Relationship between Lineament Density Extraction from Satellite Image and Earthquake Distribution of Taungtonelone Area, Myanmar

Myint Soe[a], Krit Won-In[b], Isao Takashima[b], Punya Charusiri[c]

a   Graduate School of Engineering and Resource Science, Akita University, Akita 010-8502 JAPAN
b   Center for Geo-Environmental Science, Akita University, 1-1 Tegatagakuen-cho, Akita 010-8502 Japan
c   Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand
*   Corresponding author, E-mail: myintsoe68@gmail.com

Abstract:
We studied relationship between lineament density extraction from satellite image and earthquake distribution using remote sensing applications. The result of this study aim to set up a complete earthquake hazard Map. The selected area is located in the Taungtonelone area, northern Myanmar. Myanmar is an earth-quake-prone country. It lies in a major earthquake zone of the world called Mediterranean – Himalayan belt. As the major urban areas in Myanmar lie in earthquake prone zones, earthquake hazard reduction program is needed. Seismic monitoring and seismic database in Myanmar is in the early stage of developing. The current seismic hazard map of Myanmar is based on historical seismicity. Thus, there is a pressing need to prepare national seismic hazard maps for earthquake. Tectonic faults are often associated with characteristic geo-morphological features such as linear valleys, ridgelines and slope breaks that can be identified as lineaments in remotely sensed images of digital elevation models. A lineament map was prepared using stereo pair image of ASTER image, Landsat 7ETM+ image, SRTM DEM image. A variety of image processing techniques were used to highlight linear features of images. Known techniques such as color composite, Pseudo color DEM shade relief and 3D stereo anaglyph have been applied to enhance images for visual interpretation. The lineament reflects the geological structures such as faults or fractures. All lineament frequencies and lengths per unit area are calculated and combined to generate lineament density map. A grid system was used to obtain the data for lineament density values. This analysis produced a map showing concentrations of the lineaments over the area. The lineament density map can be used for the quantitative evaluation between lineaments and the earthquake risks monitoring for the future.
Key words: earthquake prone zones, image processing, lineaments, lineament density

1. Introduction

The study area of focus covers the Taungtonelone area, northern Myanmar. It is situated between latitudes 23°30'N to 25°30'N and longitudes 95°00' E to 96°30' E. Taungtonelone area were selected for the study because there have been active tectonic features such as fractures, folds, and active Sagaing fault zone. The total area is about 20000 km^2.

Myanmar has suffered from more than 16 large earthquakes (the magnitude (M> 7) during the last 170 years. Seismic monitoring and seismic zoning in Myanmar is in the early stage of developing. The current seismic hazard map of Myanmar is based on historical seismicity. As the major urban areas in Myanmar lie in earthquake prone zones. Thus, there is a pressing need to prepare national seismic hazard maps for earthquake.

According to geological data, Myanmar is an earth-quake-prone country. It lies in a major earthquake belt of the world called Mediterranean – Himalayan belt. There are three regions of earthquake epicenter concentrations in Myanmar. The first one lies along the eastern foothills of Rakhine Yoma, Chin Hills and Naga Hills. The second zone is located along the Sagaing facet, the third zone is situated along the northern edge of Shan plateau south of Mogok. These belts are closely related to the tectonics of Myanmar (Fig. 1).

The seismotectonics of Myanmar is shown in Figure 1. Earthquakes in Myanmar have resulted from two main causes: (1) the continued subduction (with collision only in the north) of the northward-moving

Indian Plate underneath the Burma Platelet (which is a part of the Eurasian Plate) at an average rate of 4-6 cm/ yr, (2) the northward movement of the Burma platelet from a spreading centre in the Andaman Sea at an average rate of 2.5 – 3 cm/yr (Bertrand et al., 1998). Very large overthrusts along the Western Fold Belt have resulted from the former movement, and the Sagaing fault and related faults from the latter movement. Intermittent jerks along these major active faults have caused the majority of earthquakes in Myanmar. The well-known and seismologically very active Sagaing Fault deserves a brief special mention. The Sagaing fault is a major dextral strike-slip right lateral continental fault that extends over 1200 km and connects to the Andaman spreading center at its southern termination. The linear Sagaing fault was also initiated 5 Ma ago with the Andaman spreading center, when deformation was localized on a single boundary from Vigny et al. (2001). These seismotectonic processes are still going on.

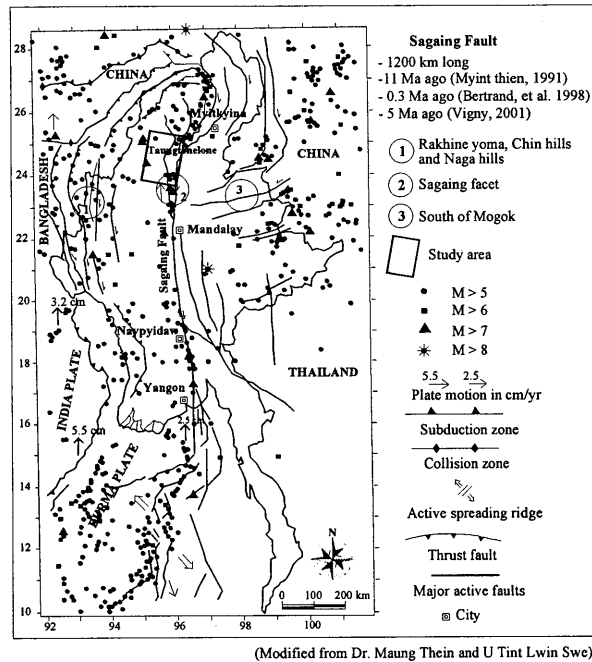(Modified from Dr. Maung Thein and U Tint Lwin Swe)

Fig. 1 Seismotectonic map of the Myanmar region (Earthquake data: NEIC for the period 1964-2004; from other sources for 1912 - 1963. Tectonic boundaries and fault locations are mainly based on GIAC reports (1997, 2000)).

Seismicity is associated with major lineaments. Relationship between earthquakes and the geological structure of the area of earthquake due to the study of lineaments was studied by a number of authors. For example, Cotilla-Rodriguez and Cordoba-Barba (2004) studied the morphotectonic structure of the Iberian Peninsula and showed that the main seismic activity is concentrated on the first and second rank lineaments, and some of important epicenters are located near the lineament intersections (Stich et al., 2001).

Tectonic faults are often associated with characteristic geomorphological features such as linear valleys, ridgelines and slope breaks that can be identified as lineaments in remotely sensed images of digital terrain models. It supposes that lineaments are able to detect, at least partially, the presence of ruptures deep in the Earths crust (Jordan, G., 2004). The lineament features and stripe density fields caused by seismic activity (Arellano-Baeza, et. al, 2006). Lineament is used in a variety of applications, such as fault line and fracture system analysis in geology and many innovative topographic and lithographic ones.

Lineaments are any linear features that can be picked out as lines in aerial or space imagery. Geologically, these are usually faults, joints, or boundaries between different formations. Others causes for lineaments include roads and railroads, contrast emphasized contacts between natural or man-made geographic features.

Most of lineaments were attributed either to faults or to fracture systems that were controlled by joints. Lineaments are well-known phenomena in the Earth's crust. Clear lineaments are often used as indicators of major fractures in near-surface. Lineament detection of early stage was made from aerial photographs. Recently, geologists have been interested in tracing lineaments from satellite images which have broad coverage under the uniform conditions.

The lineament reflects the geological structure such as faults or fractures. In this sense, the lineament extraction is very important for the application of remote sensing to geology. The nature of lineaments is related to the presence of faults and dislocations in the crust, situated at different depth. If a dislocation is situated close to the surface, the fault appears as a clear singular lineament.

The principal objective of the study is to determine whether there is a relationship between lineament density and earthquake. This can provide a valuable tool for earthquake study, complementing other ground based and satellite studies.

2. Satellite data and processing

A lineament map was prepared using stereo pair image of ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) image, Landsat 7ETM+ image, the Shuttle Radar Topography Mission (SRTM) 90-meter resolution DEM image. A variety of image processing techniques are used to highlight linear features of images. Known techniques such as color composite, Pseudo color DEM shade relief and 3D stereo anaglyph have been applied to enhance images for visual interpretation. The lineaments were extracted and adjusted circle plan by TNTmips and AutoCAD softwares. And then using Excel, the number and lengths of lineaments were calculated. The lineament density result compared and confirmed with horizontal ground acceleration (HGA) map of Myanmar. It is computed from various seismic events, using known earthquake data set for the period 1912-2004 (Dr Maung Thein and Tint Lwin Swe, 2006). Acceleration at a particular site is related to the distance from the site to the epicenter. In addition, acceleration is related to earthquake magnitude – the greater the earthquake, the bigger the acceleration at all locations (Seekins and Boatwright, 1994). Ground motion expressed as a fraction of the acceleration of gravity (1g = the acceleration of gravity = 9.8 m/sec^2).

2.1 Data Preprocessing of Digital Elevation Model

Moellering & Kimerling (1990) used multi-image operation of false color composites, RGB color model in morphotectonic studies to simultaneously analyse three Digital Elevation Model. The similarly the study area used this method in RGB and interpreted the lineaments. RGB shade relief images sun direction created 270:325:360 (R:G:B) pseudo color shade relief image (Fig. 2). Pseudo color representation can increase the contrast of hill shade image.
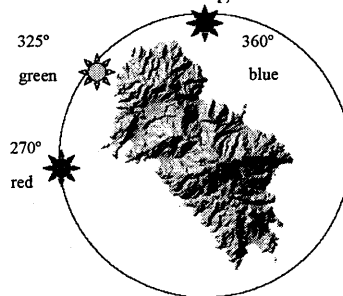

Fig.2   Pseudo color shade relief image model (modified from Moellering & Kimerling, 1990).

2.2 Anaglyph Image Generation

The stereoscopic images have been prepared from the available ASTER data that has the stereoscopic sensor performing nadir viewing (3N) and simultaneous backward viewing (3B) in VNIR Band 3. The glasses had a red colour for the left eye and cyan colour for the right eye was used to observe the 3D effect of the terrain.

2.3 Color Composite

The human eye can only distinguish between certain numbers of shades of gray in an image however, it is able to distinguish between much more colors. Therefore, a common image enhancement technique is to assign specific digital number (DN) values to specific colors to increase the contrast of particular DN values with the surrounding pixels in an image. An entire image can be converted from a gray scale to a color image, or portions of an image that represent the DN values of interest can be colored.

2.4 The Final Lineament Map Generation

The above mentioned techniques are used to extract lineaments from the satellite image. There is not a commonly accepted method to prepare the final lineament map. Although any of these techniques can be used to extract lineaments, three different techniques are applied here in order to be sure that no lineament is missed in the study area. The reason for this is that the area is not homogenous in terms of the surface characteristics, and it is believed that each method may enhance on aspect of the surface.

2. 5 Lineament Length Density Analysis

The purpose of the lineament density analysis is to calculate frequency of the lineaments per unit area. This is also known as lineament-frequency (Greenbaum, 1985). This analysis will produce a map showing concentrations of the lineaments over the area. The procedure of density analysis is shown in

Figure 3. First a unit area (a circular area with a search radius) is defined by the user. Every time, the frequency of the lineaments is counted and the number is recorded in an ASCII file for the center of corresponding unit area. The resultant text file that contains X, Y and Z values (Easting, Northing and frequency, respectively) and is stored to be processed for preparing density (contour) map of the area.
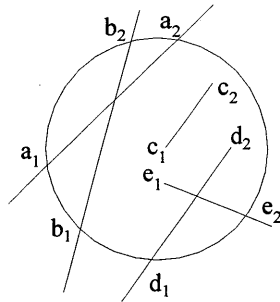
- Lineament Length density

= Sum of lineaments length within circle / Area of circle

$= (a_1a_2 + b_1b_2 + c_1c_2 + d_1d_2 + e_1e_2) / \pi r^2$
- Counts density
= Number of lineament within circle / Area of circle
$= 5 / \pi r^2$
- Cross-points density
= Number of lineament cross-points within circle / Area of circle
$= 2 / \pi r^2$

Fig. 3   The calculation method of lineament density values using the circular method (the center of the circle is one of the grid points).

A grid system was used to obtain the data for lineament density values: the length density of lineaments, the numerical density of lineaments and the cross-points density of lineaments within the unit circular cell.

The length density of lineaments is the total length (in km) of lineaments per cell area (km^2), the number of lineaments is the total number of lineaments per cell area (km2) and the cross-points density is the total number of cross points of lineaments per cell area (km2) existing within the unit circular cell (Fig. 3).

3. Result and Discussion

Analytical relief shading is the computer based process of deriving a shaded relief from a digital elevation model (DEM). Shade relief images created from digital elevation model (DEM) was helpful in identifying faults in rugged mountains. Unlike airphoto interpretation, the method enhanced lineaments by simulating topographic illumination under varied light direction. RGB shade relief images sun direction created 270:0:325 (R:G:B) pseudo color shade relief image (Fig. 4A). Pseudo color representation can increase the contrast of hill shade image.

A   B
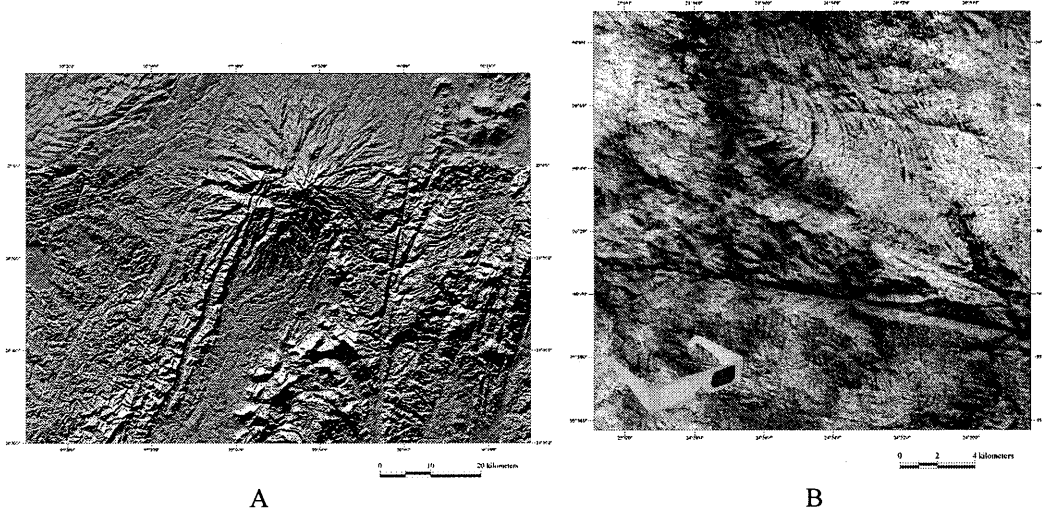
Fig. 4   (A) Pseudo color shade relief image created 270:0:325 (R:G:B) of Taungtonelone area, (B) The 3D anaglyph image of ASTER stereo pair. Use anaglyph glasses to see the three-dimensional aspect of the terrain and part of sagaing fault.

Anaglyph images were generated and found as the most suitable method. Anaglyph images have been generated using ASTER stereo pair image (15 meter resolutions). The image requires red/cyan anaglyph glasses for viewing in 3D and is in colour. The image has been orthorectified so can be used for purposes

requiring spatial accuracy. 3D topographic surface views such as these provide an excellent tool for interpretation of surficial lineaments and bedrock geological features (Fig. 4B).

False color images are produced for manual lineament extraction because they increase the interpretability of the data. Different combinations of three bands are examined and the best visual quality is obtained with a false color image bands 7, 5 and 4 (in blue, green and red respectively) (Fig. 5). Although any of these techniques (or combination of more than one) can be used to extract lineaments, three different techniques are applied here in order to be sure that no lineament is missed in the area. The reason for this is that the area is not homogenous in term of the surface characteristics. It is believed that each method may enhance one aspect of the surface. Each process will generate a GIS layer that can be linked to other layers easily. Presence of multiple lineament maps, however, may result in confusion and complexity. To overcome this problem a single lineament map should be generated from the results of all these methods.

Fig. 5 Lineament interpretation result draped on Landsat 7ETM+ false color image bands 7, 5 and 4 (in blue, green and red respectively).
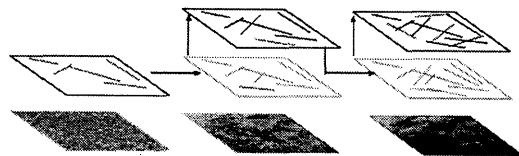

Fig. 6 Steps of combining the lineament maps generated by different methods.

The procedure for combining the lineaments obtained from all methods into one map is shown in Figure 6. Accordingly, here is always one output file which is overlaid every time on a different processed image. Following steps are applied for the generation of final map: (1) manually extracted lineaments are overlaid onto the same map, one map at a time. The order of the overlay analysis is not important during this process. The order used in this study is applied for this step. (2) Duplicated lineaments are erased from the map every time a new layer is added. Erasing of duplicated elements is performed by manual interpretation. In case of different lengths, the shorter lineaments and the roads are deleted. Lineaments patterns have been summarized using rose diagram, when lineament processing is completed, the final geological lineament file is also converted to a vector format (Fig. 7B). The stress vectors were used to predict orientations of different faults types for each model in accordance with the Andersonian theory of faulting (Park, 1988) (Fig. 7C).

According to image interpretation, lineaments with North and South orientations are longer and more distinct along the Sagaing fault and Igneous rocks. This direction coincides with the Sagaing main fault and they are right-lateral fractures. Lineament distribution and its general orientation are shown in Fig. 7. Major lineament trend can be summarized as NS, N50-70E, and N10-40E, under considering exaggeration due to imaging orientation. N50-70E lineament structure widely distributes and might be old structure before Tertiary sedimentation in the study area. N-S structure is the most dominant orientation, and is common to occur as longest lineaments more than 60 km. This structure concentrates especially around the central portion close to N-S trending Sagaing fault. N 10-40 E structure usually occurs as an aggregate of short lineaments less than 10 km and tends to accompany with longer N-S trending lineament. Some of these structures can be identified as dilational fault jog related to strike-slip faulting. Dilational fault jog is an aggregate of open fissure and/or sheared fracture. The lineaments described above are the younger lineaments covering most of the eastern part of the Wuntho massif. Lineaments with northwest and southeast orientations can be seen mainly in the southeastern region of Kawlin-Wuntho area. This orientation coincides with the direction of extensional fractures attended by the right lateral strike slip fractures and they are generally a normal fault.

The test points were selected using the grid system with equal distances of 16.5 km latitudinally and 16.5 km longitudinally. Figure 7A shows the grid model circle plan of lineament density calculation. The total

number of grid points was 110, which appeared sufficient for a statistical analysis. The area of a unit circle is 855 km^2. After calculation of the lineament density values for each radius, the graphs for the relation between lineament density values and radius of the unit circles were constructed, from which the representative elementary area point was determined.
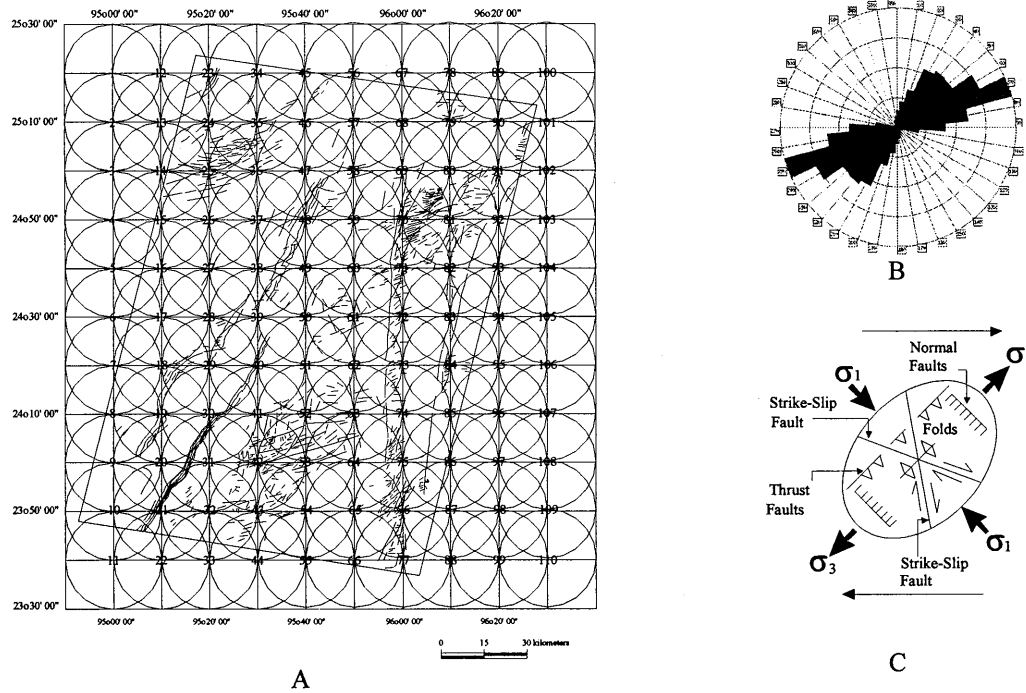

A

B

C

Fig 7. (A) The arrangement of circle plan for lineament density calculation (Actual 110 test points used to calculate) map for Taungtonelone area, northern Myanmar, (B) Rose diagram of the mapped lineament of Taungtonelone area, (C) Diagram representing the structural pattern produced by dextral simple shear (after Park, 1988).
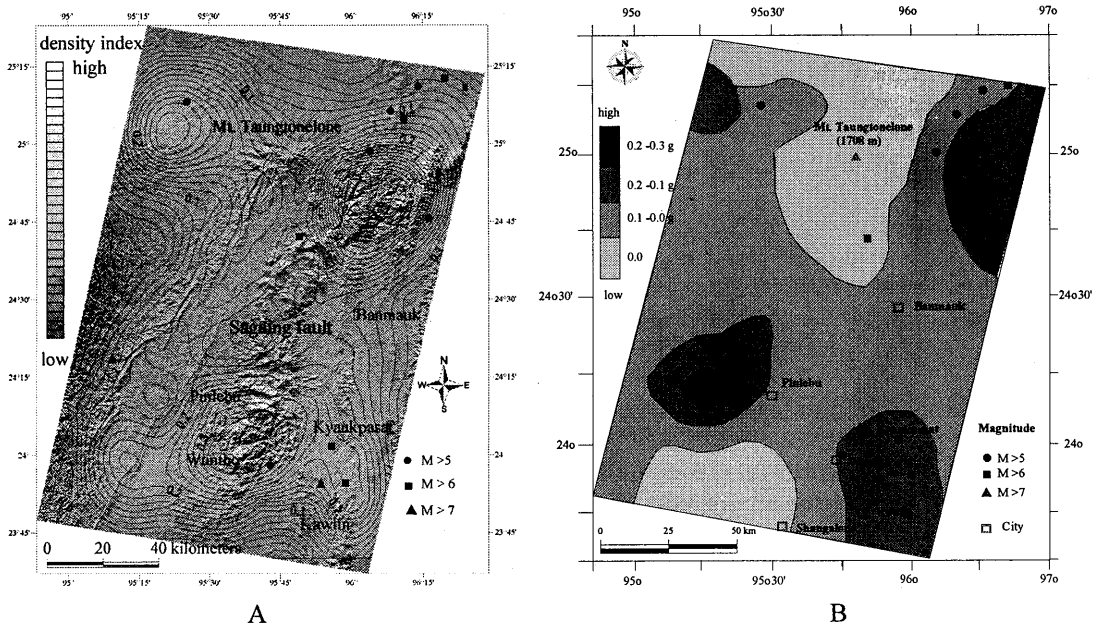

A

B

Fig. 8 (A) lineament density contour draped on shade relief image, (B) Horizontal ground acceleration earthquake hazard level map of Taungtonelone area, using known earthquake data set for the period 1912-2004 (modified from Dr. Maung Thein and U Tint Lwin Swe, 2006).

Figure 8 shows the lineament density contour for the lineament analysis of Taungtonelone area. The zone showing highest lineament density contour lies along the Wuntho-Kawlin massive area, Kyaukpasat area and east of Mt. Taungtonelone area. Lineament density contour also showed good correspondence with horizontal ground acceleration earthquake hazard level map computed from various seismic events of these areas. Eastern part of Mt. Taungtonelone area, there are high lineament density contour level and this region was high frequency and heavily affected by the earthquake.

4. Conclusion

The lineament density map can be used for the quantitative evaluation between lineaments and the earthquake risks monitoring for the future. If the average lineament density values for the whole study area are known, better or more accurate earthquake monitory map can be drawn using satellite image data. The lineament analysis can be convert one of power tools for earthquake study, complementing other ground based and satellite studies in the future. This could significantly increase the reliability of the earthquake forecast. The using of anaglyph image produced from ASTER image in the visual interpretation of the identification of the structural elements and the geomorphic characteristic has been found to be the most suitable method in this study. The using of the false color image of Landsat 7ETM+ and the pseudo colour shade relief images produced by the SRTM DEM also gives good results. It is possible to identify clearly the effects of the extensional tectonic on the satellite images by visual interpretations based on experience and knowledge.

This study is to be used for new recognition of seismic hazards and is expected to increase the awareness for disaster prevention. Fortunately, the proposed method does not require any special satellite program and can use any multi-spectral high-resolution images, such as obtained by ASTER, Landsat, etc., which makes it a very low cost. T. The lineament density method could be used not only for earthquake zone but also for mineral exploration. This observation also can be applied to other seismic fracture zone of mountainous area. The study has proved that the lineament high density areas are closely within seismic zones. Thus lineament density map can be used for the quantitative evaluation between lineaments and the earthquake risks monitoring for the future.

5. Acknowledgments

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