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Lineaments in enhanced remote sensing images: An example from the Upper Perak Valley, Perak Darul Ridwan

JUHARI MAT AKHIR

School of Environmental Science and Natural Resources, Faculty of Science and Technology
Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Darul Ehsan

Abstract: Linear structural features (lineaments) mapped from remotely sensed images are often used as indicators of fractures in near-surface rocks. Previous lineament mapping and interpretations of Malaysia have used aerial photographs and relatively unenhanced satellite images. Images covering the Upper part of Perak River Basin have been produced from LANDSAT MSS data using several digital image processing techniques, particularly filtering, intended to enhance the visibility of lineaments. The contrast stretched of MSS band 7 was found to be the best in displaying lineaments for the area, hence, was further processed by using directional filters. The four directionally filtered images, which contain lineaments in EW, NS, NE-SW and NW-SE direction, were used for lineament mapping. All lineaments longer than 1 km were traced and mapped at scale 1: 250,000; their orientations were determined and lengths measured, and further analyzed by preparing rose diagrams for analysis, interpretation and comparison with published maps. Fracture analysis of the mapped lineaments was carried out together with its relation with rock types and mineral deposits in the study area. A good correlation, both in terms of direction and location, do exist between image lineaments and previously mapped faults. In addition, new prominent lineaments which are probably newly identified faults were delineated and recorded along with new circular features, thus, updating the structural geologic map of the area as well as to facilitate the planning of mineral exploration and identification of new mineral deposits.

Abstrak: Fitur struktur linear (lineamen) yang dipetakan daripada imej penderiaan jauh sering digunakan sebagai penunjuk kepada retakan batuan hampir permukaan bumi. Pemetaan dan tafsiran lineamen terdahulu di Malaysia menggunakan fotograf udara dan imej satelit yang secara relatifnya tidak ditonjolkan. Imej kawasan Hulu Lembah Perak telah dihasilkan daripada data LANDSAT MSS menggunakan teknik pemprosesan imej secara digit, terutamanya penapisan, bertujuan untuk menonjolkan maklumat lineamen. Imej MSS jalur 7 yang diregangkan kontrasnya didapati memaparkan maklumat lineamen terbaik dan dipilih untuk diproses menggunakan tapisan berarah. Empat imej hasil penapisan berarah yang mengandungi lineamen arah TB, US, TL-BD dan BL-TG, telah digunakan untuk pemetaan lineamen. Semua lineamen melebihi 1 km panjang disurih dan dipetakan pada skala 1: 250,000; orientasi dan panjangnya ditentukan dan diukur, dan seterusnya dianalisis menggunakan rajah mawar, ditafsirkan dan dibandingkan dengan peta geologi yang diterbitkan. Lineamen yang dipetakan dilakukan analisis retakan dan juga mengkaji perkaitan antara ketumpatannya dengan jenis batuan dan juga longgokan mineral di kawasan ini. Wujud perkaitan yang baik, sama ada daripada segi arah dan kedudukan, antara lineamen dengan maklumat sesar yang dipetakan. Selain itu, beberapa lineamen baru yang terpapar jelas berkemungkinan merupakan sesar yang belum dipetakan turut disurih dan direkodkan di samping fitur membulat. Ini bermakna hasil kajian ini membolehkan peta struktur geologi dikemaskinikan serta memudahkan perancangan eksplorasi serta penentuan lokasi baru longgokan mineral.

INTRODUCTION

This paper describes the results of lineament mapping on digitally enhanced LANDSAT MSS images of the Upper Perak River Basin, Perak Darul Ridwan. The main objective of the study is to produce a lineament map of the area based on interpretation of satellite images which show some newly identified lineaments (faults) of the area. Another objective is to show the applicability of remote sensing data in structural geological study (lineament mapping). Linear features (lineaments) on the surface of the earth have attracted the attention of geologists for a long time. Hobbs (1904) defined lineaments as "significant lines of landscape that reveal the hidden architecture of the rock basement". However, O'Leary *et al.* (1976) defined the term lineament as "a mappable, simple or composite linear feature of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs distinctly from the pattern of adjacent features and presumably reflects some sub-surface phenomenon". The O'Leary definition is applied in this study.

Early lineament mapping was carried out using aerial photographs. In recent years, developments in remote sensing and in particular, the availability of large-area, small-scale imageries obtained from satellite has made this technique extensively used for this purpose. In Malaysia, however, geological mapping and lineament interpretation are produced from relatively unenhanced satellite images. The benefits and importance of using enhanced satellite data are well known and shown by several researchers. Consequently, in more recent work, enhanced digitally processed satellite data is becoming more popular and is frequently used in geological mapping as well as in lineament mapping and interpretation (Azlikamil *et al.*, 1996; Juhari & Ibrahim, 1997). The potential economic importance of lineaments in terms of groundwater potential mapping and exploration, base metal deposits and petroleum exploration and also slope stability or landslide zoning, has promoted numerous investigation of lineaments using satellite images (Halbauty, 1976; Ahmed, 1983; Azlikamil *et al.*, 1996; Khairul Anam *et al.*, 2001).

STUDY AREA AND SATELLITE DATA

The study area covers parts of the Upper Perak Valley. The area contains a diversity of topography, so it is more appropriate for lineament mapping and analysis. In addition, the area is covered by one of the two best LANDSAT MSS images, with very low percentage of cloud cover and very good quality coverage of that part of Malaysia. Figure 1 shows a generalized geological map of the area. The map shows that most of the area is underlain by intrusive igneous rocks (Hutchison, 1973; Geological Survey of Malaysia, 1985), metamorphic rocks (Hutchison, 1973) and sedimentary rocks (Geological Survey of Malaysia, 1985). In addition, Tertiary basin deposits consisting of semi-consolidated sediments also occur in the area (Jones, 1970). The major elements of structural pattern in the area are large fractures and faults including the Bok Bak Fault (Burton, 1965; Raj, 1982), which runs in the northwest-southeast directions in the middle of the area.

DATA PROCESSING AND IMAGE PRODUCTS

Various enhancement techniques were applied to the satellite images including contrast enhancement and filtering. Before these operations, the data has also gone through several preprocessing stages in order to remove or minimize errors which occur in the data. Generally, the MSS band 7 (Figure 2) is better for overall geological information content compared to the other three bands, and hence, was selected and used in this study. The contrast stretched image of MSS band 7 was processed through directional filtering to further enhance linear features including lineaments.

Lineament mapping was carried out on four directional filtered images based on the methodology suggested by Juhari (2003). The lineament map prepared from LANDSAT MSS data was analyzed and compared with the geological map in terms of their orientation, number, length and also their locations. Apart from fracture analysis, the relationship between the mapped lineaments with rock types and mineral deposits in the area was also discussed.

RESULTS AND DISCUSSION

A total of 370 lineaments longer that 1 km with a total length of about 1600 km were mapped. Figure 3 shows the lineaments with a minimum length of about 2 km. Length, orientation and frequency of the total lineaments are summarized in Figure 4. The preferred directions of the mapped lineaments coincide very well with the line of the Bok Bak Fault System, where 325° and 035° are the most common fracture trends (Burton, 1970; Tjia & Zaiton, 1985), and also correspond with the two main directions of faulting, particularly in areas underlain by granite (Burton, 1970). Based on orientation, therefore, it is evident that the main features of the fault pattern are clearly brought out in the lineament map. The result shows that a large number of mapped faults were revealed and are coincident with the interpreted lineaments, and in several cases, the mapped faults should be extended (Figure 5). In addition, a few prominent lineaments are shown in Figure 3 which are not coincident with the known faults, and they may well represent fault lines not previously mapped or reported

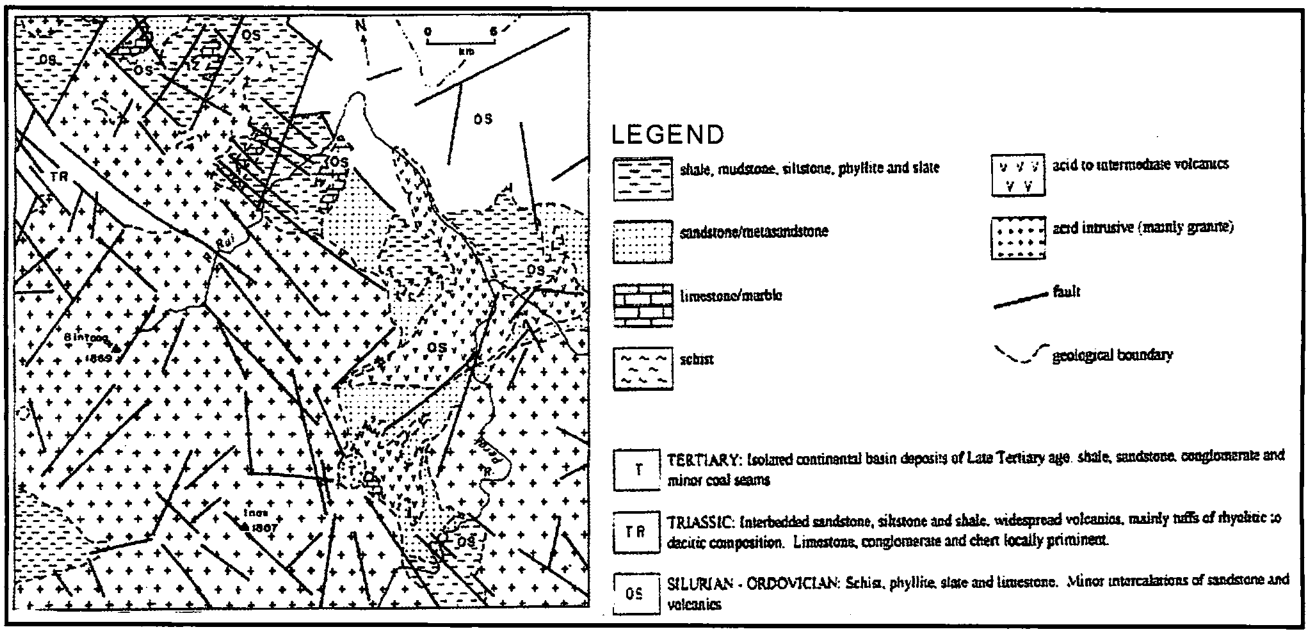

Figure 1. Simplified map of the geology in the Upper Perak Valley (after Geological Survey of Malaysia,1985).

(Figure 5), rather than fractures. In addition, a few circular features are also depicted on the images and were mapped (Figure 5).

By using the structural information of the study area and the basic criteria in fracture analysis (Tjia, 1972), nearly all the maximum frequencies in Figure 4A may be interpreted as one particular type of fracture as a result of one particular compression. The lineaments in Figure 4A, therefore, have been interpreted as follows: tension (045°-060°), extension (325°-340°) and so on. The results show a lack of similarity with the results interpreted by Tjia (1972). There are two possible reasons for the findings. First, the area of study covers only about 10% of the total area of tectonic domain 3 (Tjia, 1972); therefore the results may not represent the characteristics of tectonic domain 3. Second, the area is adjacent to tectonic domain 1 (Tjia, 1972), and also close to the area of tectonic domain 2, therefore there are possibilities that the area is still affected or influenced by the principal compression in these domains.

Figure 2. Linear contrast stretched of Landsat MSS band 7 of the Upper Perak Valley area. The image is found best particularly for lineament mapping compared to other images.

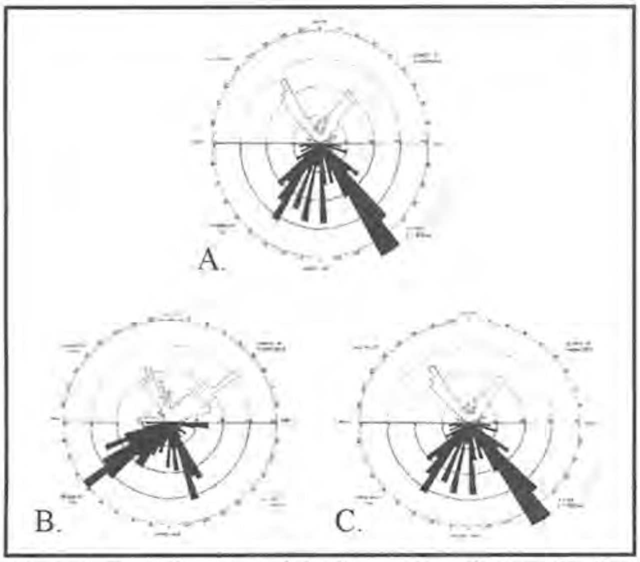

Figure 4. Rose diagrams of the lineaments calculated by both lengths as well as number of observation on the Landsat MSS for the study area (A), lineaments longer than 2 km (B) and mapped fault of the area (C).

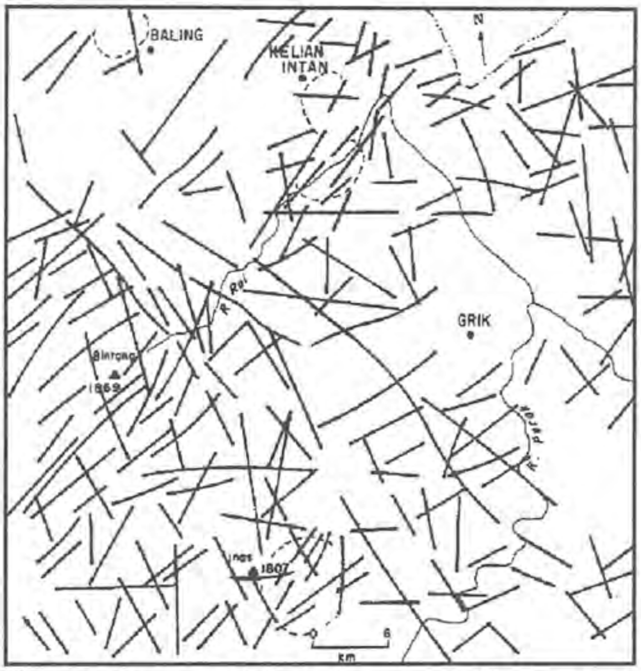

Figure 3. Lineaments and circular features map of the Upper Perak Valley area derived from the Landsat MSS images. See Figure 1 for comparison with the mapped faults of the area.

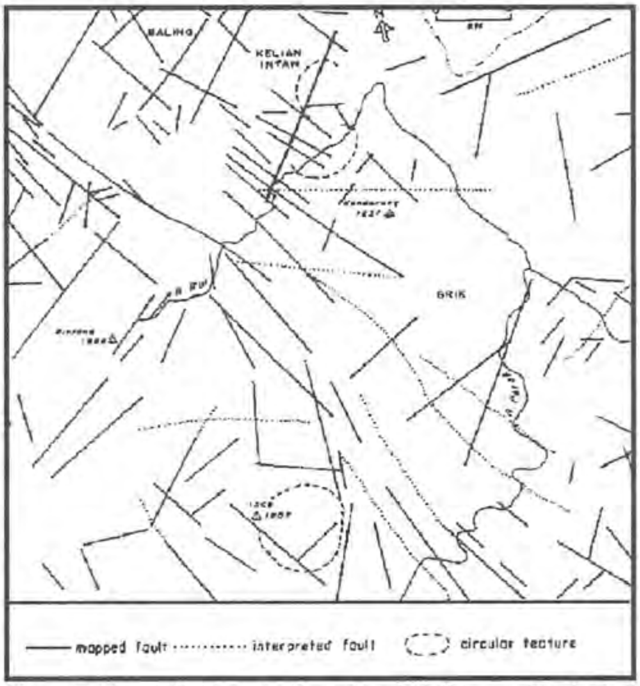

Figure 5. Mapped faults in the Upper Perak Valley area (Geological Survey of Malaysia, 1985). Dotted lines represent several major lineaments on the Landsat images which do not correspond to any mapped faults, and are interpreted as new fault lines in the area. In addition, a few circular features which are depicted on the images are also shown.

Consequently, the lineaments in 70°-80° and 35°-40° directions are perhaps more or less related to the principal compression in domain 1 (070°), and the lineaments in 270°-280° are possibly related to the principal compression in domain 2 (Tjia, 1972). Despite differences in terms of information content, the plotted faults (Figure 4C) also show similarity with the plotted lineaments taken from LANDSAT MSS for the study area (Figures 4A and 4B). However, the plotted faults show a lack of similarity with the results found by Tjia (1972). The probable reasons are, first, the plotted faults (Figure 4C) are not representative of the whole area of tectonic domain 3, and second, the plotted lineaments represent a wide range of fracture types ranging from joints to faults, whereas the plotted faults only represent mapped faults.

The occurrence and concentration of rock fractures are governed by rock type, thickness of uppermost weathered mantle and brittleness of rocks (Harris *et al.*, 1960) and also by the positive structure and depression (Gol'braykh *et al.*, 1966). In the lineament analysis of Peninsular Malaysia, Tjia (1972) reported that many lineaments are very well displayed in areas underlain by granite, whereas in other areas they are poorly shown. Kim (1979) also reported that extremely low concentrations of lineaments occur in the volcanic area of the northern part of the Korean Peninsula. The density map of lineaments for the area was overlapped with the published map of the distribution of rock types, in order to test the above conclusions and findings. As shown in Figure 6, clear relationship between rock types and concentrations of lineaments are undetectable. Notwithstanding this, it may be recognized easily that high concentrations of lineaments are mostly related to higher terrains underlain by the granite (G) and that low concentrations of lineaments are usually related to lower terrains of the Triassic rocks (TR) and the Silurian-Ordivician rocks (OS). However, it is evident that the lineament density is low in places where the granite forms lowland areas. On the other hand, the lineament density is high in places where the Triassic and Silurian-Ordovician rocks form highland areas. Therefore, the high lineament concentrations in the area are closely related to higher terrain which is formed by more resistant rocks such as granite and sandstone, whereas low lineaments concentrations are associated with lower terrain which is mainly formed by less resistant rock types such as shale and slate. Around Grik, the area mapped as volcanic rock was found to have a low lineament concentration. Although in some areas the causes of lineament concentrations remains unclear, they seem to have some structural significance.

It has been said that areas with numerous fracture intersections are good prospecting targets because channels, such as faults or joints are conduits for ore-forming solutions (Riley, 1959; Halbauty, 1976; Ahmed, 1983; Raj, 1984). Local fracture patterns are mappable on enlarged LANDSAT images; hence, are being used on a worldwide basis for exploration. The lineament density map of the study area was constructed and compared (overlapped) with that of the mineral distribution map (Figure 7). There is only one place where the concentration of lineaments and the occurrence of circular features apparently coincide with the distribution of mineral deposits, whereas in other

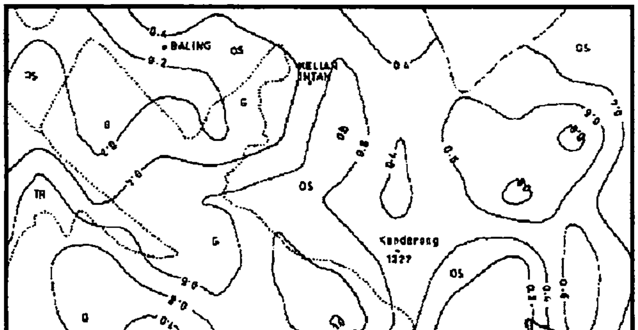

Figure 6. Relationship between the rock types and the density of lineaments seen on Landsat MSS image for the Upper Perak Valley area. The geological boundaries are taken from the map by Geological Survey o Malaysia (1985). G = granite, T= Tertiary, TR= Triassic and OS Ordovician-Silurian.

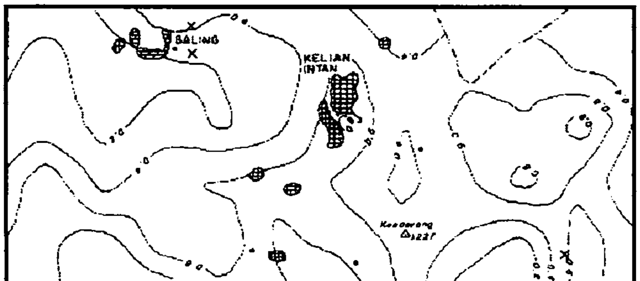

Figure 7. The relationship between mineral deposits and lineament density as depicted on the Landsat MSS images of the Upper Perak Valley area. The information on mineral deposits is taken from the map by Geological Survey of Malaysia (1976).

areas this relationship is not obvious. The mineralized area near Kelian Intan (Figure 7), which coincides with the concentration of lineaments and one circular feature is the largest primary mineral deposit that has been reported in the area, and is being mined whereas other deposits may be small, secondary deposits and with no potential or unknown potential economic interest (Jones, 1970: GSM, 1976). Because there is evidence that large mineral deposits in the area is related to the concentration of lineaments and circular features, the location and recognition of faults and extension fractures, fault intersection patterns and such other regional features will, therefore, facilitate the planning of mineral exploration and in the identification of new mineral deposits.

CONCLUSION

This study has demonstrated that LANDSAT MSS images are very useful for structural (lineaments) mapping and interpretation. Despite the dense vegetation cover, the study has shown that remote sensing data can be used in locating known features (faults) and additional previously unknown features such as faults and circular features which may be of economic importance in the area. Hence, lineament analyses from satellite data can provide a new, rapid and stimulating overview for structural information which can be used for other studies.

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