Remote Sensing Technique for Lineament Extraction in Association with Mineralization Pattern in Central Belt Peninsular Malaysia

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Abstract. Geographical information system and remote sensing data are now more remarkable for the extraction of lineaments. Lineaments studies provide the tectonic history of geological settings. It is the objective of this study to demonstrate the extraction of lineaments from Landsat 8 Operational Land Imager (OLI) of Kelantan area. The current approach applied different image processing techniques on Landsat 8 imagery to achieve its gold. The image processing techniques include; principal component analysis (1,2,3), Band ratios (7/5,6/4, 4/2) and Minimum Noise Fraction bands (7,5,3). Gamm stretching and directional filtering facilitate the extraction of lineaments. The results of this study indicate that the area is affected by several structural trends (N–S, NW–SE, and NE–SW). The structural trends sever as conduits for gold mineralization fluids. The methodology demonstrates capability in extracting lineaments from Landsat 8 imagery. The methods locate known gold deposits and also highlight new locations for new ones.

1. Introduction

The interest in Geographical Information System (GIS) and remote sensing technology had increased its application in various fields of scientific research. Scientific research fields such as geology and mineral exploration considered GIS and remote sensing data as an excellent resource for structural mapping. Its importance in structural geological studies is remarkable. Remote sensing technology is capable of capturing and storing geological features from the earth surface. Lineaments are straight lines surface element that can be extracted directly from satellite imagery [1, 2]. Remote sensing research had reported the successful application of Landsat 8 imagery in arid and semi-arid regions in pieces of literature including [3,4, 5].

Remote sensing techniques such as PCA (principal component analysis), MNF (Minimum Noise Fraction), and Band rationing, improve and enhance satellites images. The enhanced images facilitate the differentiation and characterization of the structural geological elements [6,7, 8]. This study reviews the application of Landsat 8 imagery with regard to climate conditions. The review shows a more successful application in arid to semi-arid region compared to tropical environments[9,10,5]. Thick vegetation cover characterizes tropical environments. Landsat 8 application studies are challenging by vegetation cover in a tropical environment. Most times the techniques produced images without much clarity. The solutions to this hurdle lie in the selection of bands for the image analysis. This research provides the appropriate band combination for Landsat 8 application in Kelantan. The study extract lineaments from Kelantan area. And further, established the relationship between lineaments and gold deposits distribution within the study area. The idea of this work applied different image enhancement techniques on Landsat 8 imagery to achieve its gold.
1.1 Study Area

The study area is located between longitudes E 101˚48′30″-102˚ 0′ 10″ and Latitudes N 4˚38′50″-4˚54′0″ in the southern part of Kelantan state Malaysia (Figure 1). Kelantan is located at the north-eastern corner of Malaysia Peninsular. The area covers approximately 570km². The region is characterized by tropical monsoon climate, with a significant temperature, which ranges from 21°C to 32 °C from January to December. An average yearly rainfall range of 2030 mm to 2540 mm characterizes the study area. The wettest months begins from November through January. The topography is mountainous with extensive deep valley. In this selected area of study, the altitude ranges between 80.0 m to 780 m (Figure 2). The high mountainous region is located North-central and the South-eastern part of the study area. An extensive drainage network with other small tributaries cut the study area and conditioned the morphology. The drainage pattern often displayed a general orientation, i.e. N-S, to NW-SW and NE-SW, N-S to NW-SE, furthermore, these orientations are related to the past orogeny activity. The study area is partly accessible by vehicle. The region is known for its historic gold exploration and mining activities.

Peninsular Malaysia is an integrated part of the Southeast Asian continental core of Sundaland, and it is characterized by two tectonic blocks/terranes, the Sibumasu terrane in the west while the Sukhothai Arc in the east [11,12, 13]. The selected region of study is composed of a variety of rocks, Igneous, sedimentary and metamorphic. The rocks are evenly distributed in a north-south trend. Further classification of the rocks in the area of study highlight four classes, granitic rocks, sedimentary/metasediment rocks, extrusive rocks and unconsolidated sediment. Localized geological features also characterize the area comprises of faulting and jointing in the granitic rocks and folding, faulting and jointing in sedimentary rocks[13].

Figure 1. Geology and study area map (modified from Mineral and Geoscience Department Malaysia).
2. Methodology study

Focused on lineaments extraction have rendered many methods for their identification. Review in this regards has identified the application of the individual bands of Landsat 8 imagery. Band 5 is specific for soils and rock discrimination. While Band 7 is specific for geology, Band 3 is for soil discrimination from vegetation [10, 14].

2.1 Data Description and Image Enhancement

Data and equipment such as (i) Gold deposits locations provided by Mineral and Geoscience Departments of Malaysia (GJM) (ii) ArcGIS 10.3 and (iii) Landsat 8 OLI imagery (Path 127, Row 57) acquired on 3rd July 2016 free downloaded from USGS web page, were used in this study. The approach applied different enhancement techniques such as PCA, Band combination, and Band ratios on Landsat 8 imagery for lineaments extraction. PCA analysis considered bands (1-7). PC (1, 2, 3) revealed the structural information. Gamma stretch was applied to the RGB combination of PC 1, 2, 3 for better distinction of geological features. MNF analysis considered band (7, 5, 1). All the considered bands enhanced lithological features. All the resulted images were also compared with the band ratios RGB combination of the band (7/5, 6/4, 4/2) for lineaments extraction.

2.1.1. A Manual Lineament Extraction from enhanced Landsat 8 OLI imagery and Geological Map.

As earlier defined, lineaments are the observable straight lines structures on satellite images. The definition excludes anthropogenic features such as road, railways, and electric grids. This study avoided all anthropogenic features [2, 15]. The Current study delineates and extracts lineaments from the geological map of Kelantan. The extractions were performed using on a scale of 1:200000 using ArcGIS.

The idea also delineates and extracts lineaments from enhanced Landsat 8 images of the study area. The number of lineaments extracts from satellite imagery depends on the analysis applied to the images. The images realized to bring out lineaments details includes PCA 123 as RGB (Figure 3a) and MNF 751 as RGB (Figure 3b) Lineament clarity relied on enhanced textural property observed in band ratios.
RGB of 7/5, 6/4, and 4/2 (Figure 3c). Resolution of the satellite imagery data determined the quality of images and the information contents. This work performed a layer stacking of 1 to 7 bands combined with band 8 as resolution merge, the resultant image enhanced lithology and allow differentiation of natural lineaments from artificial ones.

3. Results and discussion

The combinations of bands from the visible, mid-infrared and shortwave infrared bands highlight geological features. Images resulting from RGB combination of PCA (PC 1, 2, 3) (Figure 3a), MNF (band 7, 5, 1) (Figure 3b) and Band ratios (7/5, 6/4, 4/2) (Figure 3c), were used as reference points to digitalized the lineaments in the selected area of study. The RGB band combination outline lithological boundaries. In this study, layer stacking of bands (1-7) combined with the high-resolution band (band 8) distinguished lithological boundaries.

The lineaments extractions and analysis recorded high counts of 58 lines from the enhanced satellite images compared to only 36 digitalized from the geological map (Table 1). Lineaments are aftermaths effects of tectonic plays on geological terrane, fewer counts of lineaments almost always suggests less effects of tectonic activity on surrounding rocks. The results of lineament analysis give us a proper interpretation of the main structural geology and tectonic forces (Figure 3(d)) and suggest the area is profoundly affected by several structural trends N-S, NW-SE and E-W directions.

The methodology of this work demonstrates the capability of lineaments extraction from Landsat 8 imagery. Band selection determines the outcome of structural mapping using satellite images. The selected band use in this research demonstrates efficiency in highlighting lineaments from Landsat 8 imagery. Directional filtering and Gamm stretching allow the orientation of lineaments to be determined. The rose diagram for both the lineament digitalized from the geological map and the enhanced images shows a dominant trending direction of NW-SE and NE-SW (Figure 4a and b). These trending directions had been reported in the literature on this focus as the dominant trending direction in the selected area of study [16]. Comparing, the distribution of gold deposits and the lineaments pattern (Figure 3d), established the spatial relationship between the lineaments and the gold deposits. The lithologies hosting gold mineral deposits are highly structured compared to regions without any gold deposits. The current research is in conjunction with the gold mineralization zonation [17], which reported that two major directions (NE-SW and NW-SE) control gold mineralization in Kelantan. Heng et al. [17], focused only geochemical and geophysical data on unraveling the distribution pattern of gold deposits within the study area. Their results conclude that lineaments serve as channels for gold deposition [18, 19], hence the presence of lineaments may indicate gold deposits occurrence. This current study uses the satellite imagery to high and delineates the lineament within the area of study. Since the known gold deposits coincide with NE-SW and NW-SE lineament directions, areas dominated by lineaments trending NE-SW and NW-SE have the high potential of gold deposits occurrence.

Table 1. The Statistical comparison between the lineaments extracted from geological map and Lineaments from the enhanced Landsat 8 images

| Criteria                              | Geological Map | Image process |
|---------------------------------------|----------------|---------------|
| Counts                                | 36             | 58            |
| Total Length of all Lineation (m)     | 174,507.1      | 230,292.73    |
| Maximum Bin Population (m)            | 8.0            | 13            |
| Mean bin Population (m)               | 3.0            | 4.14          |
| Standard deviation of Bin Population (m) | 2.13        | 3.48          |
| Maximum Bin length (m)                | 21,458.99      | 27,1567.71    |
| Mean Bin Length (m)                   | 7,271.13       | 8,224.74      |
| Standard deviation of Bin Length (m)   | 5,5169.07      | 7,414.48      |
3.1 Validation

The approach of this study compared the lineaments extracted from satellite images with the digitalized lineament from the geological map (Figure 3d). The synthesized structural map suggests a significant pattern of trend or structural direction compatible with the geology of the area. The structural pattern is also in conjunction with the published geological report on mineral resources of Kelantan region [12]. Field visits to the selected area of study also confirmed most of the extracted lineaments.

4. Conclusion

Landsat 8 OLI is characterized by high spatial resolution SWIR (30 m) (band 1-7) and band 8 (15 m). Resolution merge facilitates lineament analysis. It plays a vital role in this current study. Enhancement of images is paramount in satellite imagery mapping. PCA, MNF, and Band ratios enhancements
techniques improve satellite imagery interpretability of vegetated area. The further stretching and pan sharpening of enhanced images increased contrast on lithological features and allowed easy extraction of lineaments. This research demonstrates that band combination such as (i) RGB combination of PCA (1, 2, 3) (ii) MNF Combination of (7, 5, 1) and (iii) Band ratios combination of 7/5, 6/4, and 4/2 enhanced geological features Landsat 8 imagery in a tropical environment. The approach demonstrated efficiency in extracting lineaments from Landsat 8 imagery of Kelantan area. The study area had suffered deformation from past tectonic events. The past tectonic activity resulted in various trending lineaments extracted (NW-SE, NE-SW, and N-S). Gold deposits distributions pattern shows a spatial relationship lineaments. Two significant lineaments (NW-SE, and NE-SW), control gold deposits occurrence in the area. The study locates not only the known gold deposits but also locate the new area of possible gold deposits occurrence. Highly structured areas are site for potential gold mineralization. The methodology of this study is adoptable for Greenfield exploration especially in regions with similar geological setting like Malaysia.

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