PRJ, Vol. 6 (January 1994); p. 67–74, 4 FIGS, 5 PLATES.

REMOTE SENSING AS A TOOL TO STUDY THE GEOLOGY OF THE NORTHEASTERN PART OF TIBESTI MOUNTAIN, LIBYA

K.M. Abdulnasser*

تقنية الإستشعار عن بعد كوسيلة لدراسة جيولوجية الجزء الشمال الشرقي لجبل تيبستي – ليبيا

خليفة عبد الناصر

تم إستخدام نوعان من تقنيات الإستشعار عن بعد في هذه الدراسة وهما الصور الفضائية للقمر الإصطناعي لاندسات تي إم والصور الجوية. الصور الجوية أثبتت أكثر فاعلية في التعرف وتحديد المعالم التركيبية الصغيرة الحجم بينما الصور الفضائية من خلال تطبيق المعالجة الرقمية أثبتت أكثر فاعلية في التمييز الليثولوجي للوحدات الصخرية وكذلك لتحديد المعالم التركيبية ذات الأحجام الكبيرة.

الصور الفضائية المحسنة بواسطة الحواسيب الألكترونية أكدت جدواها في التغلب على الصعوبات في تخريط الصخور القليلة التكشف. الوصف البصري للصور الغير مدعوم بالعمل الحقلي تمخضت على إنتاج خريطة جيولوجية مبدئية وخريطة للمعالم الطولية لمنطقة الدراسة.

تم التعرف على ثماني وحدات صخرية والعديد من الظواهر الدائرية والتي تعتبر أماكن قيمة للإستكشاف المعدني.

من خلال هذه الدراسة إتضح أن إستخدام نوعين أو أكثر من تقنيات الإستشعار عن بعد في آن معاً تعتبر الطريقة المثلى في الدراسات الجيولوجية لأنه إلى حد كبير يعتبر كلاهما مكمل للآخر.

ABSTRACT

Two types of remote sensing data are used in this work. These include Landsat TM imagery and aerial photography. Aerial photographs proved to be more useful in locating and determining local structures. Landsat TM imagery, through the application of some image processing techniques, proved more effective for lithologic discrimination of rock units and regional structure of the study area. The computer enhanced images are used to overcome the difficulties of mapping small outcrops where most of the lithological rock units are identified. Interpretation of image processed products, not supported by field checking, are concluded by constructing a preliminary geologic map and lineaments map for Jabal Eghi area. Eight lithological rock units and many circular features are recognized. These circular features should serve as potential areas for mineral exploration. As a result of this study Landsat TM imagery has proved more important than aerial-photography. The use of more than one remote sensing data type such as is employed in this work is the ideal choice of proceeding with such studies because to some extent these two data complement each other.

* Petroleum Research Centre, P.O. Box 6431, Tripoli, G.S.P.L.A.J.

INTRODUCTION

Geological application has become more interesting through the use of satellite imagery as Landsat MSS, TM and SPOT. Arid areas, devoid of vegetation, are suitable for study by remote sensing techniques. Various image processing techniques are applied to get high quality images suitable for photogeological interpretation.

The study area is located in the Southern Central part of Libya (Fig. 1). It covers the Northeastern part of the Tibesti Massif and lies between lat. 22°30′ N to 23°00′ North and long. 19°30′ E to 20°00′ E. It is widely known as Jabal Eghi, located near and around Jabal Tushidi.

The aim of this work is to update the geological map of the area by using computer enhanced Landsat TM imagery and aerial photographs. The results are

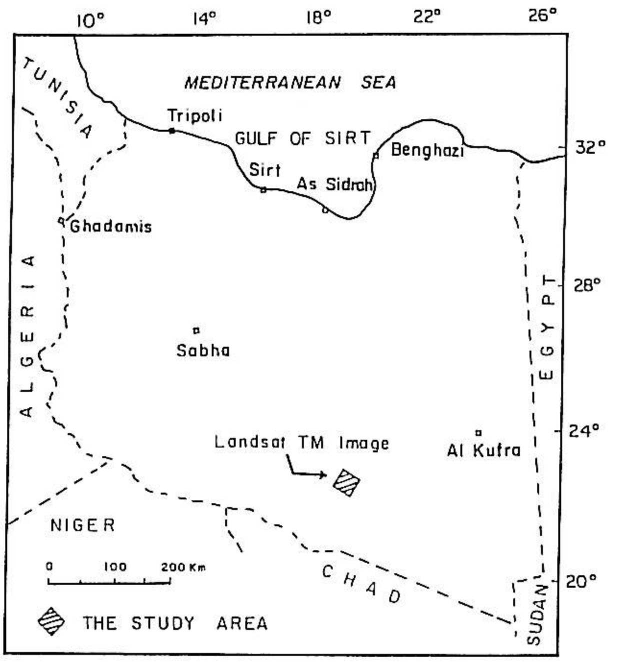

FIG. 1. Map of Libya showing location of the area.

compared with previous studies based, mainly, on aerial photographs.

Image Processing Techniques

Three infrared bands (4, 5 and 7) on CCT were used in this work. Some subscenes (512 × 512) covering the area were generated. By using the R-chips image processing system, different image processing techniques were applied to the images (colour combination, image ratios, principal component analysis and edge enhancement). The output of the subscenes were visually interpreted and incorporated into the final maps. This processing technique is performed simultaneously with the interpretation of aerial photographs of selected areas by using stereoscopic view. Finally the results of two data sets were compared and interpreted.

Aerial-Photographs Interpretation

This interpretation is based on the conventional visual interpretation of B and W aerial photographs by using stereoscopic method. The interpretation, which follows the classic interpretation of geological studies, is divided into two parts: lithological and structural interpretations. Lithologically the different rock units have been identified using standard aerial photographic interpretation techniques, i.e. analysis of textural, tonal, geomorphological and erosional characteristics. Due to the difficulty in determining the age of different rock units by using aerial photographs, the classification by age is mainly determined by correlating the rock units with those of known age in the area based on the geological map of Libya (Conant and Goudarzi 1977) and previous studies (Fig. 2).

Landsat TM Imagery Interpretation

Even though in this work Landsat imagery is divided into three subscenes (Plate 1), the work mainly focused on two subscenes. Area 1 shows all major structural elements and helps in selecting areas for detailed studies. Smaller area is selected by choosing the best region which contains the most geologic work units record according to age. It is labelled as area 2. The study area is visually interpreted and a

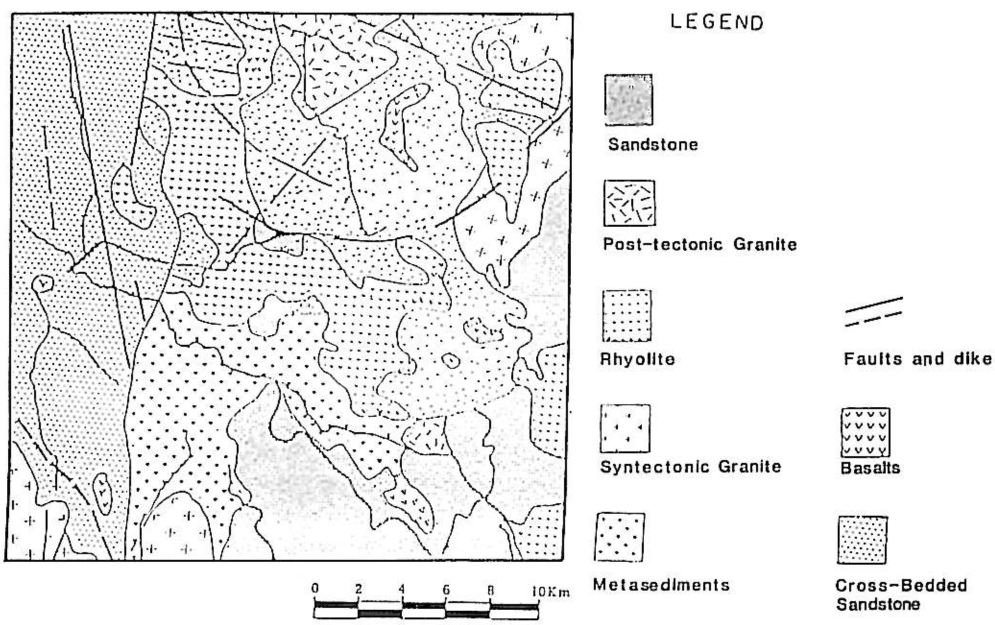

FIG. 2. Geological map of the area (simplified after Missilati *et al.*, 1979).

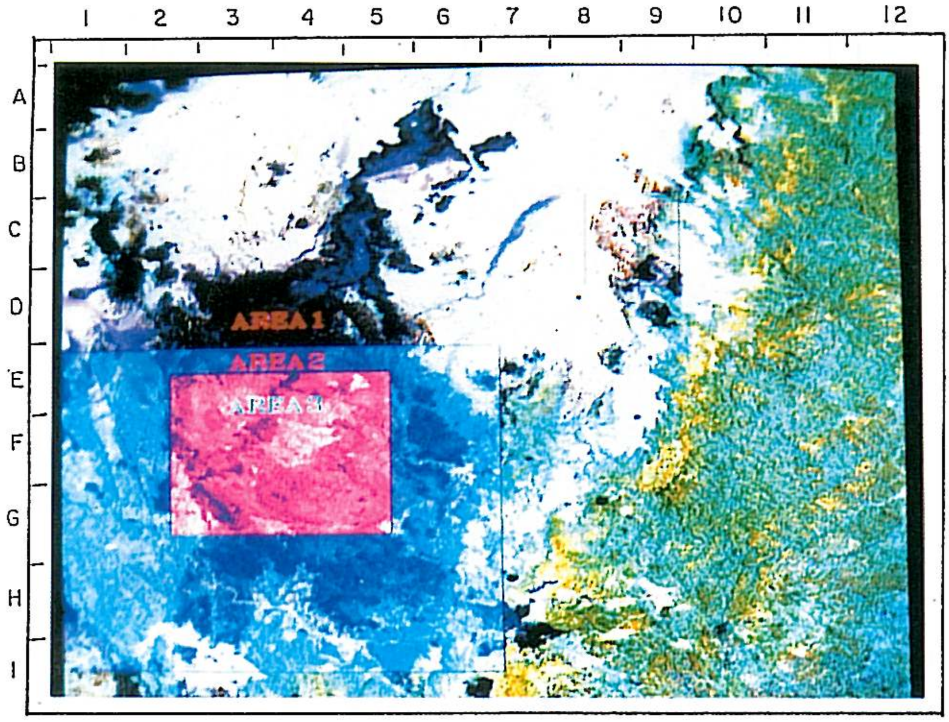

PLATE 1. Location of the selected areas used in this work.

combination of spectral and textural characteristics is used to identify and map the rock units.

DISCUSSION OF THE PRELIMINARY GEOLOGIC MAP

Precambrian metamorphic rocks, which include meta-volcanic and meta-sediments, are the oldest exposed rock unit identified and plotted in (Fig. 3).

It was very difficult to identify this unit due to its mixing with the surrounding units especially rhyolite. In the images produced, these units have similar shades of colour except in Plate 2 where the metamorphic rock units appear as blue and rhyolite unit appear pink and in some places dark yellow when mixed with some sediments. The fractures of dikes in the rhyolite unit is an alternative way to distinguish these units. Precambrian diorites to gabbros unit is identified and labelled as the second rock unit according to age. This interpretation is based on the difference in spectral reflectance of this unit compared with the adjacent granite unit. In previous studies this unit was included with the granite unit. It appears completely different from the adjacent granitic unit. It is darker than the granitic unit due to the richness of this unit in Fe and Mg.

The third unit identified in this map is the granitic unit which includes the syntectonic and post-tectonic granites. This unit appears very clear in Plate 3 as yellow colour. The fourth rock unit is Ordovician rhyolite covering most of the central part of the area. It is completely mixed with the metamorphic and the basaltic flow units. It is difficult to distinguish between them. In Plate 2 it is possible to distinguish areas where rhyolite unit appears as pink to dark yellow and metamorphic rock unit appears as light blue colour where as basaltic flow units appear as deep red to dark blue. Another characteristic that is helpful in identifying these units, is the abundance of fractures and dikes (green lineaments) in the rhyolite unit (Plate 4). Palaeozoic sandstone is the fifth unit recognized in the area. It appears as green colour and deep yellow. This is due probably to variation in Fe-minerals.

Tertiary sandstones appear similar to Palaeozoic sandstones. The discrimination between them is very difficult and is based on previous studies which refer to this unit as Tertiary cross bedded sandstone. Extensive basaltic flows Tertiary cover most of the area. They appear as black to very dark blue (Plate 3) and also as deep red in Plate 2. In some places, when covered by aeolian material, they appear as grey colour. The youngest unit identified in this geologic map include Quaternary alluvium and Wadi sediments. They are deposited in the low areas and valleys distributed in various parts of the area and appear as white in colour. This white colour reflects the high albedo of this kind of material.

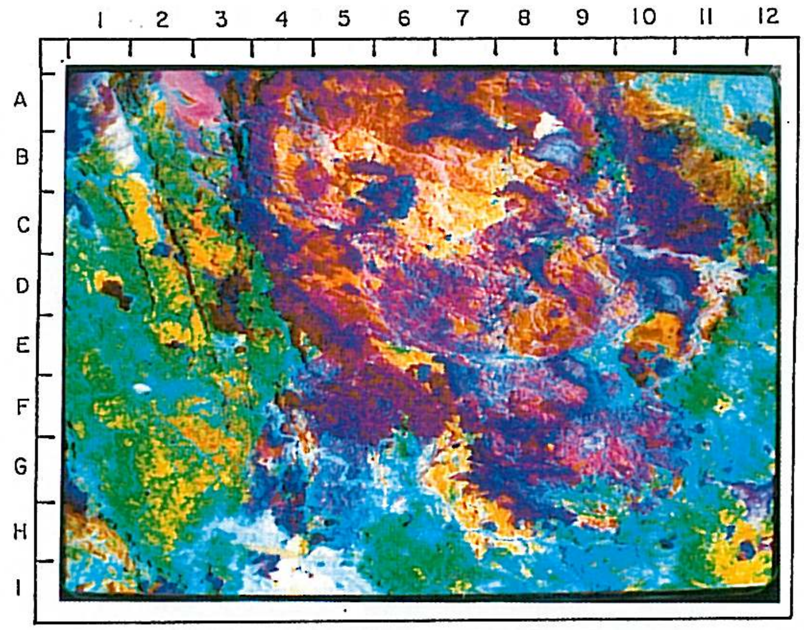

PLATE 2. Automatic stretched principal component image, Pc3, Pc1, Pc2 as RGB.

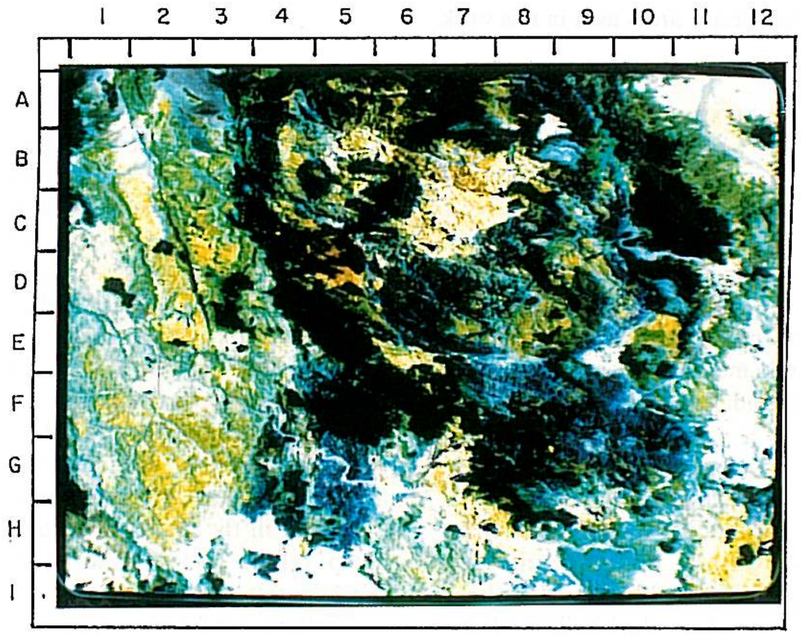

PLATE 3. Automatic stretched FCC image (bands 7, 5, 4 as RGB).

DISCUSSION OF THE PRELIMINARY LINEAMENTS MAP

Figure 4 shows the most clear lineaments which are recognized in Plate 5. These lineaments and edges are enhanced by using edge enhancement technique. Laplacian (3 × 3) filtering was applied which enhanced the edges in all directions. These lineaments reflect, to some extent, the structural style of the area.

As shown in this map the area is dominated by four kinds of structural features:

(1) Long lineaments (from 3–10 km) which reflect faults, dikes.
(2) Short lineaments (from hundreds of meters to 3km) which may represent small faults, dikes or fractures.
(3) Ring structure which reflects the complex structure in this area. It is a curved line and appears to be filled with green siliceous dikes.

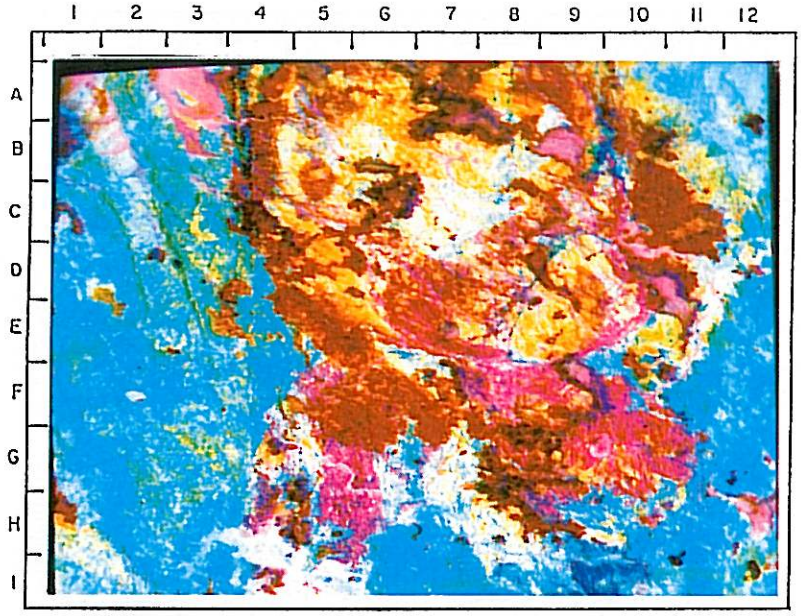

PLATE 4. Histogram equalization of the coloured image. (Ratios 7/5, 7/4 and TM band 4 as RGB.)

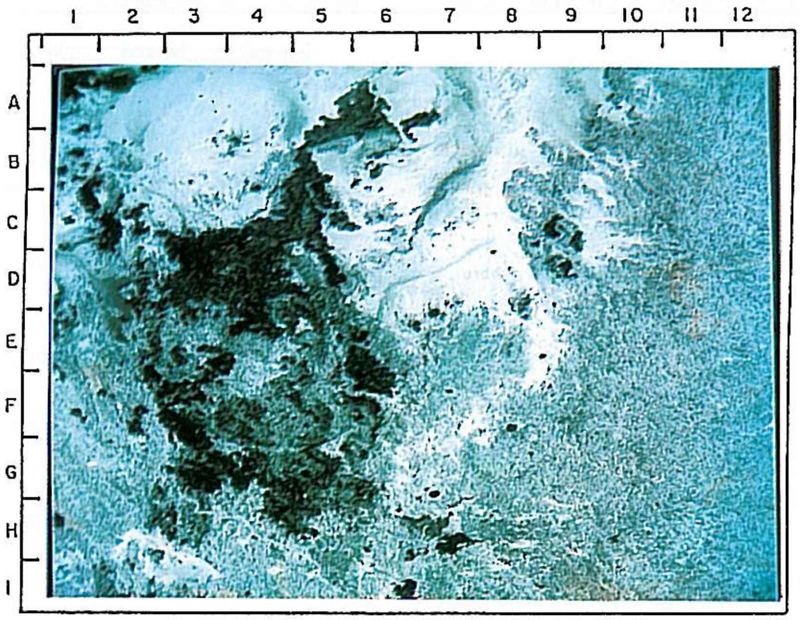

PLATE 5. Edge enhanced image of (Pc1) of the area. Laplacian (3 × 3) filter.

(4) Circular and semi-circular features concentrated mainly in the eastern part of the area and covered by Palaeozoic sandstone. The majority of these circular features are granitic intrusions which are uncovered partly or completely by erosion. They may represent intrusive bodies which have not quite reached the level of the present land surface. Such buried intrusives should make a promising target for mineral exploration.

This complex structure proves that the area under study has suffered many deformation phases. Three lineament trends are recognized; a NW–SE trend which is mainly dominant in Palaeozoic and Tertiary sandstones. Secondly few lineaments take NE–SW trend which is dominant in Palaeozoic and Tertiary sandstone. These two trends may belong to the main orogenies. The Caledonian orogeny took place from the beginning until the middle of Palaeozoic and takes NW–SE trend. The Hercynian orogeny took place through the middle of Palaeozoic until the beginning of Mesozoic Era. This orogeny takes a NE–SW trend. The third lineament is N–S trend and is mainly dominant in Precambrian metamorphic rocks.

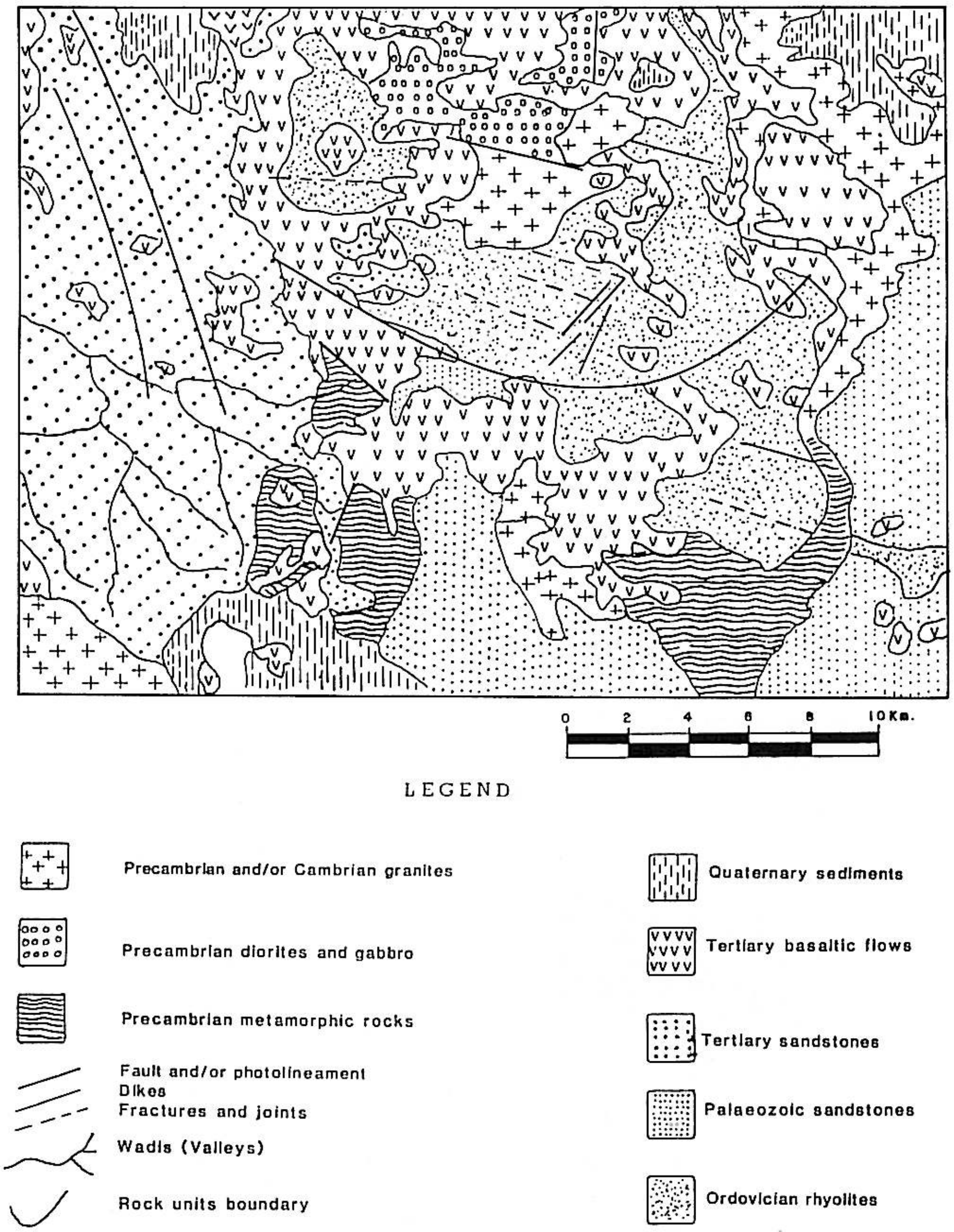

FIG. 3. Preliminary geological map of the area based on the interpretation of plates 2, 3 and 4.

COMPARISON OF GEOLOGICAL INFORMATION FROM LANDSAT TM IMAGERY AND AERIAL PHOTOGRAPHS

In order to compare data from Landsat TM Imagery and Aerial Photographs, four parameters are considered. These parameters are geometric accuracy, rock unit boundaries, lithology, and structure.

(1) *Geometric accuracy*

In this work Landsat TM images which are compared with aerial photographs proved more accurate. This is due to the fact that they are more stable than aerial photographs especially for areas of tens of kilometer or more. Using Landsat imagery it is possible to use only one image to study these scales instead of a large number of aerial photographs from which one has to build a mosaic to cover these scales. This mosaic is a major reason for loss of positional accuracy of the geological features. Also Landsat TM imagery has the advantage of digital geometric correction over aerial photographs.

(2) *Rock unit boundaries*

The use of satellite imagery can be helpful in rapid delineation of the boundaries between the rock units by virtue of its synoptic overview, multispectral and multitemporal coverage. The geological boundaries have been mapped with a high-contrast boundary with

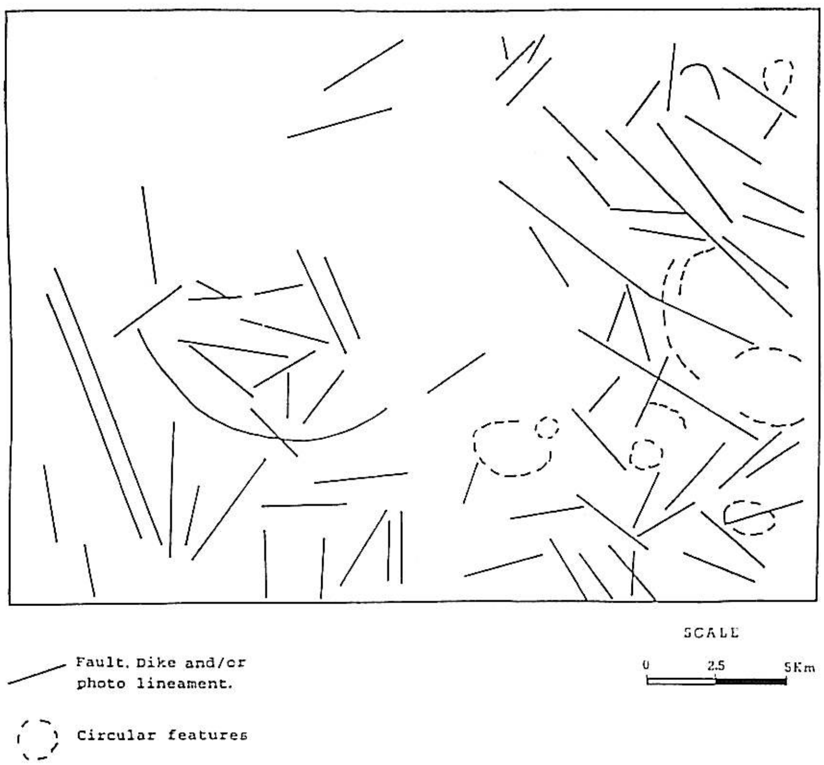

FIG. 4. Preliminary lineaments map of the area based on the interpretation of plate 5.

the aid of different bands of Landsat TM. Most rock units are well delineated, for example the boundaries between the granitic unit and diorites to gabbros unit in region B7,8 and C7,8 (Plates 2 and 3)
have been clearly marked. These units appear as one unit in the aerial photographs.

(3) *Lithology*

The problem of differentiating between units exposed as small outcrops in the area has to be overcome by computer methods, using many image processing techniques. The most effective techniques are: principal component analysis which is very helpful in lithological discrimination. This can be seen in Plate 2 where the basaltic flows appear in two or three units and this colour difference may be indicative of the age of the rock. The other technique is ratio images which enhanced the differentiation even within one unit (Plate 4). Sandstone in the western part of this area appeared in green and yellow colours. These findings point out that satellite imagery, with the advantages of multispectral coverage and digital image processing, is more effective than aerial photography.

(4) *Structure*

Aerial photographs are more effective in delineating and determining the local structures mainly as a result of better spatial resolution and stereoscopic viewing. However Landsat imagery proved more effective in interpreting regional structures.

CONCLUSIONS

The use of more than one type of remote sensing technique is very effective. Aerial photographs proved useful in delineating the local structures, mainly as a result of better spatial resolution and stereoscopic viewing. Landsat imagery proved more effective in the regional structural analysis due to its ability to cover large areas. Circular features are detected easily by Landsat imagery. By using edge enhancement technique, most of the structural features are clearly mapped. High-contrast rock unit boundaries are mapped through the application of colour ratios and principal component analysis images. Unmapped lithologic unit labelled as diorites to gabbros is identified as a result of differentiation in its spectral reflectance over the surrounding rock units. The problem of locating and enhancing the small outcrops were overcome by computer methods, using many image processing techniques. A geologic map and a lineaments map were constructed in order to show most of lithological and structural features which appeared in the produced images. Eight rock units have been identified and plotted in the geologic map. The mapping was based on the spectral reflectance which gives different colours in false colour composite images used in this paper. Structurally, the area is dominated by two lineament trends with a few taking a trend of N–S direction as shown in the lineaments map. The common trend is NW–SE which takes place especially in Palaeozoic and Tertiary sandstone to the east and west sides of the area.

The results achieved indicate that Landsat TM imagery is more effective than aerial photographs by virtue of its synoptic overview, multispectral and multitemporal coverage. It is also more simpler, faster and cost-effective.

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ABBREVIATIONS

TM	Thematic Mapper
MSS	Multispectral scanner
CCT	Computer compatible tape
B&W	Black and White
Pc	Principal component
RGB	Red, Green and Blue
FCC	False colour composite