# Application of TM data to a geologic structure study of the eastern Liaoning Province, China

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## ABSTRACT

Lineament analysis is part of structural studies employed to determine the tectonic features of the eastern Liaoning Province, China. Landsat TM (Thematic Mapper) images, at a scale of 1:500,000, are analyzed photogeologically. Lineaments mapped visually are digitized and analyzed statistically. The results show that the study area is characterized by two major directions (NE or NNE, and EW) of lineaments, relating to regional geology and structural activities. Lineaments with NE and NNE directions are corresponding to the tectonic systems of Cathaysian, Neocathaysian trends, which are relatively recent structural trends, and ones with EW direction are related to the tectonic system of gigantic latitudinal trend, which is older structural trend.

## 1. INTRODUCTION

Lineaments have been defined as mappable linear or curvilinear surface features that are thought to reflect subsurface phenomena(O'Leary and others,1976).

This study is part of the cooperative research program between Geological Survey of Japan and Center for Remote Sensing in Geology, which consists of the research on remote sensing techniques for lineament analysis, spectral analysis and textural analysis and investigations of geologic structure on a regional scale in the eastern Liaoning Province.

The present study of lineaments from Landsat TM (Thematic Mapper) data was performed to determine the regional structural trends in the study area of the eastern Liaoning Province, to develop an enhancement technique for better interpretation of geologic features, and to investigate some relationships between the distribution characteristics of lineaments and lithologic units.

The study area is located to the southeast of Shenyang city, which is the largest city of Northeast China. The area is

between Long.123° and 124°40'E and between Lat.40° and 41° 20' excluding the southeast sub-area. Figure 1 shows the study area in Liaoning Province. Liaoyang, Benxi, and Xiuyan are located in the area. The study area is about 16,600 square kilometers. Four TM full scene images are necessary to cover the area. The used TM images are cloud-free images of P119-R031, P119-R032, P118-R031, and P118-R032. These TM data were acquired by Landsat-5 satellite on 1st. and 24th November,1984 and received at Earth Observation Center of NASDA(National Space Development Agency of Japan) which is located in Hatoyama, Saitama Prefecture. A mosaic image in digital is prepared from the above four Landsat TM scenes(Figure 2). Visual mapping of lineaments over the area, however, was carried out carefully using the false color composite photoprints of individual scenes. Figure 2 shows that vegetation covers the whole area and frost remains a little in valleys in the northwest part of the area where the brightness is relatively high on the image.

This paper describes regional characteristics of lineament distribution in the study area of Liaoning Province and the relationship between the distribution of older lithologic units of Proterozoic and Archean and a prominent lineament system with EW. An edge-enhancement method is presented to extract linear features from TM image in detail.

## 2. GEOLOGY

The eastern Liaoning area is underlain by Archean, Lower Proterozoic , Paleozoic and Mesozoic rocks. The geological description given below is based on the Tectonic System Map of the People's Republic of China and Adjacent Sea Area on the scale of 1:2,500,000. Figure 3 is a geologic sketch map which is generalized and simplified.

Archean, Sinian and Paleozoic rocks are chiefly distributing in the northern area. Lower Proterozoic rocks are widespread in the central and southern area. These areas are characterized by anticlinorium and synclinorium with approximately east-west trending folds. Jurassic rocks are scattered in the eastern area. The magmatic rocks are distributing mainly in the lower half of the area. Kuan Dian Basin is located at the lower corner of eastern area. The basin is formed by Cenozoic basic rocks.

Tancheng-Lujiang fault zone with NNE trend run through to the west of the study area. Yalujiang fault zone is to the east.

## 3. EDGE ENHANCEMENT

Various methods have been widely used for enhancement of linear features on images. M.Urai et al.(1985) developed an edge-enhancement method based on template matching operator. The method utilizes twelve masks which enhance directional edges every 15 degrees. The size of mask operator is 12 by 12. The edge-enhanced images are displayed using HSI(Hue, Saturation and Intensity) color model which is the alternative of RGB color model. The method simply enhances differences of gray levels on image. The enhanced edges with different directions are assigned

to different colors(Hue) and the intensity of edges is displayed by color intensity(Intensity). Saturation has constant value. The resultant edge-enhanced color image shows us clearly some dominant trends of linear edges by different colors. However, enhanced linear edges includes ones corresponding to ridges, which are less important for lineament mapping. Our experience shows that lineaments may be usually delineated at valleys. With consideration of it, the originally proposed method is modified. Edges corresponding to ridges can be eliminated using a classification of edge intensity pattern considered with the direction of sun illumination(Figure 4(a),(b)). The edge-enhanced color image become more simple because of ridge elimination, therefore, analyst can easily delineate linear features using it. Figure 4(c) and (d) show a pre-modified edge-enhanced color image and an advanced edge-enhanced color image which excludes edges corresponding to ridges from all edges as shown in figure 4(c). The latter is more useful for analyst to easily map and/or check linear features in sub-regions in detail, comparing to figure 4(c).

## 4. STATISTICAL ANALYSIS OF LINEAMENTS

Geologic features including lineaments and circular structures are visually extracted using four false color composite TM images with a scale of 1:500,000. In the process of mapping, lineaments are classified into two types; clear and unclear ones. Many circular features also are mapped in the area. A typical circle structure is approximately 18 kilometers northeast of Xiuyan town.

Mapped lineaments are digitized for statistical analysis, which provides more detail characteristics of geologic structure. Figure 5 shows the digitized lineament map, including two classes of lineaments; solid lines represent clear lineaments, and dotted lines represent uncertain ones. Figure 6 is the density contour map of lineaments in the study area. The area is divided into 60 by 60 cells. The density of lineaments is calculated in each cell and then smoothed by a 5 by 5 spatial filter. Densely-contoured region indicates high density area of lineaments. There are two high density areas in southern and central parts. However, it should be noted that these two areas have different properties in the major trend as shown in Figure 5. The southern one is characterized by lineaments with NE and NNE trends, however, the central one with NWW and EW trends. The area is divided into 5 by 6 sub-areas and rose diagrams of lineaments are calculated in each sub-area for investigation of directional property. Figure 7 shows their distribution map of the normalized rose diagrams with one degree step in angle. The normalization is performed by a maximum value of rose diagram in the whole area. In Figure 6 and 7, two classes of lineaments are not distinguished. It is clear that lineaments with NNE or NE trend are dominant in the southeastern area and ones with EW or ENE trend are distributed in the northwestern area. The northernmost two sub-regions include lineaments with ENE trend. For more detail analysis, a directional density contour map seems to be useful as shown Figure 8. These maps are made each directional range with 15

degrees. Such directional density contour map presents us directional local properties of lineaments. Detail analysis of structural trend show that central high-density region is clearly divided into two parts; center of that region has NWW trending structure and both sides of the region have EW trending structures. It also show the southern high-density region is composite of NE and NNE trending lineaments. The central high-density region elongated to NEE direction. This region is in the distributing area of Lower Proterozoic rocks. Linear features located in northwest region have also same NEE trend and form a clear zone where Archean rocks appear. These are the northernmost elements of the latitudinal structure zone. Lineaments with NW trend are also recognized in this area.

## 5.CONCLUSIONS

Lineaments are reflecting to regional structures and geologic units. Hong Zuomin(1985) shows that the tectonic systems in Liaoning Province may be classified into latitudinal, meridional, Cathaysian trend, NW trend and rotational shear tectonic systems and that the latitudinal and Cathaysian trend tectonic systems consist of the regional tectonic framework. The result shows that the tectonic system with Cathaysian trend which is characterized by NE and NNE trending lineaments is dominant in the southeastern and eastern parts of the study area where younger volcanic rocks are widespread and the tectonic system with latitudinal trend is over the central and northwestern part of the area where Archean and Lower Proterozoic rocks are distributed. Two major lineament systems with EW and NE or NNE trends may present the regional tectonic systems in the study area.

## 6.REFERENCES

O'Leary,D.W., Friedman,J.D., and Pohn,H.A., 1976, Lineament, linear, lineation: some proposed new standards for old terms: Geological Society of America Bulletin, v.86, no.4, p.495-502.

Urai,M., Kouda,R., Sato,I., and Tsu,H., 1985, Linear pattern detection and color presentation for Landsat MSS images: Journal of Remote Sensing Society of Japan, v.5, no.4, p.5-15.

Institute of Geomechanics, Academy of Geological Sciences, 1984, Tectonic systems map of the People's Republic of China and adjacent sea area (1:2,500,000), Cartographic Publishing House, Beijing.

Hong Zuomin, 1985, Characteristics and evolution of tectonic systems in Liaoning Province, Collected works for Research of provincial tectonic systems in China, v.1, p.91-103. (in Chinese)

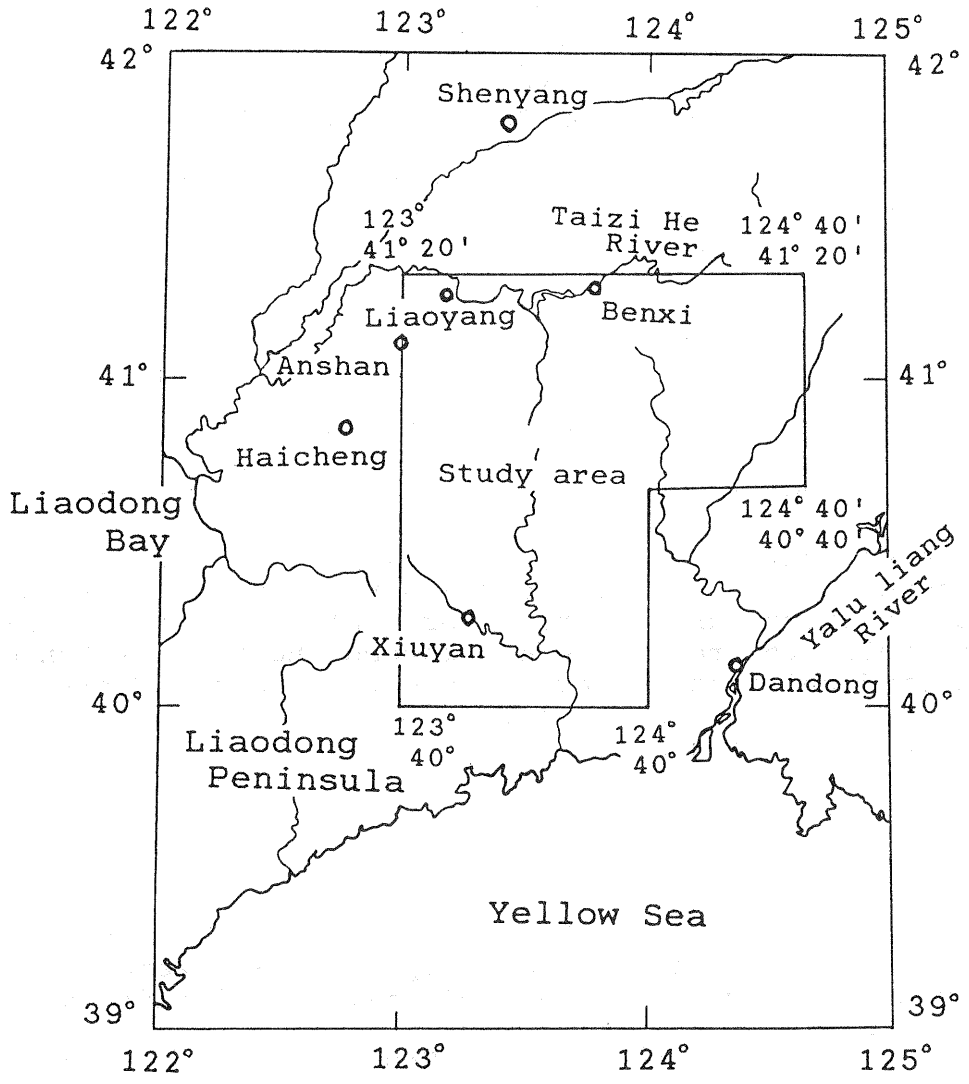



Figure 1. The sketch map of the study area

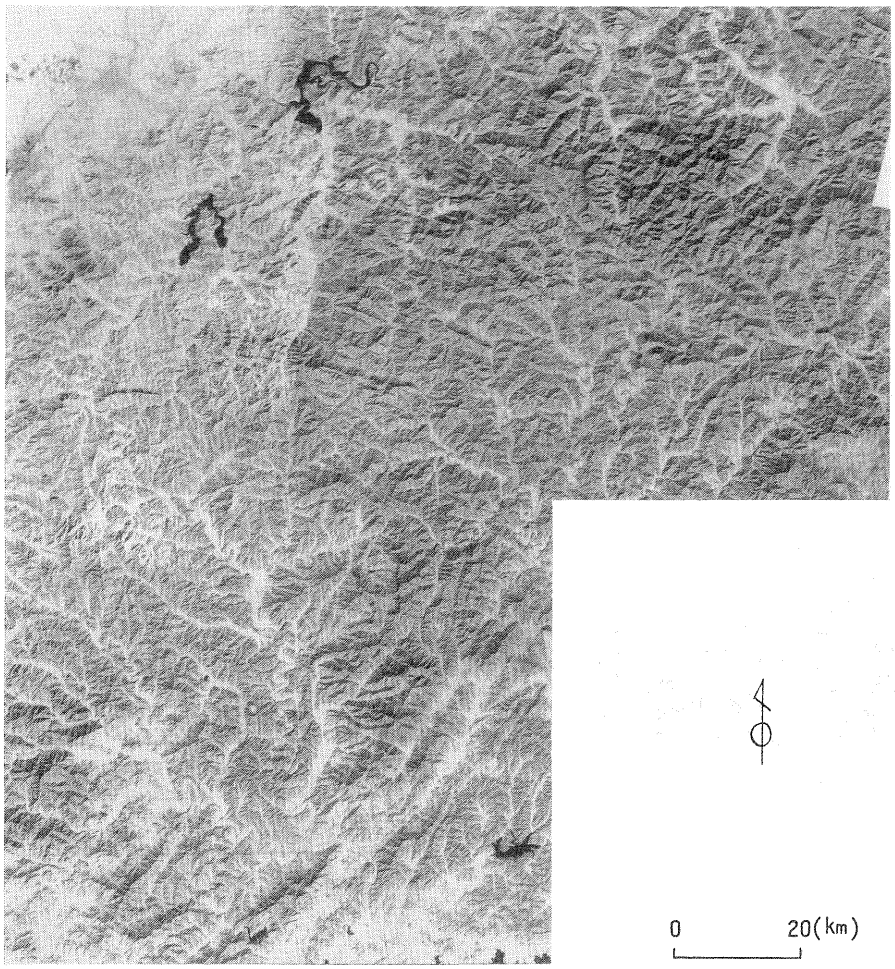



Figure 2. False color composite image of the study area in the eastern Liaoning Province. The image is a mosaic of four Landsat TM scenes. The scene identifications are:

| Path | Row | Date | Landsat |
|---|---|---|---|
| 118 | 031 | 841101 | L5 |
| 118 | 032 | 841101 | L5 |
| 119 | 031 | 841124 | L5 |
| 119 | 032 | 841124 | L5 |

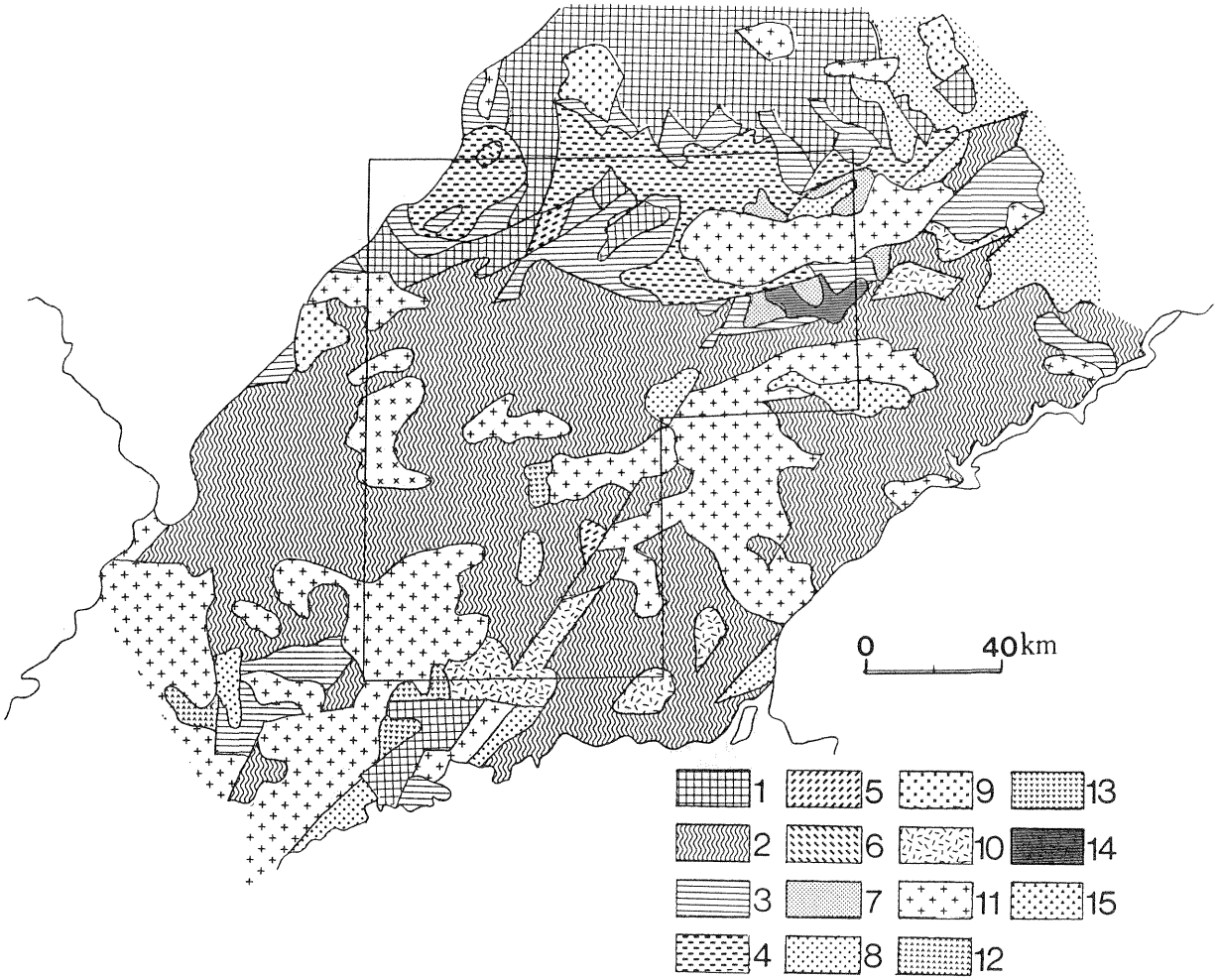
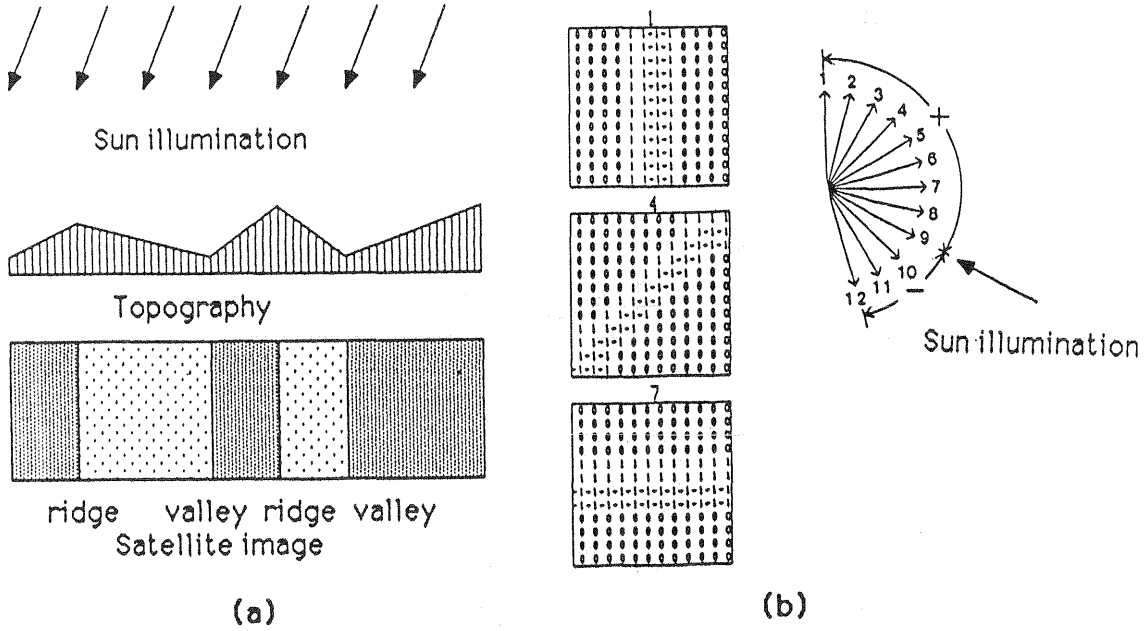
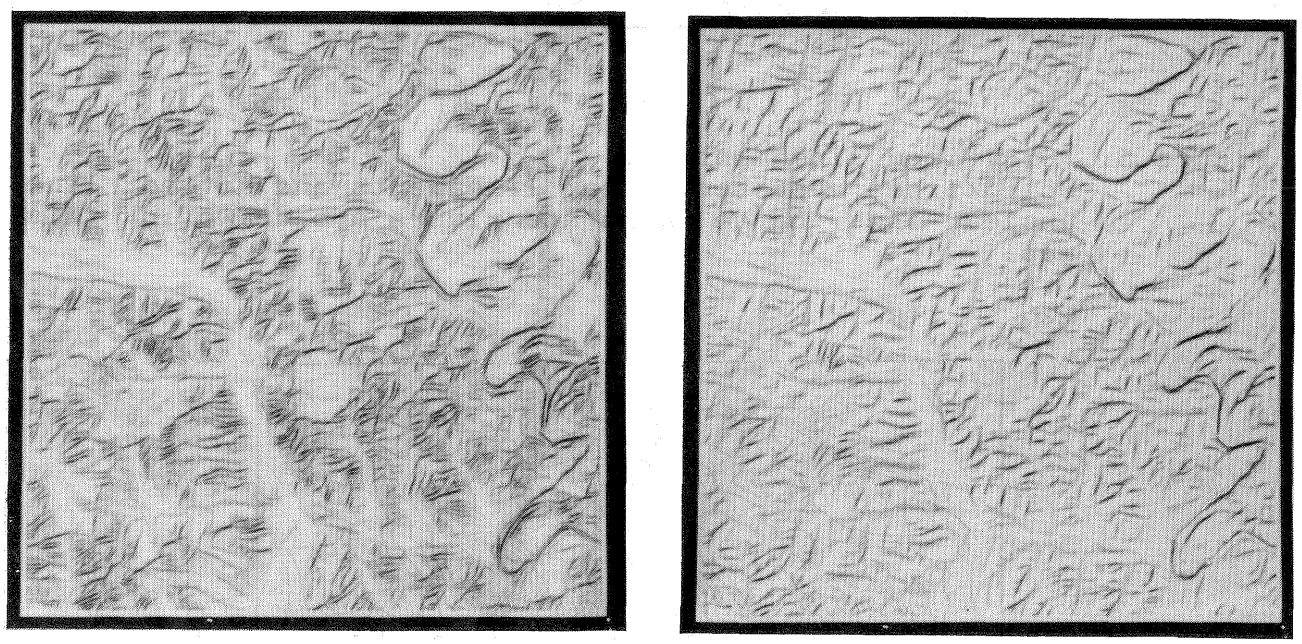



Figure 3. Geologic sketch map

1-Archaean, 2-Lower Proterozoic, 3-Sinian, 4-Paleozoic, 5-Lower Paleozoic, 6-Upper Paleozoic, 7-middle-lower series of Jurassic, 8-upper series of Jurassic, 9-Archaean and Proterozoic intermediate-acidic rocks, 10-Proterozoic intermediate-acidic rocks, 11-Mesozoic intermediate-acidic rocks, 12-Proterozoic intermediate rocks, 13-Mesozoic intermediate rocks, 14-Mesozoic alkaline rocks, 15-basic rocks.



(c) (d)

Figure 4. Advanced edge-enhancement method. (a) conceptual edge model, (b) examples of template operators, (c) an edge-enhanced color image which includes edges corresponding to ridges and valleys, (d) an advanced edge-enhanced color image which excludes edges corresponding to ridges.

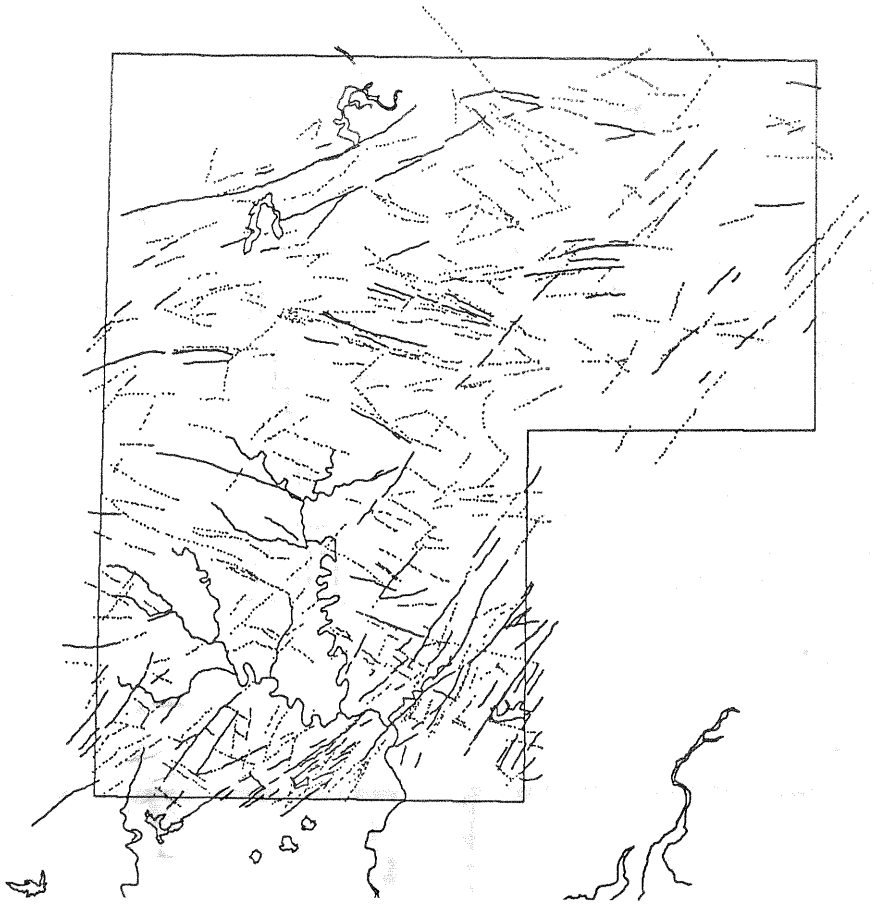


Figure 5. Digitized lineament map.
Solid lines represent clear lineaments and dotted line unclear ones. Large lakes and rivers are drawn in this map.

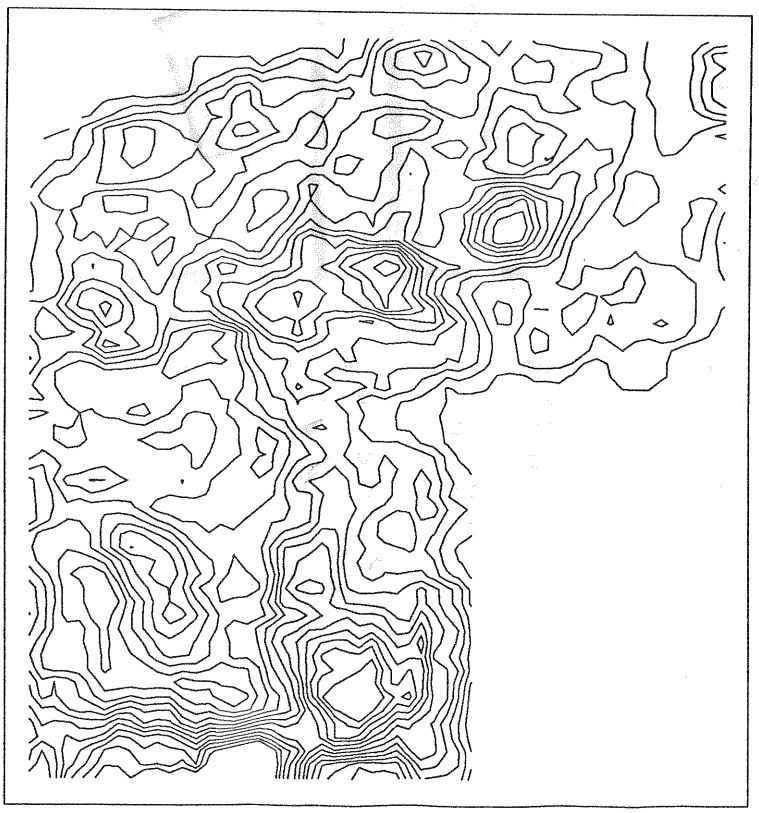


Figure 6. Lineament density contour map.

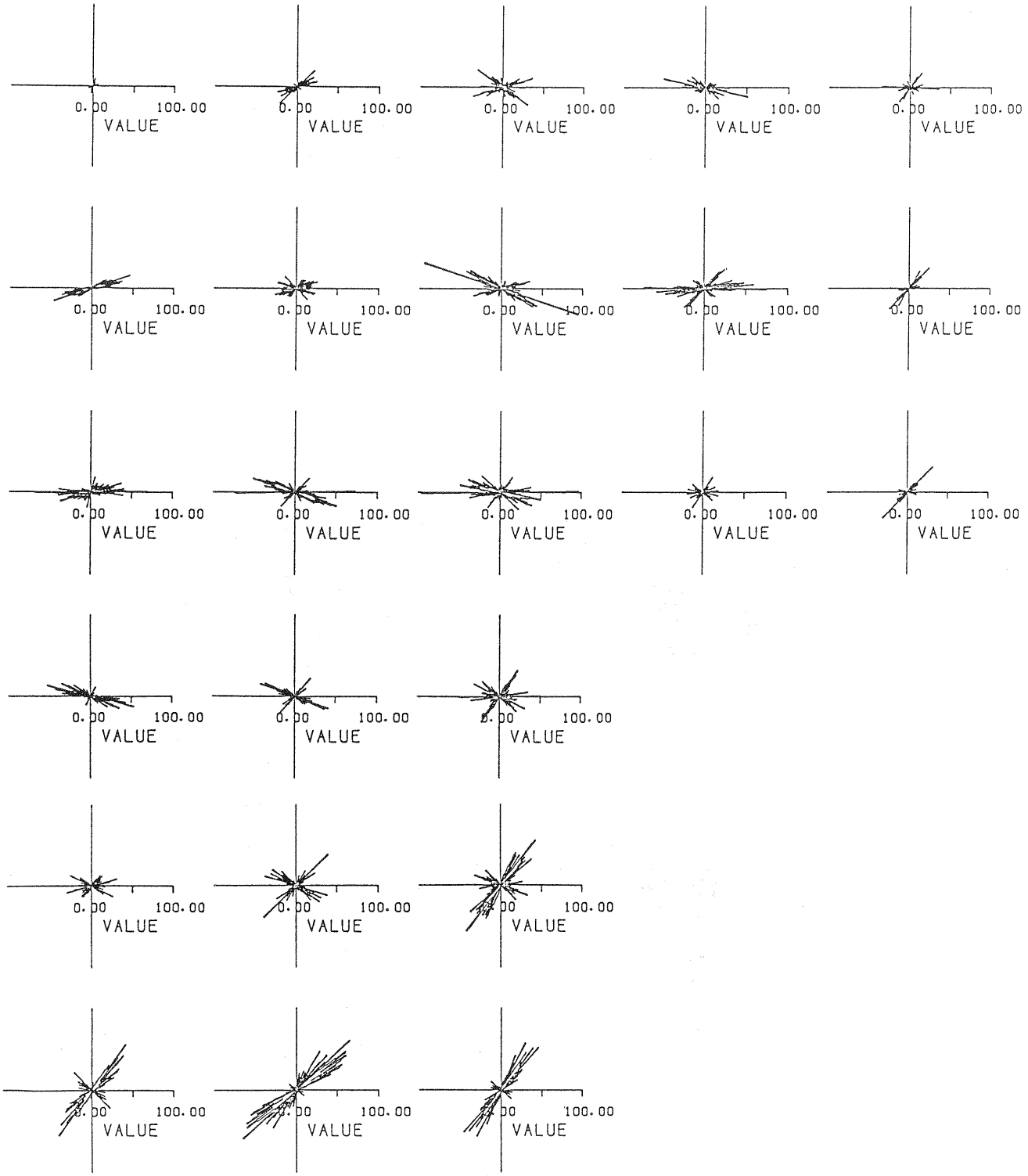



Figure 7. Rose diagrams of 5 by 6 divided sub-areas. The step in angle is one degree.

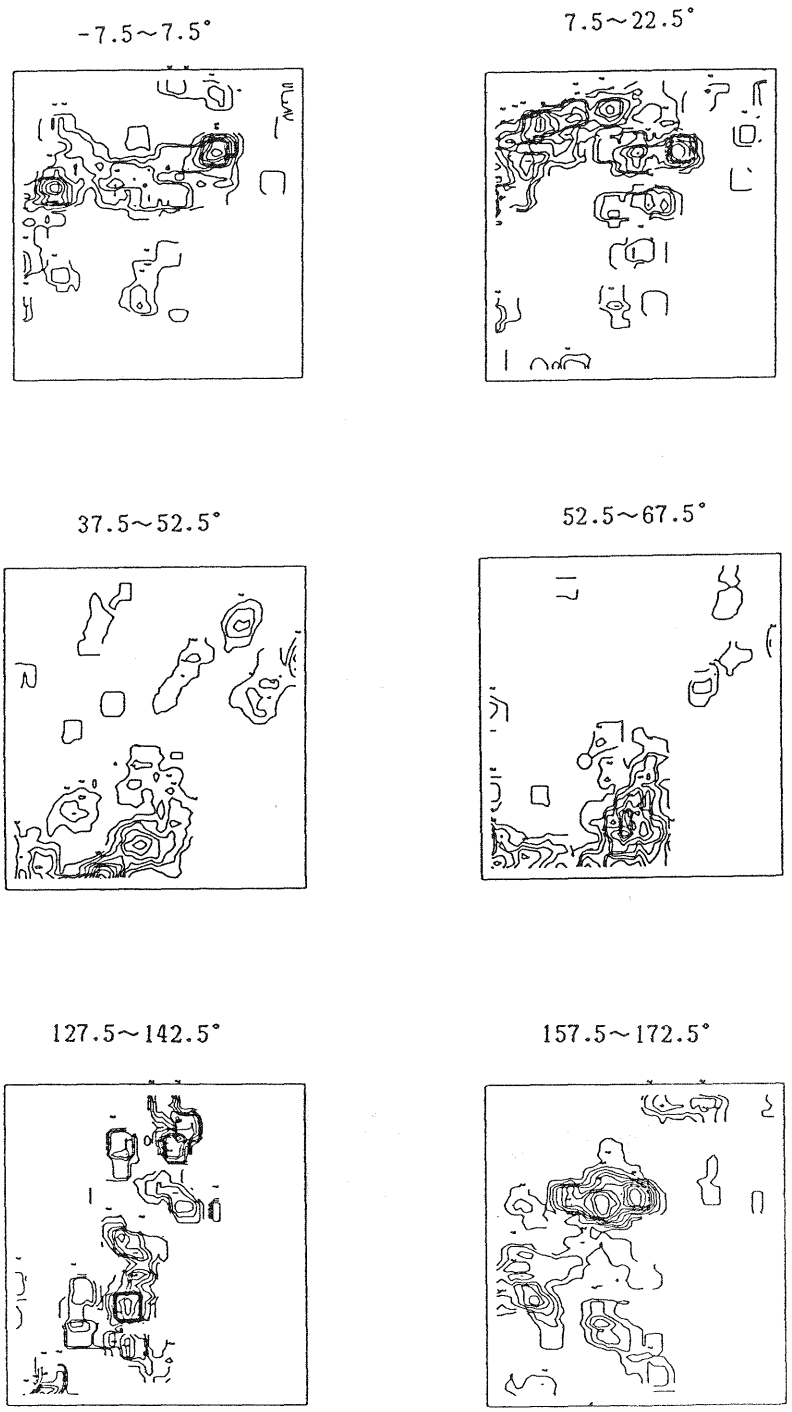



Figure 8. Directional lineament density contour maps. The range in angle, measured anti-clockwise from the east, is on the top of each map.