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Negative lineaments in the granitic bedrock areas of NW Peninsular Malaysia

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Abstract: Negative lineaments in the granitic bedrock areas of NW Peninsular Malaysia are interpreted to represent the strikes of fractures that have developed both before, and as a result of, an approximately 120°–300° directed compression during the Upper Jurassic to Early Tertiary. The fractures pre-dating this period of compression are furthermore, interpreted to be primary fractures that have formed during the cooling of granite batholiths, particularly those emplaced during the Upper Triassic.

INTRODUCTION

In photogeology, the term 'lineament' is normally used to refer to any linear geological feature that can be recognized on aerial photographs and other forms of remote sensing imagery. Although lineaments can be recognized through the linear trends of different features, as photo-image characteristics and vegetation, for structural geological purposes linear trends of topographic features are particularly useful as they reflect, and allow interpretation of, geological structures. These linear trends of topographic features are of two types for they can occur as linear trends of topographic highs (i.e. positive lineaments) or as linear trends of topographic lows (i.e. negative lineaments). Positive topographic lineaments, as strike ridges and dykes, usually represent the exposure of resistant rock units, whereas negative topographic lineaments, as straight valleys usually reflect the exposure of non-resistant rock units or the exposure of planes or zones of weakness in rock i.e. joints and faults. Although aerial photographs and other forms of remote sensing imagery offer good sources for the recognition and mapping of the lineaments within an area, LANDSAT imagery is undoubtedly the best source, for the single frame LANDSAT images can, for practical purposes, be considered equivalent to a topographic map. Thus, the various distortions (as relief and tilt distortions) that are inherent in the use of aerial photographs and most other forms of remote imagery (and that need to be corrected for) do not arise in the use of LANDSAT imagery for the mapping of lineaments. The small scale and large areal coverage of single frame LANDSAT images furthermore, allows for the regional recognition and mapping of lineaments in contrast to the large scale and small areal coverage of aerial photographs and most other forms of remote sensing imagery.

This paper discusses the results of a negative lineament analysis, from LANDSAT imagery, of the granitic bedrock areas of NW Peninsular Malaysia. As negative lineaments only have been mapped, the resulting lineaments patterns are thus interpreted to be indicative of the fracture patterns within these granitic bedrock areas. As interpretation of the origins of these fracture patterns is also discussed.

STUDY AREA

The study area comprises the granitic bedrock areas of Kedah, Perak and Penang in

NW Peninsular Malaysia, and has been selected as it is one of the few areas of the Peninsula that is included in relatively cloud-free LANDSAT imagery. The entire study area is covered by three, single frame, Band 7 LANDSAT II images that have been scanned on 5.1.78, 26.1.78 and 6.3.78 respectively (Figure 1). Although two of the frames also cover the granitic bedrock areas of west Pahang and west Kelantan, these areas have not been included in thus study as they are cloud covered. The granitic bedrock areas are all characterized by a fluvially dissected, hilly to mountainous terrain that gives rise to isolated highlands and a number of mountain ranges. These granitic areas are furthermore, believed to represent the outcrops of a number of granite batholiths that are generally elongated along a N-S to NNW-SSE direction (Hutchison, 1973; Bignell and Snelling, 1977). Although the granitic rocks of the study area show variable textural and mineralogical characteristics, the most common variety is a porphyritic, coarse-grained biotite granite (Hutchison, 1973, 1977). Rb-Sr age determinations of these granites furthermore, indicate that they have been mostly emplaced during the late Triassic, though a few have also been emplaced during the Late Carboniferous/Early Permian and possibly during the Late Devonian (Bignell and Snelling, 1977). K-Ar age determinations of these granites, however, show a much wider scatter and indicate that some of these granites have been affected by faulting (Bignell and Snelling, 1977).

Within the study area, a number of large faults are present; the more important of which are the left-lateral Bok Bak fault zone (Burton, 1965, 1970; Raj, 1982) and the Kledang fault (Gobbett, 1971). Positive and negative, topographic lineaments in the form of dykes, and linear valley segments, respectively, are found throughout these granitic bedrock areas (Gobett and Tjia, 1973) and have been studied by Tjia (1971) in the island of Penang and by Gobbett (1971) in the Kinta Valley. Tjia (1971) considered that the lineaments of Penang Island corresponded with fracture patterns that were related to a more or less E-W directed compression, while Gobbett (1971) interpreted the lineaments of the Kinta Valley as being conjugate shear joints resulting from a stress field that had its principle stress orientated along an approximately 97°–277° direction.

METHOD OF STUDY

1:500,000 scale prints were first enlarged from available 1:1,000,000 scale Band 7, single frame LANDSAT II negatives, following which the boundaries of the granitic outcrops (within the selected study area) were drawn on the prints; the boundaries being based on the Geological Map of West Malaysia (Chung, 1973) and the Geological Map of the Malay Peninsula (Gobbett, 1972). Watershed divides of the larger drainage basins (of 60 to 500 sq. km.) within the granitic bedrock areas were then drawn on the prints, after which linear valley segments (i.e. negative lineaments) were mapped within each of these basins. The lengths and orientations (relative to magnetic north) of the negative lineaments within each of the individual drainage basins were then measured with a digitizer/plotter attached to a HP-45 table-top computer and stored on magnetic tape. Frequency and length histograms (at 5 degree intervals) of the lineaments within each of the individual basins were the plotted with a printer. Visual comparison of the histograms of all the individual basins (totalling 66 basins) then allowed for the grouping of these basins into 9 broad zones (Figure 2) of closely similar patterns of the frequency and length distributions of the negative lineaments.

Fig. 1. Areas covered by interpreted LANDSAT II imagery (with dates of scanning and scene identification numbers)

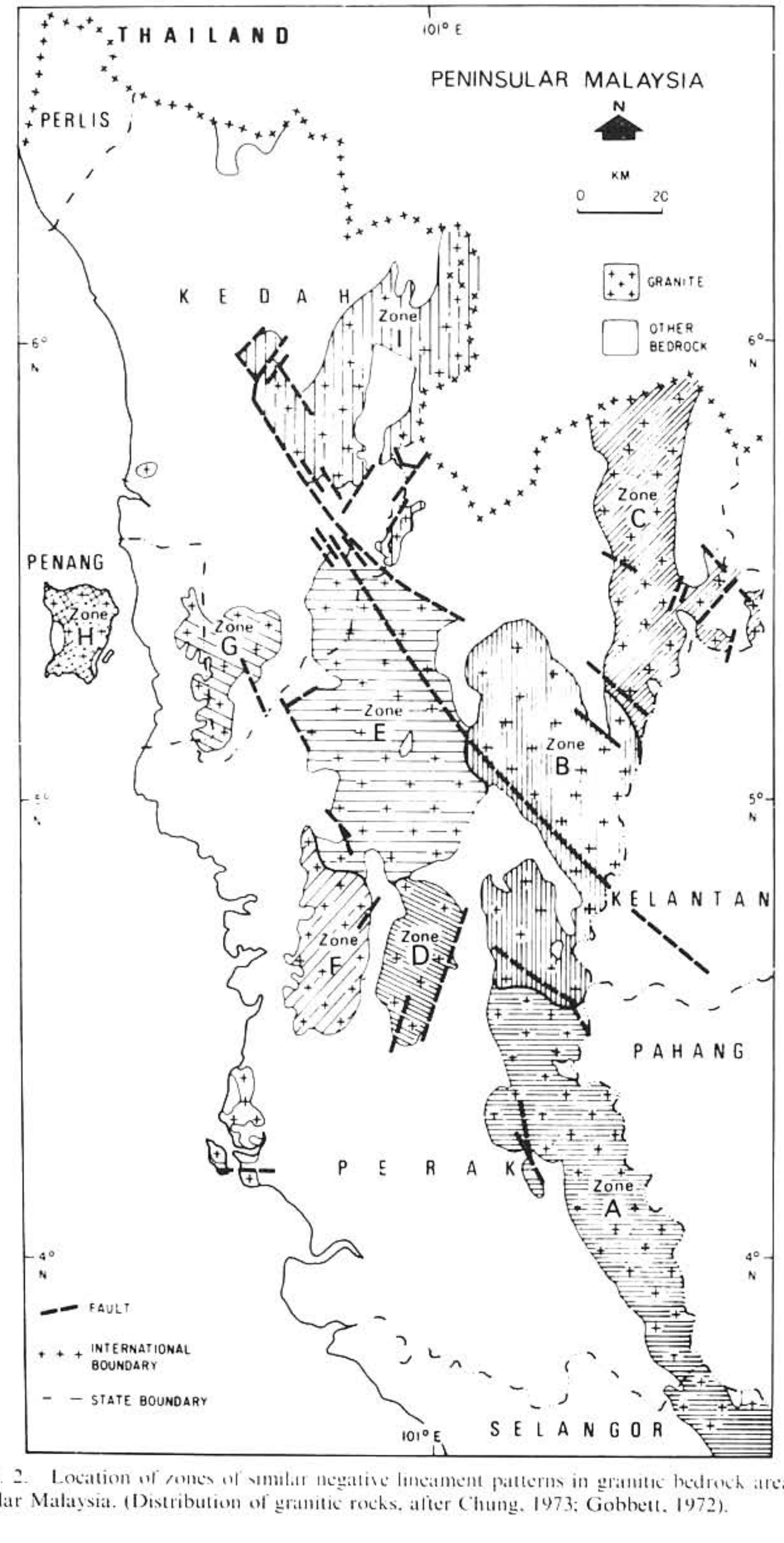

Fig. 2. Location of zones of similar negative lineament patterns in granitic bedrock areas of NW Peninsular Malaysia. (Distribution of granitic rocks, after Chung, 1973; Gobbett, 1972).

DISCUSSION

In view of the fact that only negative topographic lineaments have been identified and mapped in this study, it can therefore be considered that the resulting frequency and length histograms (Figures 3a to 3i) represent the frequencies and lengths of the strikes of fractures within the granitic rocks of the study area. This interpretation of the lineaments is thus similar to the interpretations of Tjia (1971) and Gobbett (1971). This interpretation of the lineaments as representing the strikes of fractures is furthermore justified when it is considered that linear valley segments in fluvially dissected granitic terrain are usually, if not always, due to selective erosion along fractures (Pitty, 1971).

In looking at the frequency and length histograms of the lineaments (i.e. interpreted strikes of fractures) within the nine zones (Figures 3a to 3i), it can be seen that there are certain trends that are common to most zones though the relative frequencies and lengths are variable with certain trends being preferentially developed in some zones, Lineaments trending 325° to 335°, and 55° to 65°, are for instance, found in almost all the zones, though being particularly well developed in zones, B, E and F. Lineaments trending 10° to 20°, 40° to 50° and 70° to 80° are similarly found in most zones, though being particularly well developed in zone A. The similarity of the lineaments of the different zones thus indicates that the fractures of the granitic bedrock areas of NW Peninsular Malaysia have had similar origins, though the variations of frequencies and lengths suggests that the rocks of the different zones have responded differently to possibly similar causes.

Interpretation of the origins of the fractures (interpreted from the negative lineaments) has to proceed by a process of elimination for the only available evidence is the suggested approximately E-W directed compression of both Tjia (1971) and Gobbett (1971). The generally 330° trending, left-lateral strike-slip faults associated with the Bok Bak fault zone (Burton, 1965, 1970; Raj, 1982), however, indicate an approximately 120°–300° directed compression for the faults can be considered as being equivalent to first-order shear fractures that usually form at about 30° to the direction of the maximum principal stress (Price, 1966) (Figure 4a). The complementary set of these fractures (that form right-lateral strike-slip faults) will furthermore trend approximately 90°–270° (Figure 4a) while second order shear fractures (resulting from the reorentation of stresses as result of movement of the first order shears, after Mckinstry, 1953; Moody and Hill, 1956) will trend approximately 60°–240°, 120–300° and 0°–120°, (Figure 4b) if an angle of internal friction of 30° is assumed for granitic rocks (Price, 1966). Third and possibly higher order shear fractures (resulting from the reorientation of stresses along the second and higher order shears) will, however, parallel the trends of the first and second order fractures (Figure 4c) except for the 30°–210° trending third order shears (with right-lateral displacements). In comparing the trends of Figures 4a to 4c with the frequency and length histograms of the lineaments (Figures 3a to 3i) it can therefore be considered that the lineaments, trending 265° to 275°, 295° to 305°, 325° to 335°, 355° to 0°, 25° to 35° and 55° to 60°, represent the strikes of first and higher order shear fractures (with variable right and left-lateral displacements) that have developed as a result of an approximately 120°–300° directed compression. It should be pointed out that these particular trends of lineaments may also be differently interpreted, though the writer

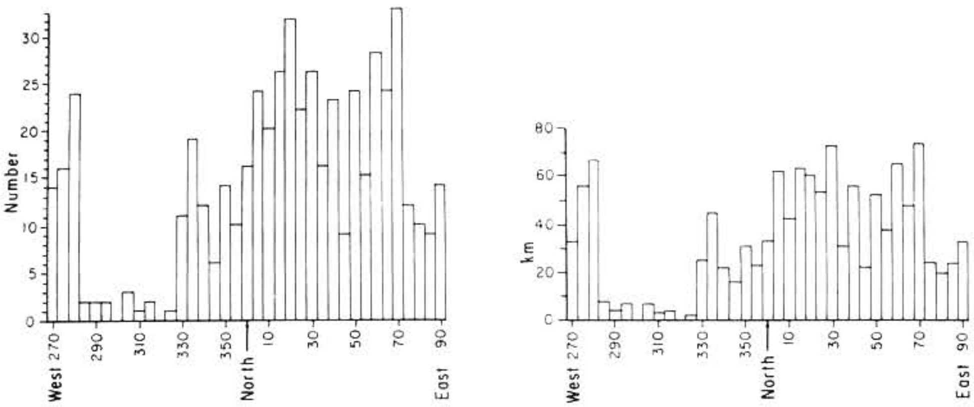

Fig. 3a. Frequency and length histograms of negative lineaments in Zone A (Main Range granite bedrock areas of S. Perak) (Total no. of lineaments = 509)

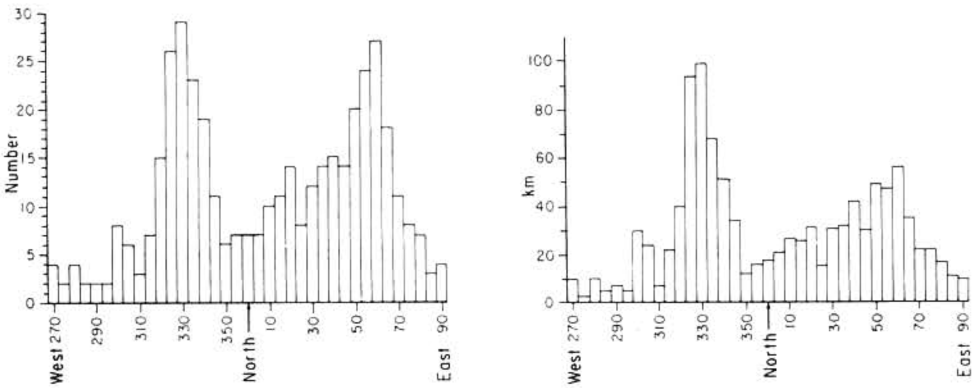

Fig. 3b. Frequency and length histograms of negative lineaments in Zone B (Main Range granite bedrock areas of central Perak) (Total no. of lineaments = 406)

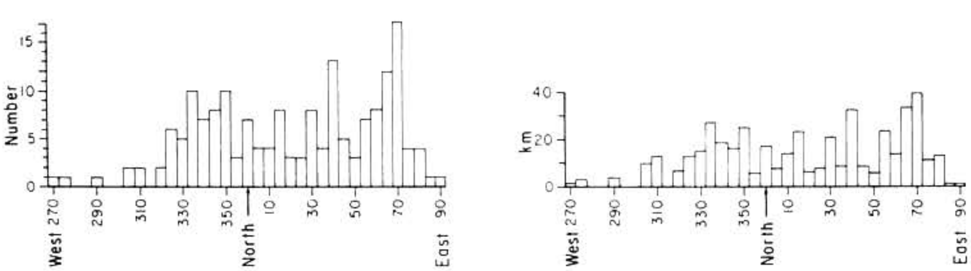

Fig. 3c. Frequency and length histograms of negative lineaments in Zone C (Main Range granite bedrock areas of N. Perak) (Total no. of lineaments = 173)

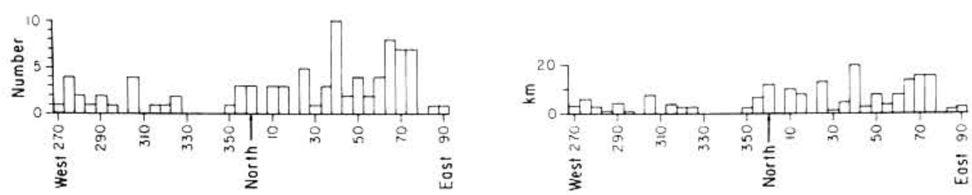

Fig. 3d. Frequency and length histograms of negative lineaments in Zone (Kledang Range granite bedrock areas) (Total no. of lineaments = 86)

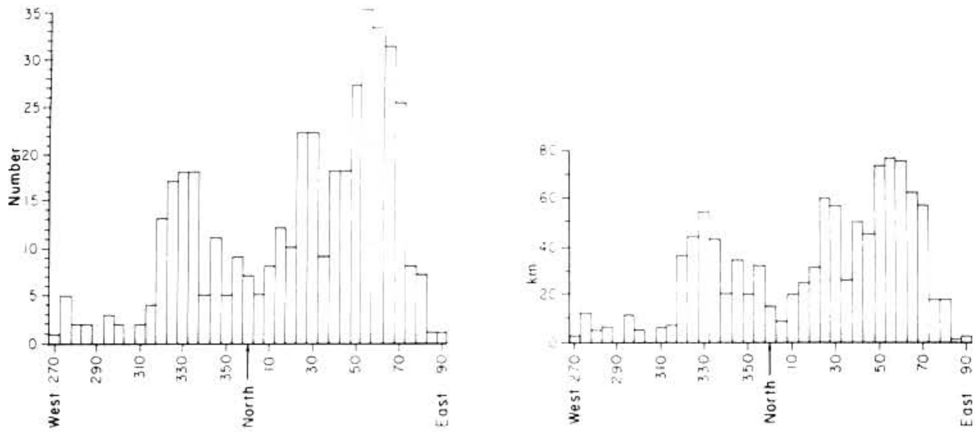

Fig. 3e Frequency and length histograms of negative lineaments in Zone E (Bintang Range granite bedrock areas) (Total no. of lineaments = 415)

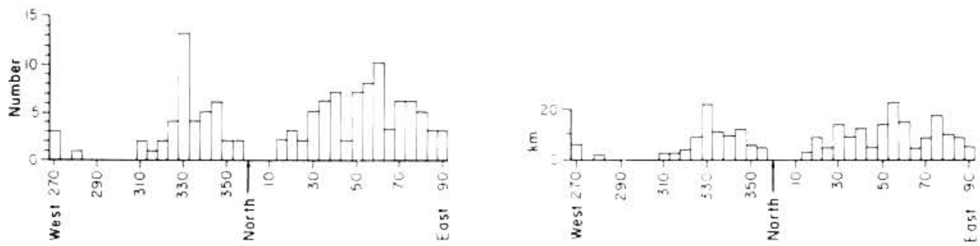

Fig. 3f Frequency and length histograms of negative lineaments in Zone F (Batu Hills granite bedrock areas) (Total no. of lineaments = 120)

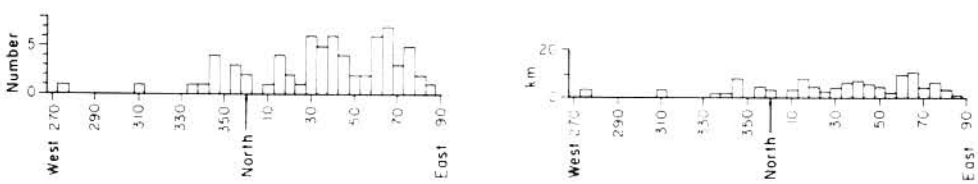

Fig. 3g Frequency and length histograms of negative lineaments in Zone G (Kulim granite bedrock areas) (Total no. of lineaments = 70)

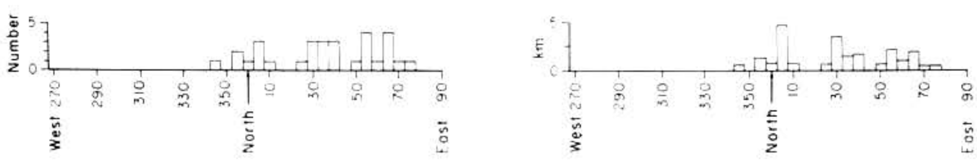

Fig. 3h. Frequency and length histograms of negative lineaments in Zone H (Penang Island granite bedrock areas) (Total no. of lineaments = 30)

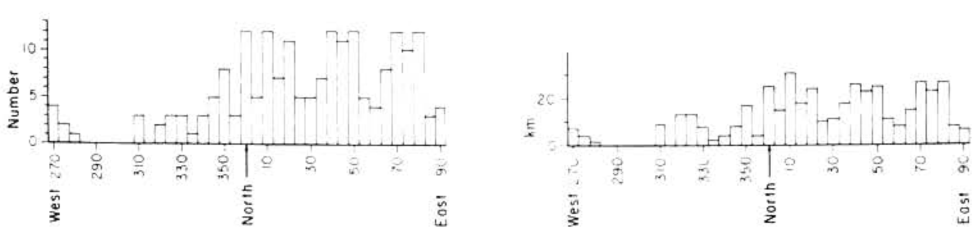

Fig. 3i. Frequency and length histograms of negative lineaments in Zone I (granite bedrock areas of E. Kedah) (Total no. of lineaments = 191)

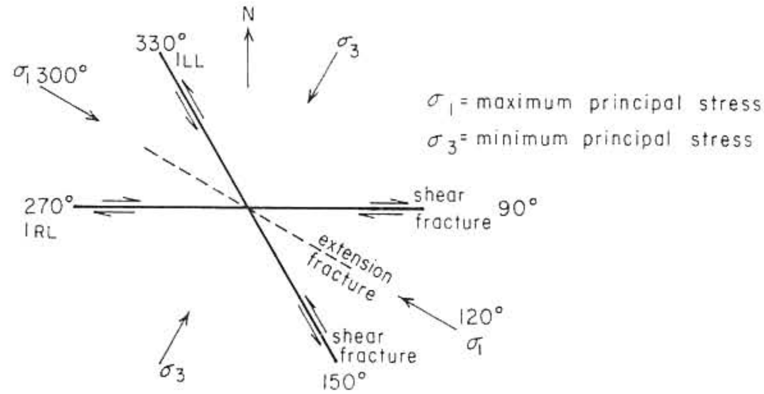

Fig. 4a: Trends of shear and extension fractures associated with a 120°–300° directed compression. Angle of internal friction assumed to be 30°
1 LL = first order left lateral strike-slip fault;
1 RL = first order right lateral strike-slip fault

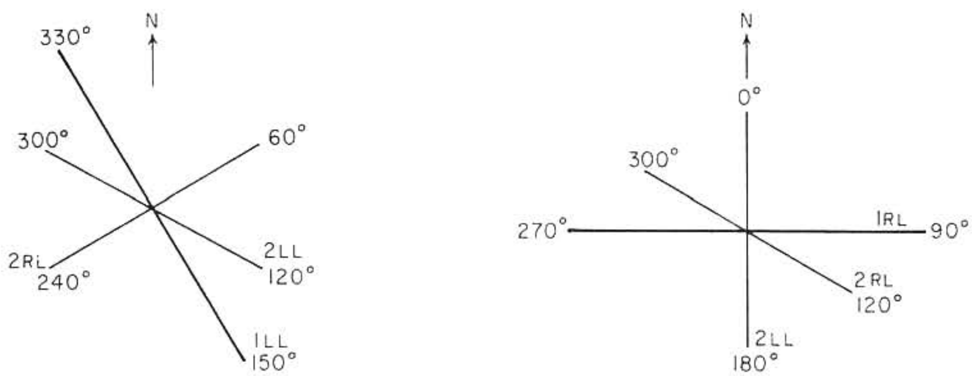

Fig. 4b: Trends of second order shear fractures resulting from reorientation of stresses along first order shear fractures (after Mckinstry, 1953; Moody and Hill, 1956)
2 LL = second order left-lateral strike-slip fault;
2 RL = second order right-lateral strike-slip fault

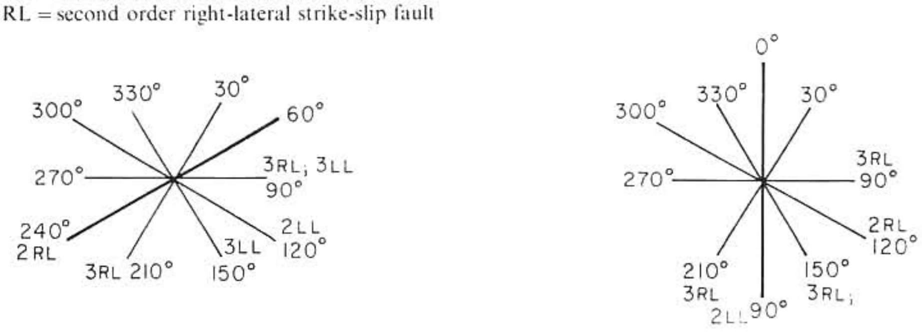

Fig. 4c: Trends of third order shear fractures resulting from reorientation of stresses along second order shear fractures. (after Mckinstry 1953; Moody and Hill, 1956)
3 LL = third order left-lateral strike-slip fault;
3 RL = third order right-lateral strike-slip fault

contends that the existence of the left-lateral Bok Bak fault zone supports the above interpretation that these trends represent the strike directions of shear fractures developed during an approximately 120°–300° directed compression. An approximate idea of the time of occurrence of this proposed 120°–300° directed compression is furthermore, possible in view of the disparity of Rb-Sr and K-Ar age determination of granitic rocks close to the Bok Bak fault zone (Bignell and Snelling, 1977). In the Baling area (zone I), for instance, Rb-Sr isochrons indicate a possible Late Devonian intrusive episode, though K-Ar determinations yield much younger ages (of Late Triassic to Early Tertiary) (Bignell and Snelling, 1977). Raj (1982) has furthermore, suggested that strike-slip displacements associated with the Bok Bak fault zone only occurred in post Upper Jurassic times. Arising from this, it can therefore be considered that the lineaments of the granitic bedrock areas of NW Peninsular Malaysia that trend 265° to 275°, 295° to 305°, 325° to 335°, 355° to 5°, 25° to 35° and 55° to 65°, represent the strikes of shear fractures that have developed as a result of a 120°–300° directed compression sometime between the Upper Jurassic and Early Tertiary. This period of tectonic deformation has also been recognized by Tjia (1978) in other parts of the Peninsula.

Apart from the above discussed lineaments, there still remain a number of other lineaments whose trends are also present in most zones of the study area (Figures 3a to 3i), in particular those trending 10° to 20°, 40° to 50° and 70° to 80°. In view of the fact the Peninsular Malaysia is considered to have been tectonically stable throughout the Cenozoic (Stauffer, 1973; Tjia, 1978), it is therefore clear that these (other) lineaments represent the strikes of fractures that pre-date the fractures resulting from the proposed 120°–300° directed compression. Although the origin of these fractures cannot be determined with certainty, it is interesting to note that the lineaments trending 40° to 50° are orientated approximately diagonally to the N-S to NNW-SSE trend of the granite batholiths of the study area. This suggests that these particular lineaments represent the strikes of primary fractures that formed during the cooling of the granite batholiths (H. Cloos, in Hills, 1972). The other remaining lineaments (i.e. those not associated with the proposed 120°–300° directed compression nor trending 40° to 50°) are also similarly suggested to represent the strikes of other primary fractures formed during the cooling of the granite batholiths. Although the exact date(s) of formation of these primary fractures is not known (due to the different periods of granite emplacement) it is likely that the majority of these fractures developed during the Upper Triassic in view of the dominance of Upper Triassic granites in the study area.

Arising from the above discussion, it is thus proposed that the negative lineaments of the granitic bedrock areas of NW Peninsular Malaysia represent the strikes of fractures that have developed both before, and as a result of, a 120°–300° directed compression during the Upper Jurassic to Early Tertiary. It should be noted that some of the earlier formed fractures may have been reorientated by the later 120°–300° directed compression, though there is no evidence to support this contention.

CONCLUSION

In conclusion, it can be said that the negative lineaments of the granitic bedrock areas of NW Peninsular Malaysia represent the strikes of fractures that have developed both before, and as a result of, a 120°–300° directed compression during the Upper Jurassic to Early Tertiary. The fractures pre-dating the regional compression are furthermore suggested to be primary fractures that have developed during the cooling of the granite batholiths, particularly those emplaced during the Upper Triassic.

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