Another weak tremor of 2.6 magnitude was recorded on 10 March 2010 at 11.10pm local time, at Taik Kenyir area at latitude 5.1°N and longitude 102.8°E, 43km southwest of K.Teningganu, 22 km west of Kuala Berang.

A plot of the earthquake epicentres on the regional fault maps of Peninsular Malaysia is shown in figure 1. The epicentres appear to be diffusely distributed throughout the Peninsular, typical of intraplate seismicity. However in a closer look they seem to be close to and aligned along major faults. The epicentres are aligned along the NNW-SSE lineaments that define a terraced topography (figure 10). When superimposed on lineament and fault maps (Figure 8 - 10), it is noted that the steep-sided basins are bounded by steep scarps. In Bukit Tinggi the basin trend NW along the Bukit Tinggi fault zone. At Jerantut area there are several narrow linear sub-parallel lineaments that define the orientation and direction of the investigated active fault segments. Practically, automatic and visual interpretation was used. This is regarded as the prime and most effective approach for identification of neotectonic or active fault geomorphic features.

The following geomorphological features were picked up in the ISFAR analysis and verified in the field:

a) Primary neotectonic features/landforms

Several morphotectonic pieces of evidence can be recognized from the ISFAR data. Among them, the most outstanding features are steep-sided basins, triangular facets and steep scarps.

i) Steep-sided Quaternary alluvial basins.

ISFAR analysis reveals several pieces of morphotectonic features such as steep-sided Quaternary alluvial basins with steep and faceted scarps. Figure 8, 9 and 10 shows the steep-sided Quaternary alluvial basins as mapped based on ISFAR. In Bukit Tinggi the basin trend NW along the Bukit Tinggi fault zone. At Janda Baik area there are several narrow linear sub-parallel NE trending alluvial basins along the NE lineaments (Figure 8). When superimposed on lineament and fault maps (Figure 8 - 10), it is noted that the steep-sided basins are bounded by steep lineaments. Thus it is interpreted as fault scarps features. Within the basin the surface is cut by sub-parallel lineaments that define a terraced topography (Figure 10). These suggest that the alluvial basin is fault-controlled and have undergone internal displacements suggesting the basin infillings were subjected to internal deformation. Figure 11 shows a panoramic view of the alluvial plain bounded by steep scarps. Outcrops along the scarps reveal the presence of fine to coarse grain alluvial deposits (figure 12). These deposits contain large boulders at their base and exhibit warped bedding (figure 12A). These implied that the alluvium have undergone neotectonic deformations.

b) Secondary neotectonic features

The drainage network derived from ISFAR DEM is shown in figure 13. It shows that the main drainage pattern is flowing from NW to SE. The distributaries flowed from N-S and from W to E. From the drainage pattern it is noted that there are several places where the streams form dog-leg pattern. From the pattern it was noted that the dog-legs are due to stream off-sets, beheadments and shifting streams (figure 13 & 14).
CONCLUSIONS

In this research, it is concluded that there are several likely active faults in Peninsular Malaysia based on earthquake epicentres distribution. Present geomorphic study from satellite images and earthquake evidences clearly depicts that within the NW trending Bukit Tinggi fault zone, there are several strands of both oblique and parallel active fault segments suggesting that the main Bukit Tinggi fault is an active fault. Offsets streams also suggest active faulting along the Benus and Karak faults. They were ancient faults that were reactivated in the Quaternary period and continued into the present. The magnitude of paleoearthquake estimated from the activity and stream offsets suggest a minimum of 6 magnitude on the Richter scale have affected the region due to movements along these faults.

Over the past decades, Peninsular Malaysia has experienced mild earthquakes. Virtually all earthquakes recorded in Peninsular Malaysia are under magnitude 5.0. However, the recognition of active faults exhibiting active tectonic landforms suggests that these faults have produced damaging earthquakes before and have potential to trigger similar tremors in the future.

References

Figure 2 The relationship between earthquake epicentres with mapped fault as plotted on SRTM.
Figure 3 The relationship between earthquake epicentres with mapped faults in Bukit Tinggi area as plotted on SRTM
Figure 5. IFSAR imagery of Bukit Tinggi area with epicentres localities.
Figure 6. The relationship between epicentres and lineaments in the vicinity of Bukit Tinggi New Village interpreted from IFSAR.

Figure 7. The distance relationship between epicentres and lineaments in the vicinity of Bukit Tinggi New Village on IFSAR.
Figure 8. The distribution of alluvial basins (Qa) in the Bukit Tinggi region, bounded by lineaments interpreted as faults.

Figure 9. 3D view of the Bukit Tinggi region showing the flat lying Qa alluvial basins.
Figure 10: 3D view showing the Qa alluvial basin with terraced surface bounded by steep scarps. Note the prominent lineaments bounding the basin.

Figure 11: A photograph showing the Quaternary alluvial plain bounded by steep scarps.

Figure 12: Alluvial deposits A) with boulders at the base and B) warped bedding. (Location Taman Bukit Tinggi)
Figure 13: The distribution of various active geomorphic features and suggested sense of slip along the interpreted active fault segments along Bukit Tinggi fault zone.

Figure 14: 3D DTM of Bukit Tinggi area showing young active tectonic landforms such as stream offsets, beheaded streams and migrating streams where these offsets occur along lineaments that pass through earthquake epicentres.
Figure 15: SRTM of Bentong and Karak areas.

Figure 16: View of Karak area showing the Karak fault.
Figure 17 shows a 3D view of the active Benus fault recognized by stream offsets.