World Applied Sciences Journal 17 (11): 1516-1520, 2012
ISSN 1818-4952

DEM Application for Geological Structure Interpretation: A Case Study at the Koh Samui Area, Gulf of Thailand

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Abstract: The Digital Elevation Model (DEM) data has been become popular and applied to many geological research areas because they have advantage over remote sensing data by more available with time and less expense. In this context, this paper examines the application and quality of digital elevation models for the detection and mapping of structural lineaments at the Koh Samui area where the one of the areas showing distinct relief and topography is is selected to be study area for applying DEM data to geological structure interpretation. Shaded relief images, variation of vertical exaggeration and sun angle and azimuth are used to enhance the DEM data for this study. The vertical exaggeration for DEM data as well as sun azimuth and angle for relief illumination can be used to support different images with different enhanced features. The interpreted lineaments in this area as inferred from various enhancing techniques are seen to trend in NW-SE and E-W directions. The interpreted linear map demonstrates that the E-W system have been offset by the NW-SE fault system which is interpreted as the right-lateral strike-slip fault. It is also visualized that the Cenozoic extensional tectonics with dextral shear movement is prominent in this area. The results of this study demonstrate that mapping structural features through DEM can provide good-enough geological information dependent on scale of interest and data quality.

Key words: DEM · Tectonics · Lineaments · Koh Samui

INTRODUCTION

DEM (Digital Elevation Model) data are digital elevation set recording the topographic surface expression of any area. The DEM data can be presented in form of grid, contour and profile due to the elevation data which is usually provided as a continuous data. The DEM data has been applied to many geological research areas such as geohazard, geological analysis of morphology [1-3], vegetation studies [4], hydrologic modeling [5], potential flooding area modeling [6] and morphotectonic analysis [7]. The DEM technique is also used for structural interpretation particularly in terms of regional study, because it can increase visual ability to interpret the data. The DEM data also provides information on the nature of vertical movements of active sub-surface faults and folds [8]. It is important to note that this method does not distinguish between rock units, so it is only useful for looking at general linear patterns. Understanding the geological structure is important for many branches of earth science including earthquake, tectonics and petroleum geology. So, the aim of this paper is to test the ability of the DEM data to map out the geological structure of the Koh Samui area, Gulf of Thailand. In addition, this documentation is used to imply regional tectonic in the study area.

The Gulf of Thailand is well known for oil and gas exploration. It is very important to understand the basic geological structure in the region for petroleum exploration and improved knowledge of geological structure enhances the ability to construct the basin model and structural evolution. The Gulf of Thailand is composed of series of north-south oriented basins. The faults observed in different basins are N-S oriented and at some places NW-SW and NE-SW bends are observed [9].

MATERIALS AND METHODS

The Koh Samui area is located in the Gulf of Thailand and nearby the peninsular Thailand (Figure 1). This area is used to be the study area and shows a significant feature related to geological structure on the DEM data.

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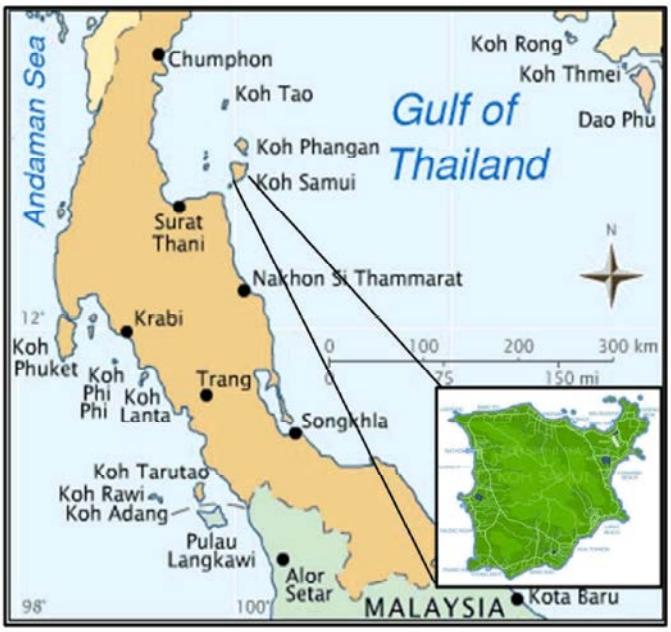

Fig. 1: Location of the study area (Koh Samui Island) in the Gulf of Thailand.

Geological structures can be recognized on the DEM data as either linear or curvilinear features. This area is occurred from the slow granite intrusion of magma through several-facies sedimentary rock during Triassic time [10]. The granite in this area has very thick weathered granite zone at their surface, ranging from 10-40 m usually and more than 50 m sometimes in the central plain. Quaternary deposits cover most of the low lands and coastal plain areas.

The DEM data with a 90 m pixel derived for SRTM (Shuttle Radar Topography Mission) data obtained from the CGIAR-CSI SRTM website (http://srtm.csi.cgiar.org). The DEM image covers an area of approximately 231 sq. km. The DEM technique for structural interpretation is on the basis of shade relief image with various elevations. In addition, the enhance techniques such as different vertical exaggeration with varying sun azimuths and angles can improve elevation image for interpretation.

In order to achieve the objectives, the following steps were undertaken: (1) image enhancement techniques, different vertical exaggeration and shading, were first applied to raw data of the DEM image; (2) the enhanced image data were interpreted using visual justification to produce a lineament map; (3) the lineaments information obtained from interpreted lineaments were plotted in rose diagram; (4) the major trends interpreted from stereo net lead to the geological structure of this area. In additional, linear features observed from the DEM image were considered to be fault and fracture.

RESULTS

Shade relief images are created by using 45 and 60 degrees of sun angles and 45 and 315 degrees of sun azimuth (Figure 2). Then, variation of vertical exaggeration is applied by using 5, 10 and 20 values (Figure 3). The different sun angle is able to map out the structures with various orientations. Areas perpendicular to the sun angle are illuminated the most while the areas with high angle or greater than 90 degree are shaded [11]. It is clearly shown that sun angle with 45 degree trends to give the NW-SE linear direction, while sun angle with 135 degree trends to give the E-W linear direction. So, the lineament azimuth data are divided into 2 groups for plotting in rose diagram (sun angle with 45 and 135 degrees in Figure 5). Areas with low elevation contrast are enhanced by increasing the topography or the relief surface. Therefore, the DEM images show that the texture and linear pattern are enhanced. This makes the geological structure determination easier.

The interpretation of these images led to the achievement of a map with total lineaments of 104 lineaments. The example of lineament interpretation is shown in Figure 4. The lineaments in this area as inferred from tonal shading variation are seen to trend in NW-SE and E-W directions. Thus, these lineaments are plotted into rose diagram in order to define structural trend of this area. The lineaments of the map are processed statically and rose diagrams are constructed according to their frequency of appearing (Figure 5).

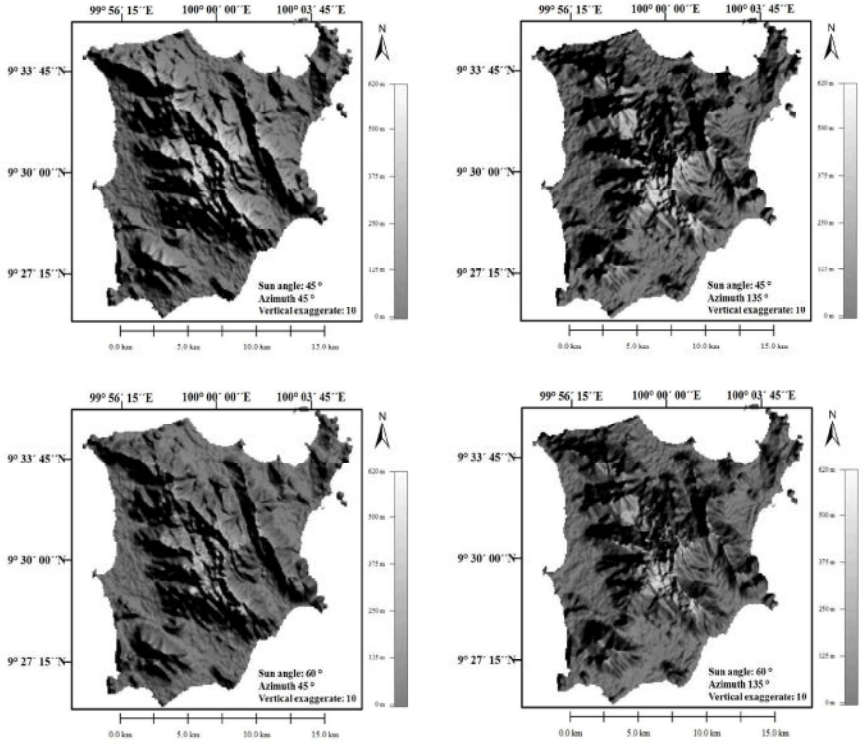

Fig. 2: Example of shade relief image with varying sun azimuth and angle that can be used to enhance structural determination in the area.

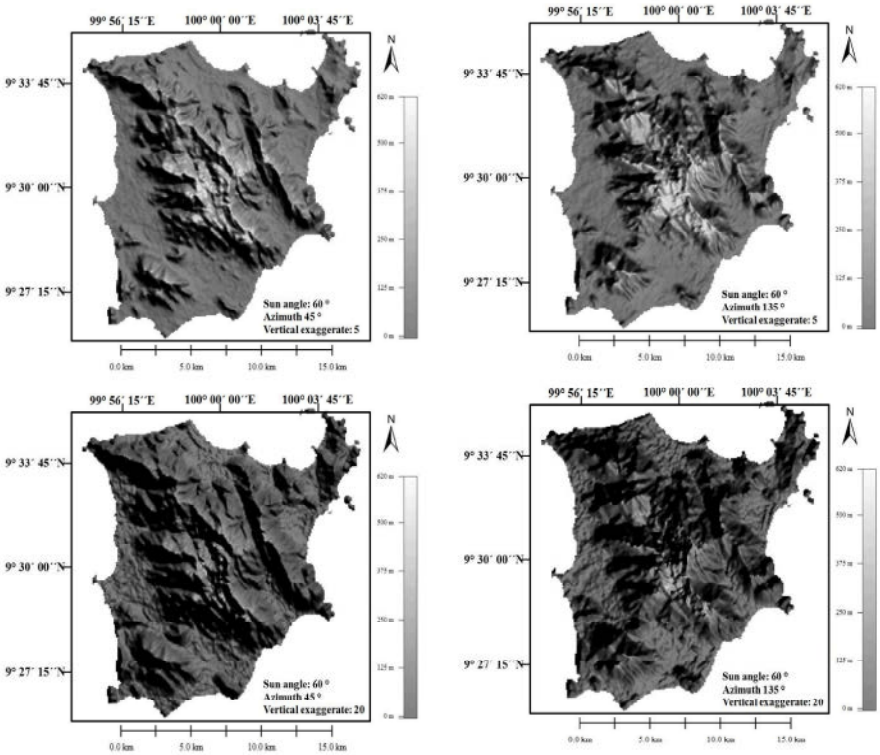

Fig. 3: Example of shade relief image with different vertical exaggeration that can be used to enhance structural determination in the area.

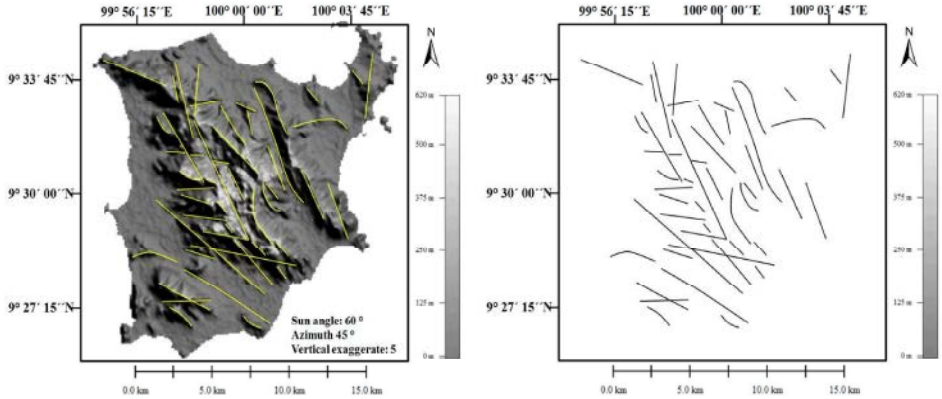

Fig. 4: Interpreted linear and curvilinear map of the Koh Samui area as inferred from various shade relief images of the area (left with the DEM image and right without the DEM image).

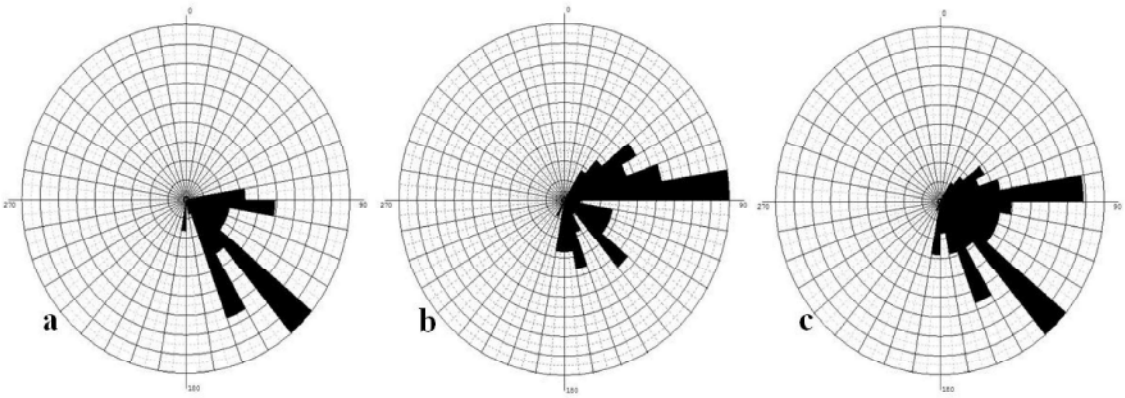

Fig. 5: Rose diagrams are created by azimuth frequency with varying sun angle shading, a) 45 sun azimuth, b) 135 sun azimuth and c) total azimuth frequency from both angles.

The rose diagram highlights the existence of orientation intervals with maximum values (131-140) as shown in Figure 5c. The intervals with maximum values from the rose diagram can be interpreted as a major structural trend coincided with regional structure in the Gulf of Thailand. The E-W linear trending was considered to be minor trend in this area.

DISCUSSION

The Koh Samui area provides an opportunity to observe structural features on land where the tectonic context may be preserved in the surrounding seafloor. The fractural tectonics of the Koh Samui is marked by fractural event of the ground, most often oriented NW-SE up to W-E. The majority of them were generated during Himalayan orogeny during Oligocene to Miocene time [12-15].

Moreover, the interpreted linear map (Figure 4) shows that the E-W system have been offset by the NW-SE fault system. On the basis of image interpretation form this DEM data, the NW-SE fault is the right-lateral strike-slip fault. Their orientations can be related to the stain ellipsoid of a Cenozoic dextral simple shear model that is with N-S compression and E-W extension, proposed earlier by Polachan and Sattayarak [13]. This linear pattern suggests that this motion is in response to regional compression with a maximum vertical stress orientated approximately N-S. This is roughly perpendicular to strike of regional structure in this area. In the Middle Eocene, parts of continental SE Asia experienced expulsion as a consequence of collision between the Indian plate and Eurasian plate. Then, fractures are parallel and sub-parallel to the regional tectonic.

CONCLUSIONS

The linear trending can be observed throughout the area from the DEM data. The DEM data can be used to map out geological structure in a satification level, particularly when some other data area not available.

The results of this study demonstrate that mapping structural features through DEM can provide good-enough geological information dependent on scale of interest and data quality particularly by vertical exaggeration as well as sun azimuth and angle for relief illumination. The DEM technique has advantage over remote sensing data by more available with time and less expense.

The applicability of this type of study can be useful for a detailed presentation of the structural characteristic features of a future study. The result show that the fault pattern of the Koh Samui is marked by faulting event of the ground, most often oriented NW-SE up to W-E. On the basis of surface fracture analysis form this DEM data, the NW-SE fault is possibly related to the right-lateral strike-slip (dextral) fault. However, the detailed interpretations of the geometry of interpreted linear here were not made.

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