Application of DEM Data to Geological Interpretation: Thong Pha Phum Area, Thailand.

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ABSTRACT

The Digital Elevation Model (DEM) data can be created from GIS (Geographic Information System) data layers i.e. contour line and spot height. The result is expressed as grid data of which their quality controls are the quality of original data and grid size assigned for interpolation process. The grid data are further processed to be shaded relief image by illumination method. The height exaggeration for grid data as well as sun azimuth and angle for relief illumination can be varied to obtain different images with different enhanced features. The Thong Pha Phum area in the west of Thailand where has been well known as one of the areas showing distinct relief and topography is selected to be study area for applying DEM data to geological interpretation. The shaded relief images of the area are used for geological information extraction by visual interpretation. This information includes geological structures (e.g. faults and lineaments) and materials such as rock types. A number of interpreted images is exhibited as examples. The result shows that the shaded relief image can provide good-enough geological information. The advantage of DEM data compared with remotely sensed data, particularly the Thematic Mapper (TM) data, is discussed. They can be used to substitute the TM data in a certain level but better as the supplementary data for this purpose.

INRODUCTION

The elevation data have been applied generally for many purposes, for example, providing flood and landslide risk zone, road corridor selection including cut and fill estimation, siting proper position for relay station, etc. These data are also good for geological interpretation, particularly in terms of morphology, rock types, and structure. This geological information allows anticipating the foundation characteristics of an area, which is very useful for engineering tasks.

In the past, the elevation data such as contour are used by means of 3D imagination to achieve topographic surface expression. This requires a skillful person. DEM technique can help young experienced person out of this because it can increase visual ability to the data. Digital elevation data in forms of contour and spot height are used to produce DEM (Digital Elevation Model) data. Elevation data in a grid form, which is a type of DEM data, are produced and converted to be shaded relief image for geological interpretation.

With varying sun azimuths and angles, together with different height exaggerations assigned, shaded relief images can be produced and enhanced from grid-form elevation data. This type of image is tried for geological interpretation in case no remotely sensed image available.

Thong Pha Phum area located in the western mountain ranges of Thailand is selected to be the study area. The area shows prominent distinct relief resulting from varieties of geological materials and structures. Lithological difference of the area resulted in different relief, topography and drainage patterns.

DEM DATA

What are DEM Data?

DEM data are digital elevation data set recording the topographic surface expression of any area. The nature of elevation data is continuous, not discrete. However, due to the limitation of recent technology, DEM data can be displayed in forms i.e. grid, contour, profile, and TIN (Triangulated Irregular Network) which are not completely continuous. In this study, these data are displayed in the form of grid.

How to Achieve DEM Data?

The diagram showing how to achieve DEM data is illustrated in Figure 1. Four data layers including contour, spot

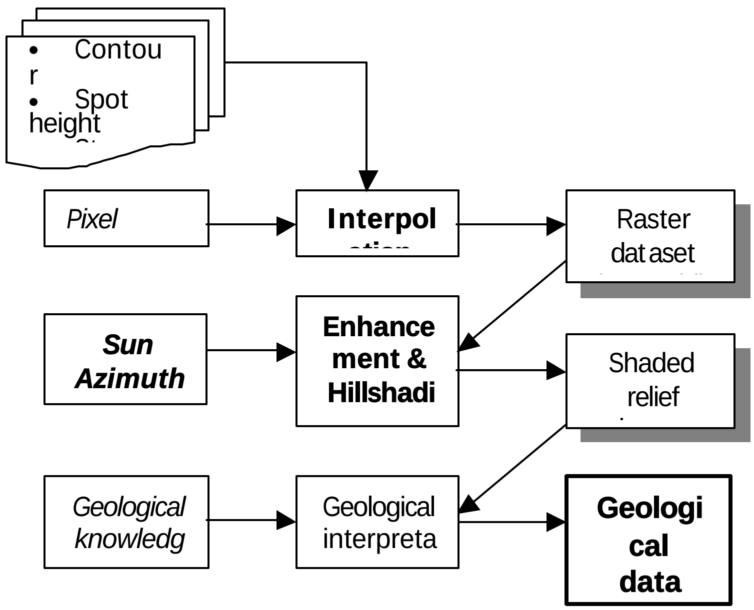


Figure 1 Inputs, processes, outputs to achieve DEM data and interpreted geology.

height, stream and study area boundary are input into the interpolation process so that a raster data set of elevation with the required pixel resolution can be achieved. This output is further used in the illumination process to produce shaded relief images. Prior using in the process, the original raster data set of elevation can be multiplied by integers to get different height-exaggeration data sets. Varying sun azimuths and angles are input parameters for the illumination process in order that output images can display enhancement on different features.

Contour and spot height layers providing linear and random elevation data are estimated and distributed into grid system using interpolation process. Several grid (pixel) sizes are tried out and found that 15m x 15m is the proper size that can keep the original topographic characteristics and the file size is not too big for computer to handle. Stream layer is used to mark the draining courses flowing from upstream to downstream. While the study area boundary tell the process the extent limit.

In this study, digital contour with 20 m interval and spot height, prepared from originally 1:50,000 scaled topographic map sheets 4738 III of the Royal Thai Survey Department (1969), are taken from the Database System of the Geological Survey Division of Thailand. The *topogrid* and *hillshade*, functions of Arc8 software equivalent to interpolation and illumination processes, are used to obtain elevation data in grid form and shaded relief image. These processes are explained in *Help online* of Arc8 software. Few examples of shaded relief image with varying sun azimuth and angle are displayed in Figure 3.

ELEMENTS OF SHADED RELIEF IMAGE

An image such as the one obtained from remotely sensed data or DEM data is, in general, composed of 7 basic elements useful for interpretation. These include *tone, texture, pattern, size, shape, shadow* and *association* (Lillesand and Kiefer, 1979; Gupta, 1991). In the shaded relief image, tone, the primary basic element, is the gray level within a certain pixel of the image. This gray level is proportion to the deviation angle from the normal incident of light from the sun. The more deviated the angle is the gray level is higher – move up to 256 level direction. Therefore, the attribute of tone in a pixel of shaded relief image depends on its slope and aspect, which are generated from height distributing in an area. Other elements such as texture and pattern are arrangements of tones, which reflect attributes of objects on surface that related to elevation or slope and aspect.

BASIC CONCEPT OF GEOLOGICAL INTERPRETATION FROM AN IMAGE

Basic Elements of an Image Related to Geology

Geology of an area can be extracted from an image by analyzing its basic elements - *tone, texture, pattern, size, shape, shadow* and *association.* According to Gupta (1991), these elements reflect surface expressions that include *morphology, soil moisture, vegetation cover*, and *drainage pattern* within an area. In turn, these expressions are influenced by their original primary factors which are *rock type, structure, process,* and *time*. From an image, geological interpretation basically extracts information on rock types and structures of an area. Therefore, from basic elements recognition of an image to determine geology is more difficult than to determine the surface expression because one more step is extra added. This can be a sensible reason explain why automated classification for geology is very difficult. Accordingly, visual interpretation for geology is so far still the most effective method and always needs a skillful interpreter. In the shaded relief image, *soil moisture* and *vegetation cover* are missing. This can certainly reduce the accuracy and details of any interpretations, even geology which the missing ones are considered not significant compared to others.

Application of Image to Geologic/Geomorphic Interpretation

As mentioned above, morphology, rock types, and structure are geological information can be extracted from shaded relief images. Several authors e.g. Strandberg (1967), Lillesand and Kiefer (1979), and Drury (1987) reviewed geological interpretation techniques.

- Morphology and processes

From the image elements, the morphology/landform of an area which is described as extent, size, shape, height, variation of slope and aspect on the surface can be recognized. The morphology reflects processes influencing landform formation and potentially active processes working on landform. For example, back swamp deposit in the flat terrain always forms by deposition of fine-grained sediments from over-bank flood. Flooding is still active on this back swamp.

- Materials

Basically, forming processes, morphology of landform, and materials all are connected. Materials on a certain landform can be interpreted e.g. the rugged topography with sinkholes, resulting from predominant chemical weathering process, indicates carbonate terrain. Drainage pattern is used as an important clue to extract types of material from an image. Drainage pattern on shale is denser than on sandstone because of lower infiltration whereas sandstone/conglomerate can stand higher form because of higher resistance to weathering and erosion.

- Structures

Geological structures recognizable in the image normally appear as either linear or curvilinear features. Linear feature can normally be fault whereas curvilinear feature indicates underneath dome structure. This dome structure can be intrusive rocks, which might relate to economic mineral deposit, and salt dome. In Thailand there are some articles using remotely sensed data to study these features and their related buried materials (Supajanya *et al*., 1992; Sarapirome *et al*., 1995; Sarapirome, 1998)

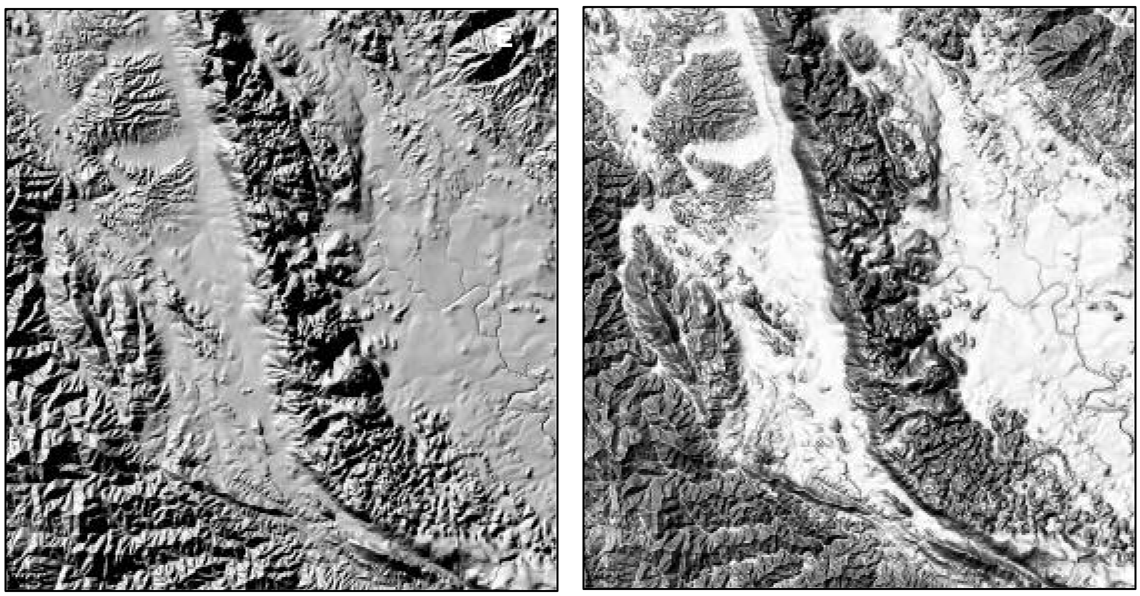
GEOLOGICAL INTERPRETATION OF THE THONG PHA PHUM AREA

Shaded Relief Image Enhancement

There are two ways in this study to enhance shaded relief images – variations of height exaggeration and sun angle and azimuth (Fig 2). The raster data set resulting from *topogrid* process is multiplied by integer numbers of 3 and 5. Then, shaded relief images are created from the multiplied raster data sets using 45^{o} and 75^{o} of sun angles and 315^{o} for sun azimuth. They show that the texture and pattern of certain areas are enhanced. This makes material type and structure determination easier. Quality of image with more height exaggeration and lower sun angle is interfered by the long-range shadow, particularly surrounding high land. Variations of sun angle and azimuth assist in enhancing some structures and rock type. Sun angles is assigned to be 10^o and 45^o while its azimuth is 315^o, 225^o, 45^o, and 135^o, and some are shown in Figure 3(1-3). Enhanced geological features present in different areas as examples listed in Table 1.

Table 1 Geologic features enhanced when sun azimuths and angles are varied.

Area	Enhanced features
A	NNW narrow valley appears as fault scarp or linear slope change.
B	NS creek with higher bank in the western side indicating faulting.
C	Showing obvious texture and pattern of clastic rocks.
D	NW and NNW channels and NW elongated hills interpretively associated with faults.
E	Circular feature indicating buries intrusive.
F	Karst topography due to prevalent chemical weathering.
G	Intermontane flat area with structural-controlled channels and scattered hills, indicating soft bed rocks on surface or at shallow depth.
H	NNW deep linear narrow valley indicating faulting.



Sun Azimuth 315 Sun Angle 45 Vertical Exaggeration 3x Sun Azimuth 315 Sun Angle 75 Vertical Exagg

Figure 2 Examples of shaded relief image with different height exaggeration.

Interpreted Geology of the Thong Pha Phum Area, Thailand

Using visual interpretation, structure and rock units of the study area can be recognized. The preliminary and unpublished geologic map conducted by Khemhleg and Jiemton (1989) was partly consulted and limited field check was carried out.

This area is characterized by ranges with narrow valleys and shallow basins due to very strong influence of faulting of the area, particularly in the zone of the famous three-pagoda fault oriented in NW and NNW directions. Three kinds and ages of limestone are exposed in the area, namely bedded to massive limestone which is NNW to NW orientation in the middle of the area, bedded and partly brecciated dolomitic limestone, and interlaminated argillaceous limestone. Granite intrusion through older clastic sediments is at the SW corner of the area whereas metamorphic complex of quartz mica schist, quartzite, and gneiss is at the NE corner. Quaternary gravel bed is clearly observed in the NW part of the area. All rock units are displayed in Figure 3(4) and described in Table 2.

Table 2 Rock units within the study area.

Unit	Description
1	Shallow basin of thin and young sediments with reflection of underneath structure
2	Gravel bed
3	Semiconsolidated gravel, siltstone and sandstone, caliche rich
4	Granitic rocks
5	Dolomitic limestone, bedded, frequently brecciated
6	Sandstone, conglomerate, and shale
7	Limestone and interbedding of sandstone and shale
8	Thick bedded and massive limestone with clear karst topography
9	Shale and minor sandstone
10	Sandstone and minor shale, phyllite and slate
11	Interlaminated argillaceous limestone
12	Quartz mica schist, quartzite, and gneiss

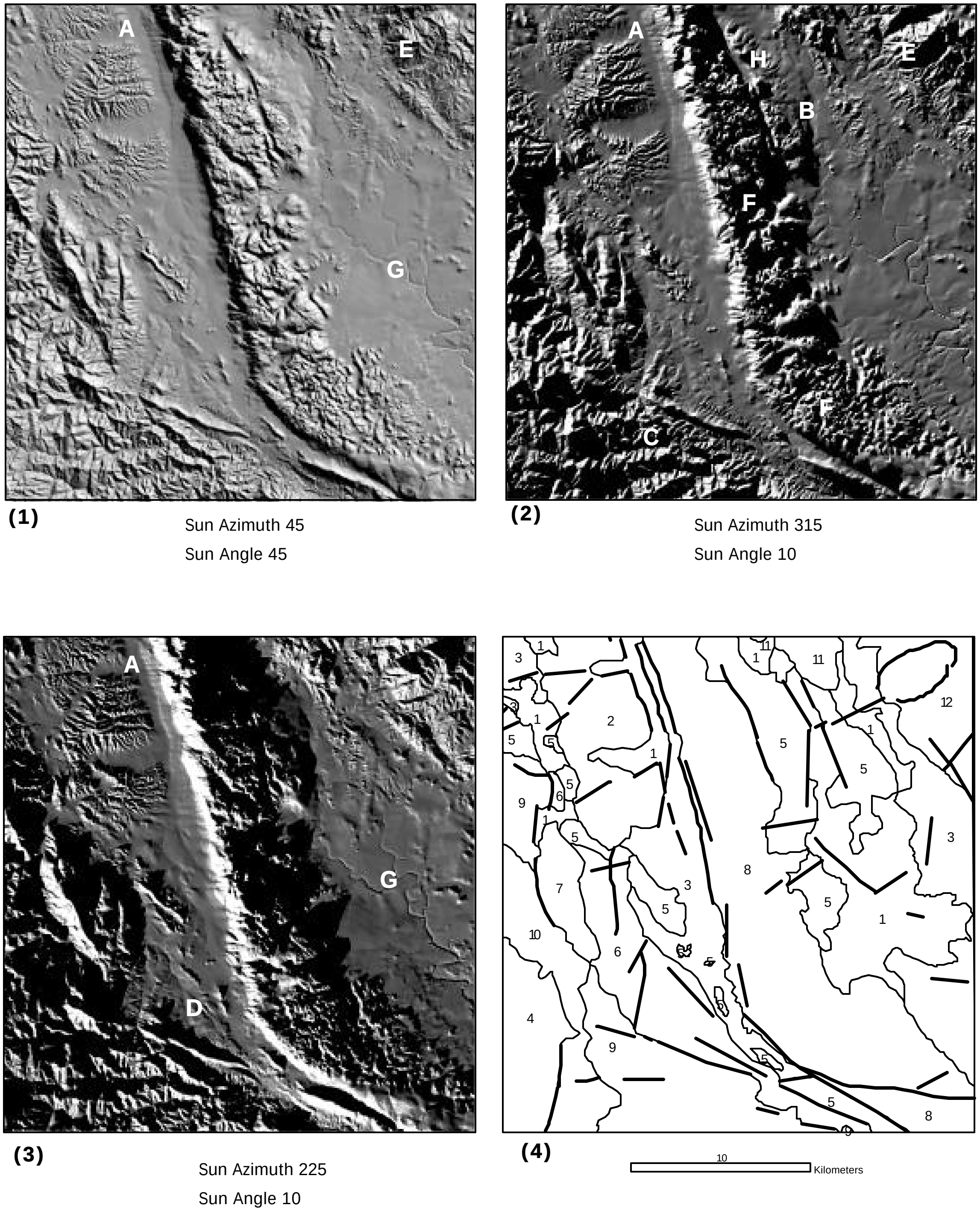


Figure 3 Examples of shaded relief image with varying sun azimuth and angle that can enhance features in areas (1-3). Interpreted geology of the area is displayed in (4), unit description see Table2.

COMPARISON OF DEM DATA TO RS DATA

The purpose to compare applications of DEM and RS data is to discuss their advantage and disadvantage including the way they support to each other.

1) DEM data can be used as supplement of RS data to enhance some features for increasing interpretation accuracy.
2) Effective when lag of RS data, because DEM will be more available with time and less expense.

3) Variations of sun angle and azimuth as well as height exaggeration in DEM data and shaded relief image assist in geological feature recognition.
4) DEM data created from old elevation data will preserve the original topography that is not disturbed by later activities such as dam and reservoir construction. These activities will change or cover the original data and can affect the accuracy of geological interpretation.
5) Compared to airphotos with mosaic form, DEM data could have a lot less resolution but be better in synopsis view.
6) Spatial accuracy of DEM data relies on original elevation data and resolution used for interpolation. However, the spatial resolution of original elevation will be the limit of the data detail. It means that even though the interpolati on resolution is higher than the original, the data detail will not be higher than the original. But they might look better when transformed to be shaded relief image. In case like this, elevation in RS data can be better recorded in every single pixel.
7) Temporal resolution of RS data is a lot better than DEM data. Original topographic data of DEM data will not be updated frequently.
8) Many bands of RS data are much more useful in terms of multi-bands analysis. Moisture and alteration zone can be extracted from this data property and cannot be done in DEM data. However, land use and vegetation cover on the RS data can sometimes be illusive or obstructive for geological interpretation.

CONCLUSION

DEM data can be used for geological interpretation in terms of morphology, materials and structure recognition, in an acceptable level, particularly when some other data are not available. Proper interpolation resolution and proper scale of shaded relief image will assist to achieve this purpose. From this study, original elevation data used is in the scale of 1:50,000 and interpolation resolution is 15 m x 15 m, the proper scale at 1:125,000 to 1:175,000 of the shaded relief image is found out. In addition of data detail, general knowledge on geography and geology of the study area can also be useful. Reconnaissance survey before and during interpretation can help identify features seen from the image.

To achieve the better result, integrated data should be employed for interpretation. These data include topographic map, air photo, satellite data, shaded relief image, previous studies including field data.

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