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Regional north-south Terengganu faults: Besut, Kampung Buluh and Ping-Teris

H.D. TJIA

Petronas Research & Scientific Services Sdn. Bhd.
Lots 3288 & 3289 Kawasan Institusi Bangi
43000 Kajang, Selangor

Abstract: Three major, roughly north-striking fault zones in Terengganu outcrop as multiple, each tens to hundreds of metres wide intervals of mylonite and phyllonite among unfaulted or less faulted rock sequences. Drag features and subhorizontal fault striations establish that these regional fractures: Besut fault zone, Kampung Buluh fault belt, and Ping-Teris fault zone are strike-slip faults. Lateral displacements on the first two mentioned had been left lateral, while the Ping-Teris fault zone moved in right-lateral sense. The amounts of displacement are not known. Along their strikes, the three fault zones appear to continue as the wide belt of north to north-northwest striking faults in the north-western end of the Malay basin. Total traceable map-lengths of the fault zones reach 300 km each. In the basin, these faults transect upper Miocene and older rocks, but onshore Terengganu the three fault zones are only known to be of post-granitoid age, that is post-Carnian. There is no evidence that the onshore faults were active during the Cenozoic. There is indication along the Ping-Teris fault zone that its pre-Tertiary slip sense was right-lateral, while during the Cenozoic its subsea extension in the Malay basin moved left-laterally.

INTRODUCTION

Several major, north-striking faults in Terengganu State are shown on the 8th edition of the Mineral Distribution Map of Peninsular Malaysia (Geological Survey of Malaysia, 1988). One fault runs for about 60 km along the west side of the Besut valley. Another similarly long fault cuts across the north portion of the so called "Lawit Granite" (MacDonald, 1967) and continues for some 35 km farther southward along the Pertang valley. From remotely sensed images, I independently interpreted two large, north-trending fault zones in the same region (Fig. 1, Fault zones 5 and 6; Tjia, 1989). In the northwest Malay basin offshore Terengganu and Kelantan, long north-south striking faults are dominant structures transecting Cenozoic sediments. Such faults are shown for instance in Tjia and Liew (1996). The regional north-south faults in pre-Tertiary crystalline and metamorphosed rocks of Terengganu State appear as the onshore continuations of those mapped offshore by petroleum companies. It is now known that the major faults of the Malay basin experienced lateral seesaw motions during the Cenozoic (Tjia, 1994), a geodynamic process that may be called "slide-rule tectonics". Several years ago, the interpreted onshore faults were traced and studied in the field. In addition, that study was a first attempt to determine the type of faulting and if multiple displacements were accommodated by the faults. Figure 2 shows the location of the faults to be discussed in this note. The structures are named (1) Besut fault zone; (2) Kampung Buluh fault belt consisting of two parallel deformation zones, and (3) Ping-Teris fault zone.

BESUT FAULT ZONE

The Besut fault zone was studied in the QMC stone quarry of Bukit Yong where medium grained granitoid is being excavated. The granitoid is part of the so called "Boundary Range Granite" (MacDonald, 1967). A Rb/Sr isochron for a sample from the north part of the mass correlates with 228 Ma. The K/Ar determination of mica in another sample from the vicinity of Kuala Kerai shows 227 Ma (Geological Survey of Malaysia, 1988). Both ages indicate the Carnian. Among the fractures stand out decimetre to metre wide, parallel zones of sheared granitoid with attitude 360/70 to 345/70 (strike/dip angle; Fig. 3). These shear zones alternate with about 6-metre wide intervals of more massive granitoid. During the field examination on 28 July 1993, one of Besut fault strands is represented by a 25-metre wide, more densely sheared zone in the northwest corner of the quarry (Fig. 3). The shear planes are commonly smooth. Fault striations are subhorizontal indicating that wrench motion had taken place. Sense of motion was probably left lateral as spalling flakes (see Tjia, 1972, for terminology on fault-plane markings) across the slickensides seem to indicate. In any case, lateral fault motion had been important.

The Mineral Distribution Map of the Peninsula (Geological Survey of Malaysia, 1988) shows that

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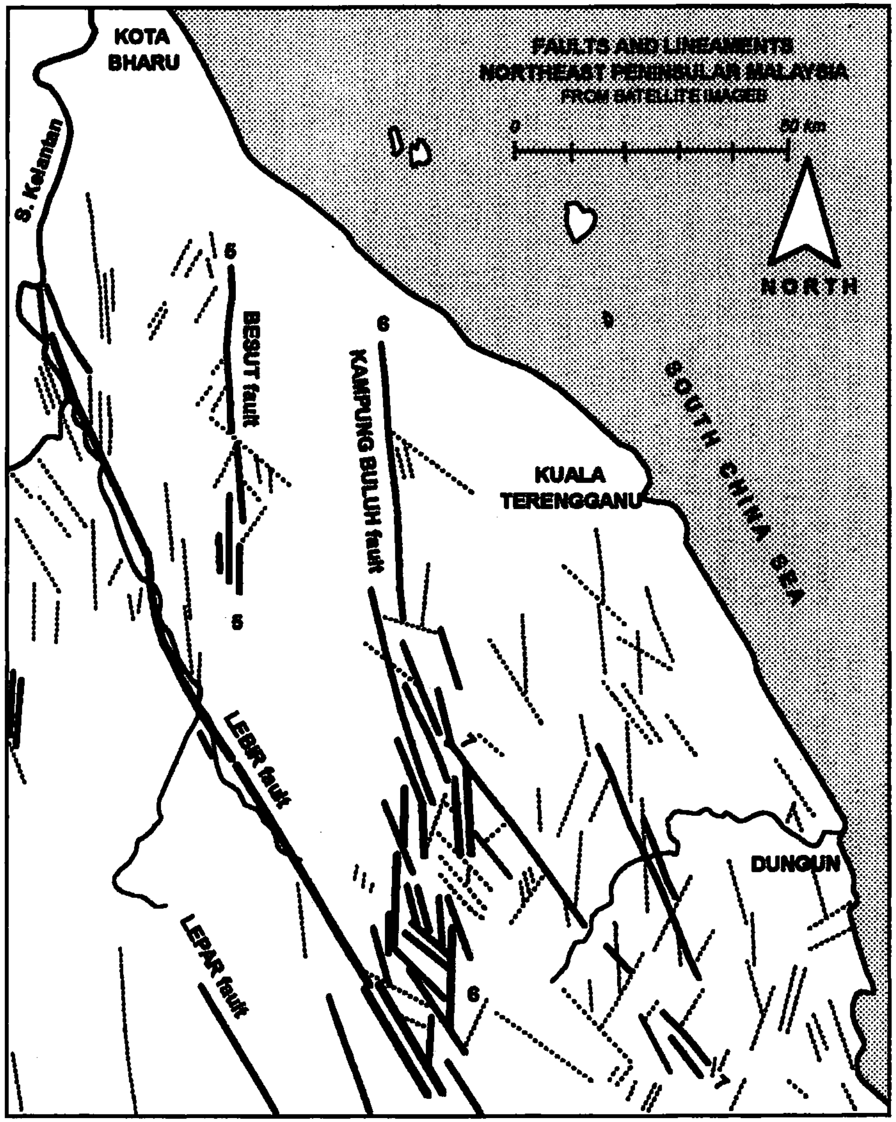

Figure 1. Major fault zones and lineaments in the northeastern corner of Peninsular Malaysia as derived from remotely-sensed images. Solid lines are faults, dashed lines indicate other lineaments.

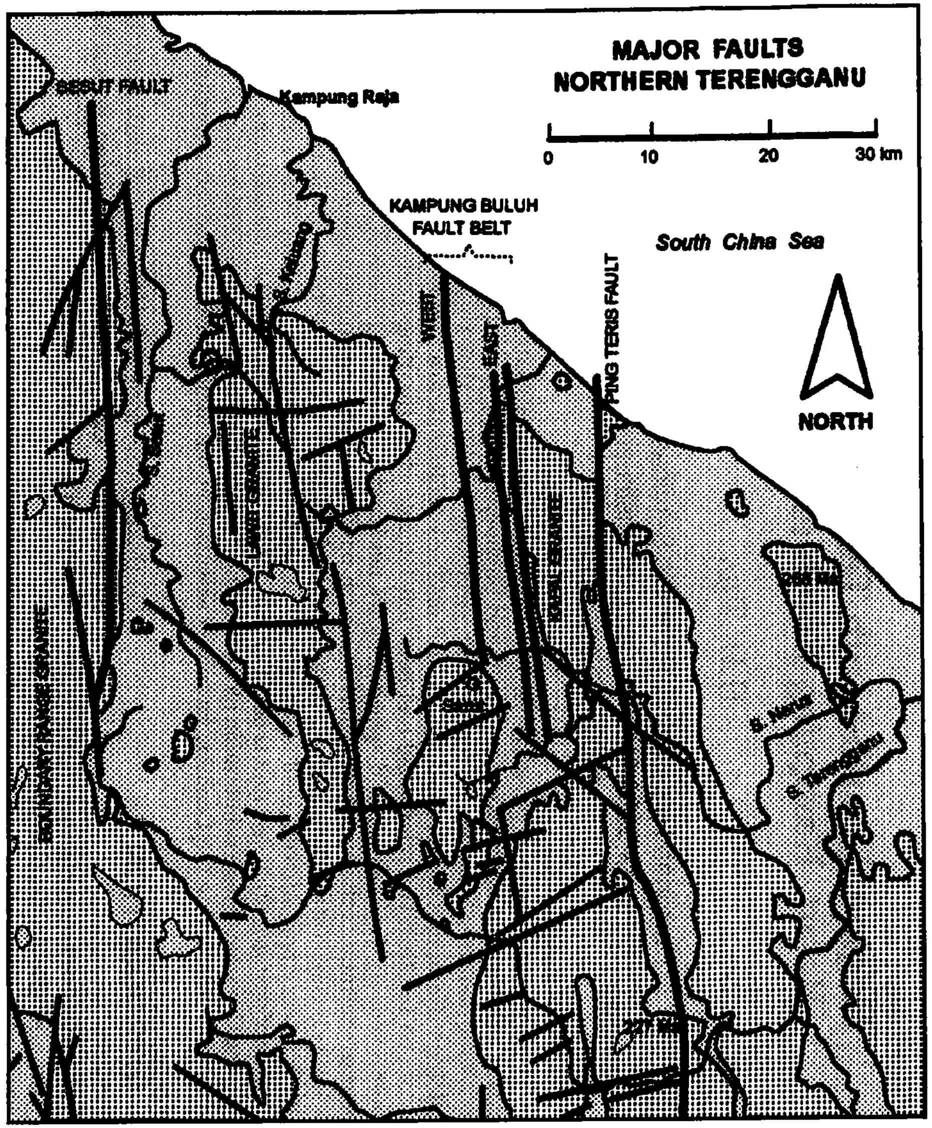

Figure 2. Index map of the three regional Terengganu fault zones discussed in this note. The base is from the "Mineral Distribution Map of Peninsular Malaysia" published by the Geological Survey of Malaysia (8th edition 1988; original scale 1:500,000).

from the quarry site southward, the Boundary Range Granite possesses an almost straight eastern boundary over a distance of 45 km. An earlier (in the mid-1970s) traverse of Sungai Tadok, a small tributary of Sungai Besut near Kampung La, I found the granitoid contact to consist of more than 20 metres wide flasered granitic rock adjacent to flasered hornfels of the country rock. The coarse foliation exhibited by flaser alignments strikes between 155° to 180° and dips very steeply westward. Associated slickensides are subhorizontal and prod steps indicate left-lateral sense of fault motion. The flasers indicate that faulting occurred in brittle-ductile mode. This physical condition was probably achieved at some depth. The flasered granitoid also suggests that faulting took place after the intrusive material had solidified. The Besut fault zone strikes along 102°25' longitude and its offshore continuation could be the northerly striking faults marking the eastern boundary of the Narathiwat High in the Gulf of Thailand.

Figure 3. Bukit Yong QMC granitoid quarry. A 25-m wide shear zone in the Besut fault zone includes metres-wide bands of unfractured granitoid. The shears strike south and dip 70° towards west (right hand side of photograph).

KAMPUNG BULUH FAULT BELT

Two subparallel fault zones (Kampung Buluh fault belt, west and east) were mapped at Kampung Buluh that has recently been renamed as Bandar Permaisuri (Fig. 2). The western zone is well exposed in a long, east-northeast trending hill cut in the vicinity of the fire station. Three kilometres to its east, at Bukit Cenggal, the eastern fault zone outcrops in an artificially terraced surface and in small road cuts along the trunk road.

The Kampung Buluh (West) fault zone consists of several metres-wide strands of mylonite or breccia. A major strand, about 6 metres wide, strikes N35°E, dips 80 degrees towards east and consists of phyllonite enclosing boudinaged metasandstone fragments, large fault-sliced metasandstone clasts, and deformed quartz bodies. Planar quartz veins and dykes parallel to bedding/

Figure 4. Part of a 6-metre wide disturbed zone is a major strand of the northerly striking Kampung Buluh (west) fault zone. The white irregular blebs are deformed quartz boundins. Near the right border, the sharp line separating rocks of darker colouration is a younger fault transecting the major fault strand. The view is towards south onto the ENE-WSW trending outcrop.

foliation represent post-faulting intrusions (Figs. 4 and 5). The phyllonite mass is transected by younger vertical faults. These younger faults are thin planes. Fault attitudes are 310/90 (with left-lateral drag) and 10/90 (with right-lateral drag). To the west and east of the major strand are a few other parallel, metres-wide fault strands. Drag by these main faults (350/80) is always left-lateral. Across its strike, the outcrop containing the fault zones is at least 100 metres wide.

All fault strands in this wide outcrop reside within the same rock formation that consists of metres-wide intervals of well-foliated brown to black phyllite with thin, lighter coloured metasiltstone/metasandstone interbeds and metres-wide intervals of massively bedded metasandstone. The regional geological map groups these rocks into the Carboniferous. Deformation features are stronger on the west side of the outcrop, where the thinner interbeds exhibit symmetrical tight folds and crenulation cleavage (Fig. 6). Regular bedding and foliation are the rule on the east side (Fig. 7). Grading in the sandy beds indicate that stratigraphic top is towards west. The rock formation in the outcrop is thus somewhat overturned. Reverse faulting, as indicated by drag and offsets, represents a later phase of tectonic transport towards east-northeast (Fig. 8).

Part of the Kampung Buluh (East) fault zone outcrops in the north slope of Bukit Cenggal. This locality on the north side of the trunk road has been artificially terraced, possibly to serve a building project. The rocks are interfoliations of silicified pelite and schist deformed into tight isoclinal folds striking north-south with limbs that dip very steeply to west or are vertical. On closer examination I found three folding phases. Folding phases 1 and 2 are coaxial, strike north-south and produced the tight isoclines. The third and youngest folding phase produced broad warps about approximately east-west trending axes. Isoclinal structure is also exhibited by granitoid sills, that may be as thick as 35 cm (Fig. 9). Over a width of more than 100 metres across the strike, the outcrop is laced by north-striking, often more than a metre wide mylonite bands and intervals of phyllonite encasing schist or quartzite boudins. Left-lateral drag indicates the importance of horizontal fault displacements.

The total width of the Kampung Buluh (East) fault zone may be more than 600 metres. This is suggested by the presence of north-striking shear zones in partly weathered schist/phyllite in a roadcut on the trunk road some 500 m to the east of the fault zone that outcrops in the terraced surface.

In recapitulation I conclude that through the Kampung Buluh area runs a major, at least 3 km wide, roughly north-striking fault belt composed of multiple, several metres wide fault zones that separate unfaulted intervals of foliated metasediments. Drag indicates left-lateral wrenching. A later phase deformation that postdated the major fault movement responded to regional compression in 70°–250° direction. By that stress regime, NNE and SE vertical fractures moved laterally in right and left sense, respectively. High-angle reverse faulting also occurred, and was associated with tectonic transport towards east. Although each of the western and eastern fault zones of the belt are contained, respectively within phyllite-metasandstone and schist sequences, yet the net effect of lateral displacement by the fault belt has placed the two rock sequences side by side. In other words, the amount of lateral displacement on the Kampung Buluh fault belt had been significant.

The Kampung Buluh fault belt strikes west by north along longitudes 102°45' to 102°47' and extrapolated offshore, the belt probably continues close to the Tok Bidan-1 well and farther northward into the NNW-trending faults that mark the wide border zone between the Malay basin and the Pattani basin.

PING-TERIS FAULT ZONE

One segment of the Ping-Teris fault zone was studied in an earth excavation near Kampung Padang Ping (topographic map sheet 37, Ulu Telemong). Sungai Ping is a small right-hand tributary of Sungai Telemong. The outcrop exhibits black, carbonaceous phyllite striking north and dipping almost vertically east. Over a total width of more than 30 m across the foliation, at least five fault zones, each 0.5 to 1.5 m wide, striking 345° to 350° and dipping 77 degrees east alternate with phyllite sequences (Fig. 10). The phyllonite zones contain contorted quartz bodies that reach several decimetres across. Fault striae pitch 30° towards SSE on a phyllonite surface and markings such as bruised steps, pluck spalls and fault drumlins indicate right-lateral motion along one north-striking fault zone. Thin 90/90 fractures cross the fault zones; left-lateral drag is associated with these cross fractures.

Next to the road, just south of Kampung Teris is another earth quarry where over a distance of 60 m perpendicular to strike are exposed up to 10-m wide black phyllonite zones. These fault zones are separated by thinner metasandstone intervals from each other (Fig. 11). Convoluted quartz stringers and contorted more equant quartz bodies are present among the phyllonite. This major fault zone strikes

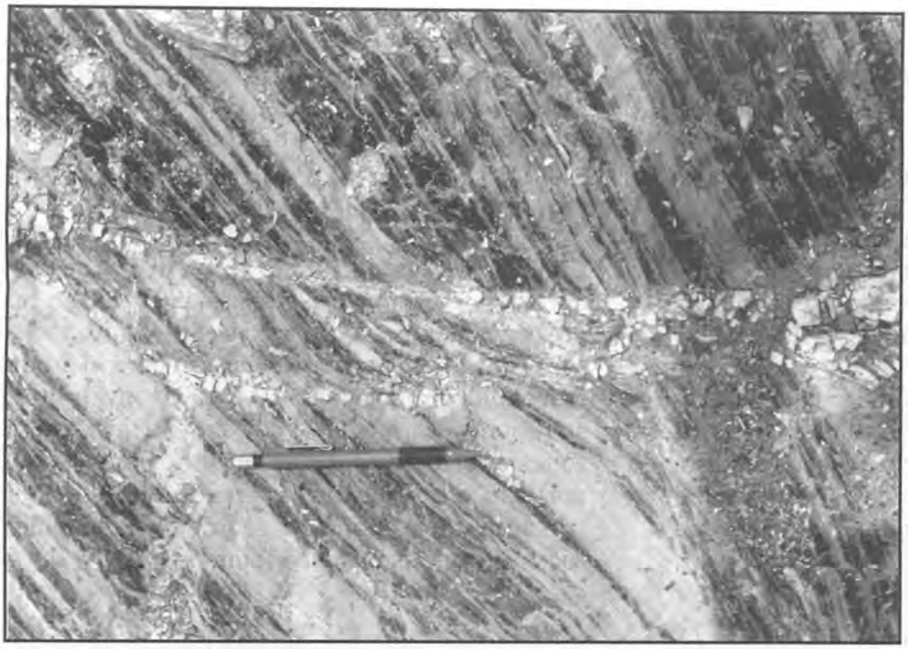

Figure 5. Left-lateral drag on two thin, 350/80 faults that parallel the Kampung Buluh (west) fault zone.

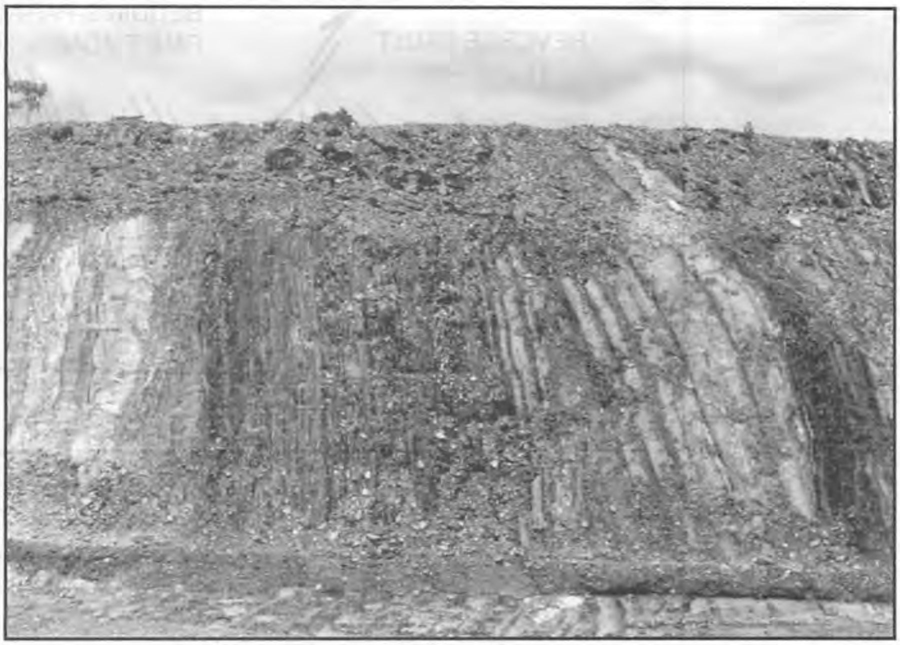

Figure 6. Regularly bedded phyllite (dark) and metapelite/ metapsammite on the east side of the Kampung Buluh (west) fault zone. Graded bedding indicates that stratigraphic top is towards right, or west.

Figure 7. Crenulation cleavage of a fault slice within the Kampung Buluh (west) fault zone is among the structures indicating stronger deformation compared to rocks outside the fault zone such as shown on Figure 6.

175° and dips to west very steeply or is vertical. Drag folds indicate right-lateral motion. Upon this was superimposed dip-slip displacement as indicated by dip parallel striations on some of the fault surfaces.

From their positions on the map I conclude that the Ping and Teris fault zones belong to the same structure. The dextral sense of motion seen in both outcrops and similarity of attitudes are consistent with that conclusion.

The Ping-Teris fault zone is thus a major strike-slip fault with dextral sense of motion. The fault zone seems to separate black carbonaceous phyllite in the east from grey, tuffaceous (?) banded metapelite (originally mudstone and siltstone intercalations) on its west side.

This fault zone runs along longitude 102°53' and seems to continue offshore as the western edge of the northwestern Malay basin.

SUMMARY AND CONCLUSIONS

1. Field work established that three major, northerly striking fault zones in Terengganu are wrench faults: occurrence of mylonite zones that contain subvertical foliation on which are traceable subhorizontal to horizontal fault striations. Extended along the strikes, these zones appear to continue into the wide belt of north to north-northwest trending faults that transect upper Miocene sediments and older rocks in the northwest Malay basin.

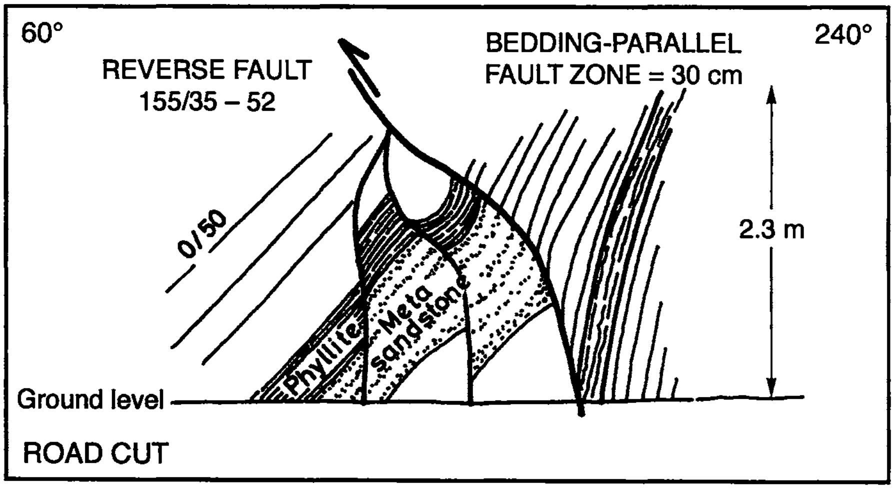

Figure 8. Younger faulting in the Kampung Buluh (West) fault zone includes reverse faulting towards northeast.

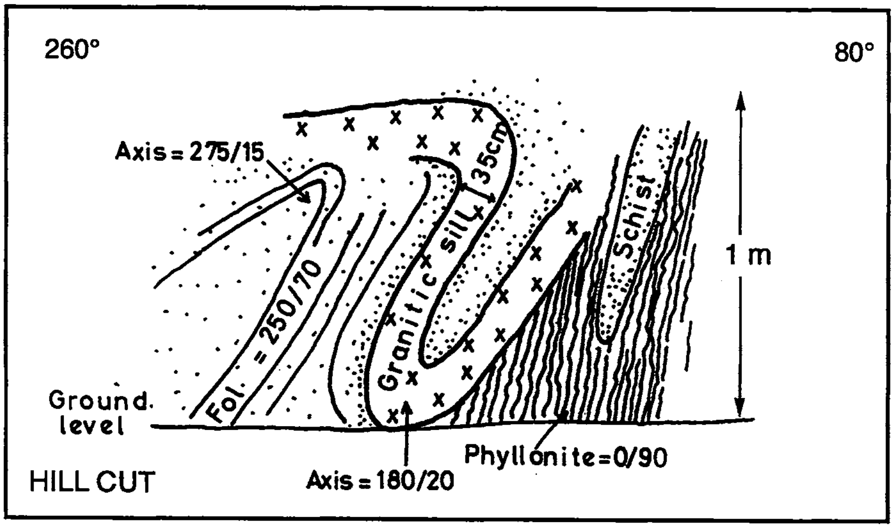

Figure 9. Isoclinally folded schist and granitic sill in a fault slice within the Kampung Buluh (East) fault zone. By virtue of its attitude, the phyllonite most probably belongs to the Kampung Buluh (East) fault zone. The discordant contact of the phyllonite with the sill suggests that both were deformed by the third folding phase.

2. The Besut fault zone strikes 350° and dips 70 degrees towards east. Left-lateral motion sense is indicated by fault-plane markings in the QMC granitoid quarry near Bukit Yong and on flasered granitoid-hornfels contact near Kampung La. In the Besut valley the fault zone is traceable for a distance of 60 km. Its offshore extension seems to coincide with north-striking faults of the north-trending Narathiwat High (Fig. 12). With its offshore extension, the Besut fault zone is more than 300 km long. The fault zone is post-granitoid, that is, post-Late Triassic. Its offshore extension had been active in the Cenozoic as it is associated with deformed Tertiary sediments of the Malay basin. It is not known if the onshore segment of the Besut fault zone was also reactivated.
3. The Kampung Buluh fault belt consists of a western and an eastern fault zone, both dipping steeply to vertically, respectively, and striking between 350° and north. Metres-wide shear zones, often characterised by phyllonite and contorted clasts of competent rock, define the widths of the western zone to exceed 100 metres and that of the eastern zone to more than a half kilometre. The fault belt appears to have juxtaposed phyllite-metasiltstone-metasandstone sequences in the west with multiply folded schist on the east. Drag features associated with the Kampung Buluh belt indicate left-lateral motion. On radar images of the SIR-A experiment taken during the NASA Space Shuttle flight in November 1981, the Kampung Buluh belt (fault No. 6 on Fig. 1) may be traced for a distance of about 50 km. At its south end, the belt seems to be interrupted by or changes strike into SSE-trending faults. The Mineral Distribution Map (Geological Survey of Malaysia, 1988) suggests that the fault along Sungai Telemong and transecting the Kapal granitoid may belong to the Kampung Buluh fault belt. The same map shows the granitoid to be 227 Ma old (determined by Rb/Sr method). In other words, the Kampung Buluh fault belt

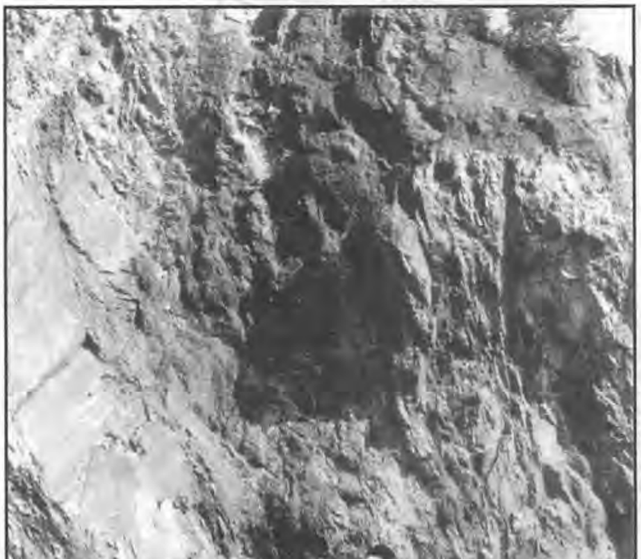

Figure 10. A shear zone within the Ping-Teris fault zone is marked by lenticular clasts of more competent rock within and conformable with encasing phyllonite. Earth quarry near Kampung Padang Ping, Kuala Berang.

Figure 11. Detail of a Ping-Teris fault strand: dark-coloured, weathered mylonite intruded by quartz parallel to foliation. Earth quarry near Kampung Padang Ping, Kuala Berang.

is post-Late Triassic. Its offshore continuation as northerly trending faults in the north end of the Malay basin adds another 200 km to the length of the fault belt. The interpreted offshore continuations transect Miocene sediments. It is again not known if the onshore segment of the Kampung Buluh fault belt was active in the Cenozoic.

4. The Ping-Teris fault zone strikes 175° and dips very steeply to vertically. Its width is more than 60 metres and it separates black carbonaceous phyllite to its east from tuffaceous (?) metapelite. These are Carboniferous rocks according to the regional geological map (Geological Survey of Malaysia, 1985). Right-lateral drag was recorded at the two outcrops where this fault zone was studied. Under the South China Sea, the Ping-Teris fault zone may continue as one or several of the north to north-northwest trending faults in the northern Malay basin. These offshore faults cut into Miocene sediments and associated secondary en echelon faults suggest left-lateral wrenching. It seems possible that this left-lateral wrenching represents a Cenozoic phenomenon, whereas the right-lateral drag mapped onshore was the product of pre-Tertiary wrench faulting. Similar seesaw lateral fault motions were detected along other northerly striking faults in the main part of the Malay Basin (Tjia, 1994).

5. Although the field study succeeded in establishing the existence, nature and sense of

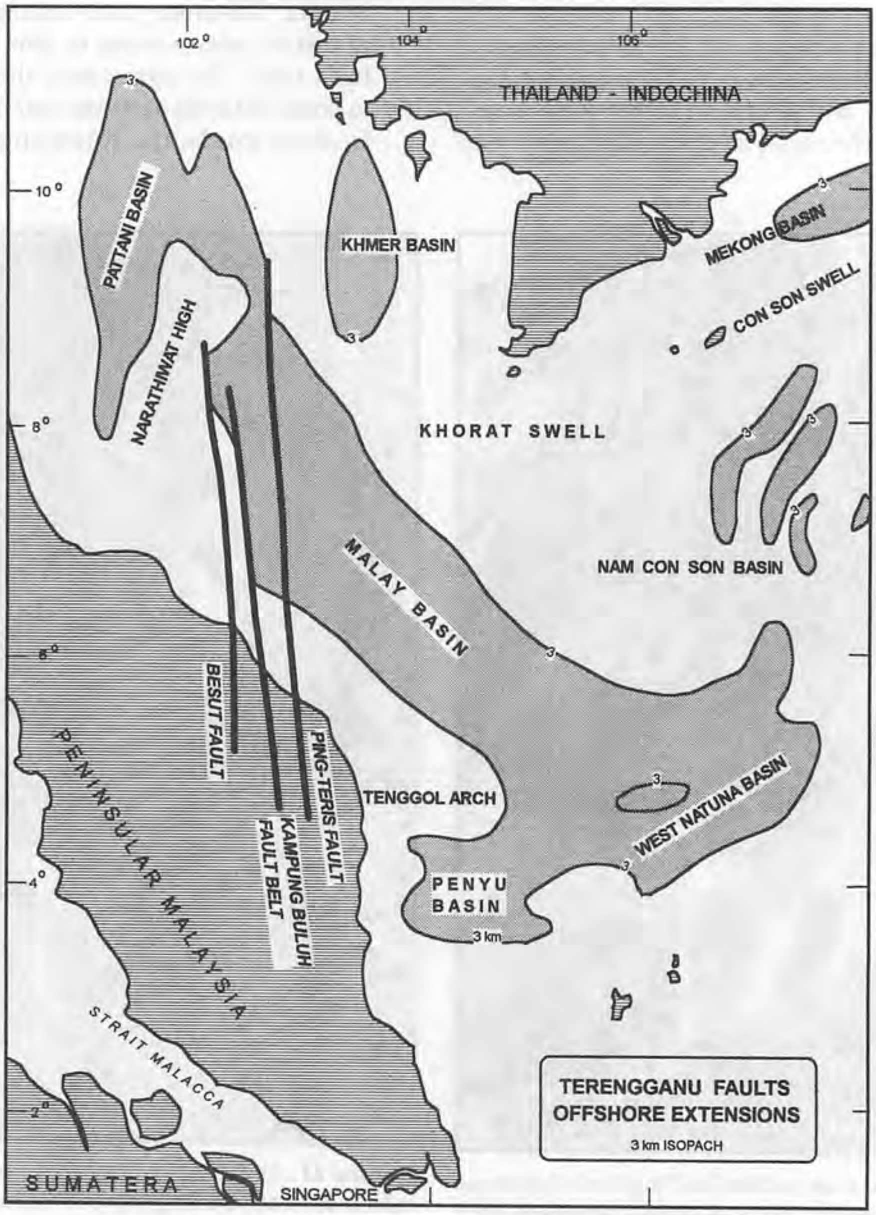

Figure 12. Probable extensions of the Terengganu faults into the Tertiary basins of the Sunda Shelf.

displacement of the three major, northerly-trending fault zones onshore Terengganu, their precise geological ages and amounts of displacements are still unknown.

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