National Oil Corporation
Petroleum Research Center

Volume.26 (2026)

Geological, Geomorphological and Structural Mapping Updates of Jabal Al Uwaynat in Southeastern Libya, Usening Remote Sensing Techniques.

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Abstract

Ten-color composite images were generated through the integration of three Landsat Enhanced Thematic Mapper (ETM) bands following dynamic image enhancement using the Histogram Equalization Contrast Stretching technique. These enhanced composites proved highly effective in facilitating the interpretation of terrain features within the Jabal Al Uwaynat region. The processed images provided additional geological and geomorphological information beyond that obtainable from the original Landsat ETM (7,4,2) dataset.

A comparison between the ten-color composite images and existing geological maps of the area, including those produced by IRC (2007) at a scale of 1:250,000 and Hunting (1974) at a scale of 1:100,000, revealed a strong correspondence between the spectral variations observed in the imagery and the mapped geological and geomorphological features. In particular, the distribution of Quaternary landforms and ring-complex structures within Jabal Al Uwaynat closely matched the patterns identified on the enhanced Landsat ETM (7,4,2) images.

The observed spectral and spatial variations are primarily associated with geomorphological characteristics such as differences in surface texture and patterns, spectral reflectance properties, lithological composition, moisture content, grain size, sediment thickness, and porosity of Quaternary deposits. Based on the interpretation of these enhanced images, updated geomorphological and geological maps were developed, leading to the identification of several previously unrecognized features that had not been represented in earlier mapping efforts.

To further investigate the terrain characteristics of the study area, a band ratioing technique was applied using the reflective bands of the Landsat ETM imagery. A total of twelve band-ratio images were generated, each emphasizing specific terrain and geological attributes. Moreover, single-color composite images derived from combinations of three band ratios successfully highlighted subtle variations among different terrain units, thereby improving feature discrimination and interpretation.

The study relied primarily on visual image analysis, and the results demonstrated that band ratioing is an effective remote sensing technique for identifying and differentiating terrain features within the Jabal Al Uwaynat region. The integration of enhanced color composites and band-ratio analyses significantly contributed to improving the accuracy of geomorphological and geological mapping and provided valuable insights into the region's surface characteristics.

Keywords: Landsat Enhanced Thematic Mapper Imagery, Jabal Al Uwaynat, Remote Sensing Techniques, Band rationing technique

تحديث الخريطة الجيولوجية والجيومورفولوجية والتركيبية لمنطقة جبل العوينات في جنوب شرق ليبيا باستخدام تقنيات الاستشعار عن بُعد

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الملخص

تم إنتاج صور مركبة ذات عشرة ألوان من خلال دمج ثلاث قنوات من بيانات القمر الصناعي لاندسات (ETM+) بعد تطبيق تقنيات التحسين الديناميكي للصور، والتي شملت معادلة المدرج التكراري (Histogram Equalization) وتمديد التباين (Contrast Stretching).وقد أسهمت هذه الصور المحسنة في تحسين تفسير المعالم التضاريسية لمنطقة جبل العوينات، وكشفت عن معلومات جيولوجية وجيومورفولوجية لم تكن واضحة في الصور الأصلية للقمر الصناعي لاندسات (القنوات 7 و4 و2).

تمت مقارنة المعلومات المستخلصة بالخرائط الجيولوجية المتوفرة للمنطقة، بما في ذلك خريطة IRC (2007) بمقياس رسم 1:250,000 وخريطة Hunting (1974) بمقياس رسم 1:100,000. وأظهرت نتائج التحليل أن العديد من الأشكال الأرضية الرباعية (Quaternary Landforms) ومعالم المجمعات الحلقية (Ring Complexes) تتوافق بشكل وثيق مع التباينات الطيفية التي أظهرتها صور لاندسات المعالجة.

وتُعزى هذه التباينات الطيفية إلى الاختلافات في الخصائص الجيومورفولوجية، وأنماط السطح، وأنواع الصخور، ومحتوى الرطوبة، وحجم الحبيبات، وسمك الرواسب الرباعية ومساميتها. واستناداً إلى تفسير الصور المحسنة، تم إعداد خرائط جيولوجية وجيومورفولوجية محدثة، أسفرت عن الكشف عن عدد من المعالم التي لم تُسجل في الخرائط السابقة.

كما تم تطبيق تقنية نسب الحزم الطيفية (Band Ratioing) بهدف تحسين عملية التعرف على المعالم التضاريسية في منطقة جبل العوينات. وتم إنشاء اثنتي عشرة صورة ناتجة عن نسب مختلفة بين الحزم الطيفية لبيانات الانعكاس الطيفي (Reflectance) الخاصة بصور لاندسات .ETM+ وقد أظهرت كل نسبة طيفية خصائص جيولوجية وجيومورفولوجية محددة، في حين نجحت التراكيب اللونية المختلفة لهذه النسب في إبراز الفروق الدقيقة بين المعالم المختلفة للمنطقة.

اعتمدت الدراسة بصورة رئيسية على التفسير البصري للصور الفضائية، وأثبتت النتائج فعالية تقنية نسب الحزم الطيفية في التعرف على المعالم السطحية وتحسين دقة الخرائط الجيولوجية والجيومورفولوجية في البيئات الصحراوية الجافة، مثل منطقة جبل العوينات في جنوب شرق ليبيا.

الكلمات المفتاحية:
صور لاندسات+ETM ، جبل العوينات، الاستشعار عن بُعد، الخرائط الجيولوجية، الخرائط الجيومورفولوجية، الخرائط التركيبية، تقنية نسب الحزم الطيفية، جنوب شرق ليبيا.

1.Introduction

The Jabal AL Uwaynat area occupies 710.62 square kilometers and is situated between latitudes 21° 45`N and 22° 00`N and longitudes 24° 45`E and 25° 00`E (Figs. 1 and 2). The eastern parts of the area border on the Arab Republic of Egypt and the Democratic Republic of the Sudan. The main road from kufrah Oasis to southwest Egypt and northwest Sudan passes diagonally southeast across the area through the police station at Ain Dua, adjacent to Jabal AL Uwaynat area, which is the only permanently occupied place in Jabal AL Uwaynat area. The distance from Ain Dua to Kufrah Oasis is about 325 km. Jabal AL Uwaynat is roughly circular with a diameter of about 22.5 km; it rises to about 1000 m. above the plain. The massif is composed of outcrops of alkaline rocks which are deeply weathered and form very large well - rounded blocks. (El– Mehdi *et al*, 2004).

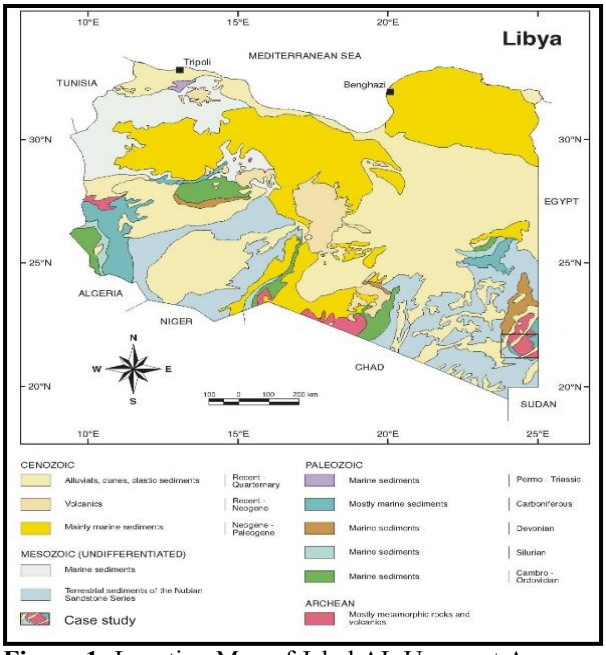


Figure 1: Location Map of Jabal AL Uwaynat Area, geological overview of Libya (modified after Conant and Gondarzi, 1979)

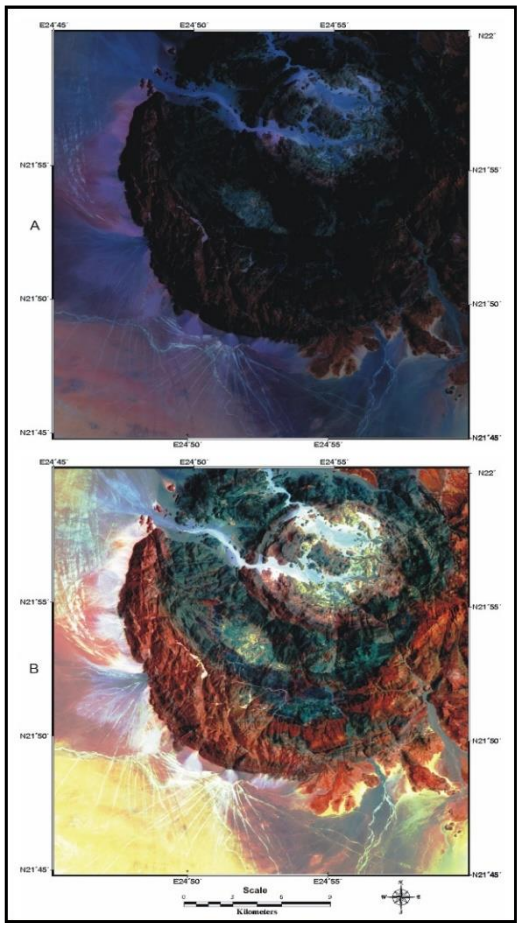


Figure 2: A – Raw Data of Jabal AL Uwaynat
B – Landsat Enhanced Area
Thematic Mapper Bands Combination (ETM 7 = Red, ETM 4 = Green and ETM 2 = Blue)

2. Research Objectives

This study has two major objectives:

1- To test the potential and utility of using Remote Sensing enhancement techniques.

2- To produce update mapping in geologic and geomorphologic study derived from analysis of Landsat Enhanced Thematic Mapper imagery by using techniques that requires less time and less expenses than more conventional field mapping.

3. Justification for Choice of Area

1- Jabal AL Uwaynat area is a classical region of geological study, and the geology is known in considerable detail. However, geomorphologic mapping has lagged behind studies of the geology of the province; in particular, remote sensing data have not been used for geological and geomorphologic analysis.

2- The region has sufficient complexity, both of terrain and surface cover, to permit an evaluation of the applicability of Landsat Enhanced Thematic Mapper data to study of the geomorphology, structure and lithological units in areas of rugged terrain area which is difficult to access.

3-The region possesses a broad range of surface conditions of alkaline complexes so that results in this area should have and has economic problems typical of those which occur throughout Al Kufrah Basin, so that results in this area should have a wider applicability.

4- Therefore, it is desirable to sum the knowledge of visual satellite image interpretation to produce a series of update maps: geological, tectonic and geomorphologic maps that provides information on the mappable units and highlight the signature and their appearance on satellite images.

4. Jabal AL Uwaynat Area

Jabal AL Uwyanat area is one of a linearly arranged series of five ring complexes straddling the Libyan – Egyptian - Sudanese borders in SE Libya, (Fig.3). The five complexes vary in diameter up to 24 km and are arranged along a 130 km line with a NNE trend (Fig.4). The largest and best exposed is the Jabal AL Uwaynat intrusive complex (Fig.5). This is clearly shown by (Fig.4) which is a simplified version of the map provided by Hunting, (1974). It shows each of Jabal AL Uwaynat and Jabal Archenu complexes as a series of zones composed of complete and incomplete ring dykes, here labeled zone UZ1, UZ2, UZ3, UZ4 and UZ5 for Jabal AL Uwaynat. According to the interpretation presented is (Fig.5), the Jabal AL Uwaynat complex is composed of the following zones:

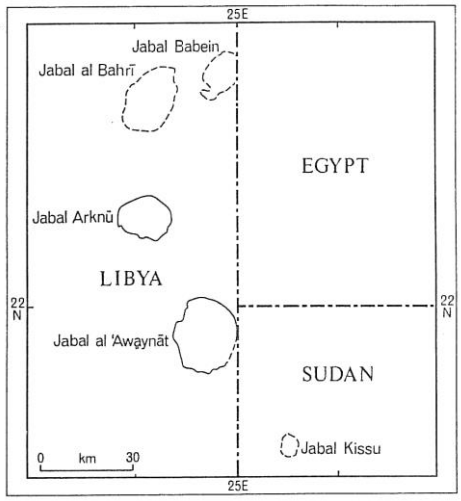


Figure 3: Location map of the alkaline complexes of SE Libya and nearby Sudan, (Derek. F., et.al., 1987)

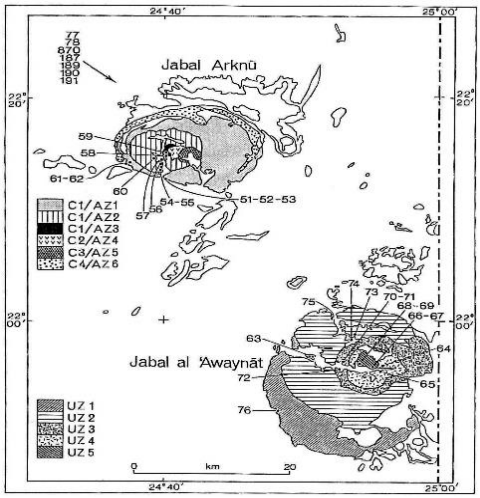


Figure 4: Geological map of the Jabal AL Uwaynat inlier (1= phanerozoic cover; 2= ring complexes; 3= basement rocks) showing the location of the 5major Ring complex: A= Jabal Kissu; B= Jabal AL Uwaynat; C= Jabal Archnu; D= Jabal al Bahri; E= Jabal Babein, (Andre. L., et. al., 1987)

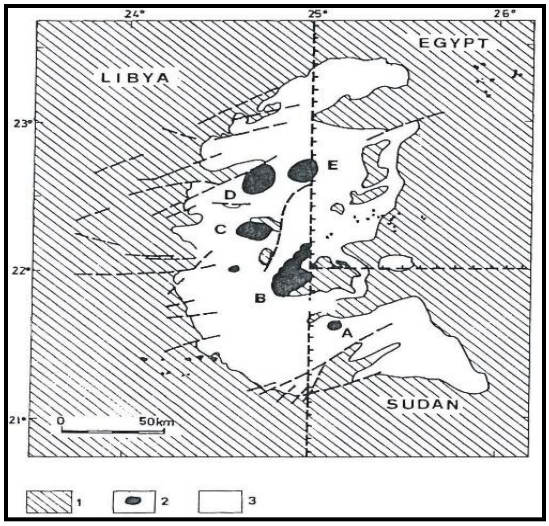


Figure 5: The Jabal Archnu and Jabal AL Uwaynat ring complexes and locality map for the rock specimens used in this paper. Map based on Hunting geology and Geophysics Ltd (1974). C1 - C4: Centres 1-4 in Jabal Arknu. AZ1-AZ6; zones in Jabal Archnu. UZ1-UZ5: zones in Jabal AL Uwaynat.

5. Geologic History

To a certain extent, the stratigraphic framework of Jabal Al Uwayant area developed during the current field programmed is based upon extrapolation from the findings of earlier petroleum – related work in Southern Libya. Few fossils were observed in this area and none were well preserved.

Consequently, the paleontological approach has yielded inconclusive results and the ages adopted for the various parts of the Palaeozoic and Mesozoic succession have not been modified in the absence of clear evidence for making changes. Thus, there is sedimentological evidence for the stratigraphic breaks separating so- called Devonian, Carboniferous and Cretaceous sediments, the absolute ages assigned to the units themselves are, to a certain extent, assumed.

In the case of igneous rocks, the two age dating obtained for rocks from the major ring complexes assign the Jabal Baboir granite to the Ordovician period and the central Jabal AL Uwaynat syenite to the Devonian, (Hunting, 1974). In view of lithologic differences between the complexes and the obvious composite rigin of the complexes themselves, it would be premature to attempt to derive a detailed history of igneous activity based on so little evidence. What can be said is that at least two major episodes of post Precambrian igneous activity are represented in the area.

The large-scale ring complexes in the east area of middle Palaeozoic age whilst the widespread minor intrusions in the west, inasmuch as they intrude sediments believed to be Cretaceous are of late Cretaceous and Tertiary age, (Hunting, 1974).

On the geological map accompanying this report, definite age has been assigned only to those intrusions cutting cretaceous sediments, and due to their proximity, the same age has been applied to those minor intrusions which cut Carboniferous strata in the same area. Likewise, widespread

Trachytic dykes cutting basement adjoining the Jabal Archenu and Jabal AL Uwaynat ring complexes could be related to the Palaeozoic igneous phase. In the interest of separating fact from interpretation on the maps, no age has been assigned to them.

6. The Evaluation of Enhancement Techniques

The major goal of this study is to develop available methodology for producing remote sensing data flow chart for update mapping geologic and geomorphologic study using remote sensing enhancement techniques. The approach adopted in this study has therefore the following steps as illustrated in this flowchart and (Fig. 6),

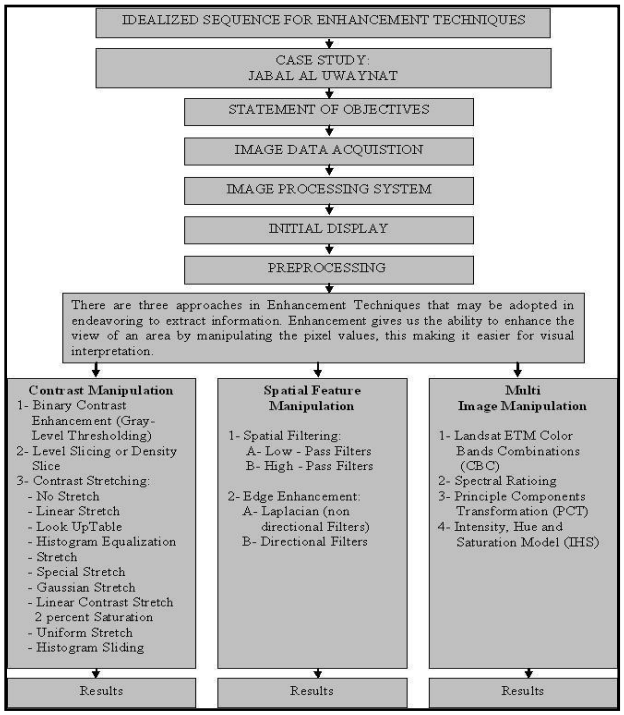


Figure 6: Flowchart illustrating the methodology adopted in the present study, (Lillesand & Kiefer, 1999 and Sabins, 1997)

7. The principal findings of this research are:

1. Landsat ETM 7,4,2 and ETM 5,4,3 band imagery synoptic view of the Jabal AL Uwaynat provided the basis for update geologic interpretation (Fig.7). Published map (Industrial Research Centre (IRC), 2007) on the lithological mappable units were updated (Fig. 8), therefore some discrepancies were found, as follow:

a. IRC(2007)misinterpreted the PLIESTOCENE - HOLOCENE mappable units. Compare between (Figs 7 and 8), the author mapped six mappable units instead of three mappable units.

b. IRC (2007) misinterpreted the PALEOZOIC RING COMPLEX mappable units. Compare between (Figs 7 and 8), the author mapped ten mappable units instead of eight mappable units.

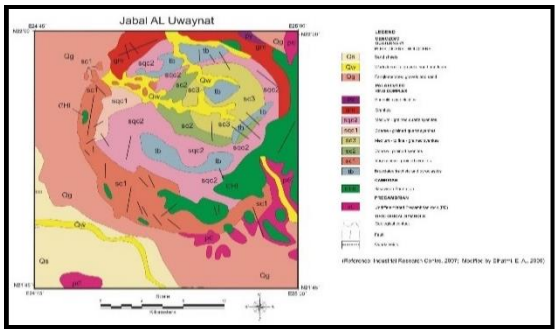


Figure 7: Geologic Map of Jabal AL Uwaynat

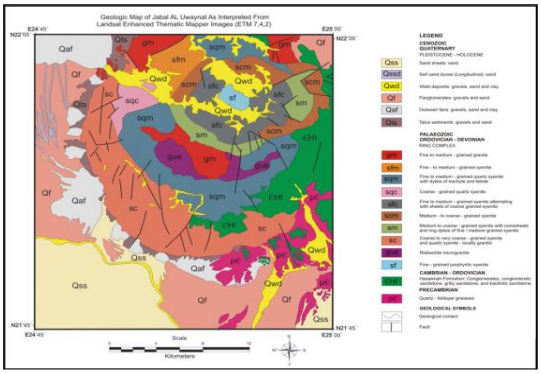


Figure 8: Geologic Map of Jabal AL Uwaynat (IRFigure 8: Geologic Map of Jabal AL Uwaynat (IRC, 2007)

2. To the author's knowledge, no geomorphogic interpretation previously was available (Fig.9), and therefore the present work should greatly highlight the landforms analysis of the district

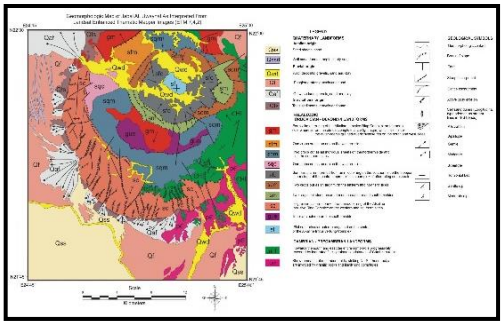


Figure 9: Geomorphologic Map of Jabal AL Uwaynat

3. Published information on the location of major faults and lineaments generally was accurate, although some discrepancies were found, compare the (Figs 10 and 8), and therefore the present work should greatly highlight the structural grain of the district (Fig. 10).

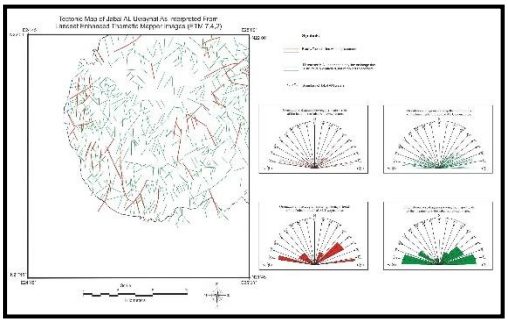


Figure 10: Tectonic Map of Jabal AL Uwaynat

4. The optimum Landsat ETM channels for lithological and structural discrimination was ETM3, ETM5 and ETM7 (Fig.11). Histogram Equalization Contrast Stretch was used to improve image contrast and was effective in highlighting and enhancement of terrain features in rugged terrain as in Jabal AL Uwaynat.

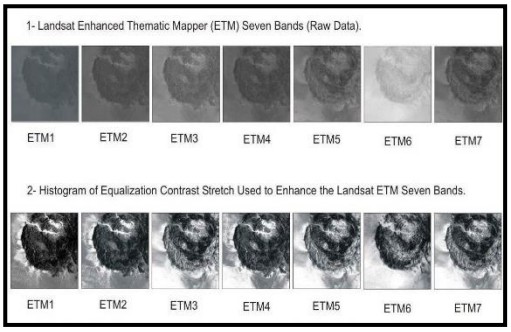


Figure 11: Original Landsat (ETM) images and the dynamic enhancement contrast Stretch Equalization applied in Jabal AL Uwaynat

5. Color composites of different bands (Figs12and 13) have been selected. Each of the three (ETM) color composites has been assigned to a particular color gun of RGB composite. These ten color composites of different band allow for the discrimination of terrain features and material classes .

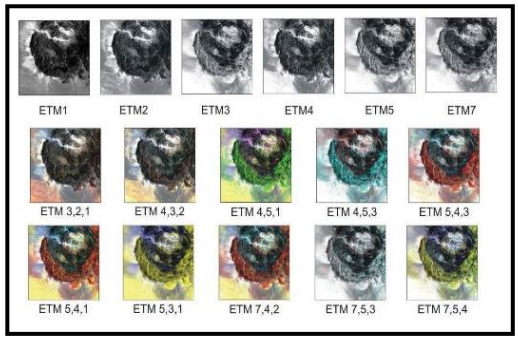


Figure 12: Landsat (ETM) images resulting from applied of histogram Equalization contrast stretch and color – composite combinations applied in Jabal ALUwaynat

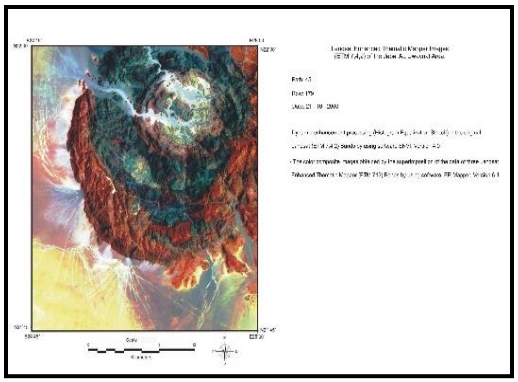


Figure 13: Landsat Enhanced Thematic Mapper Images (ETM 7,4,2) of the Jabal AL Uwaynat

6. Terrain features can be fairly detected and mapped using color combination of three ratioed images. In this study, twelve band ratios were created. Each radioed image enhanced at least three or more terrain features(Fig. 14), but it could not enhance the entire feature. Four colors composite combinations of three band ratios were classified all terrain features (Fig.15 and Table.1)

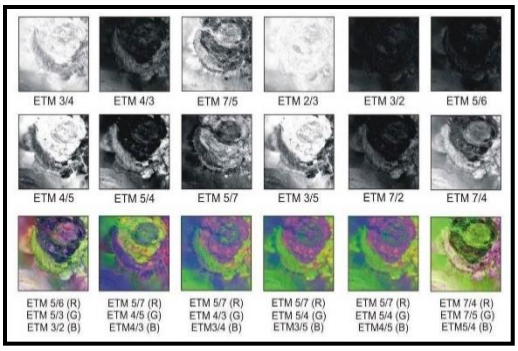


Figure 14. Twelve ratio combinations for Landsat (ETM) applied in Jabal AL Uwaynat and six color – composite combinations of band ratios, applied in Jabal AL Uwaynat

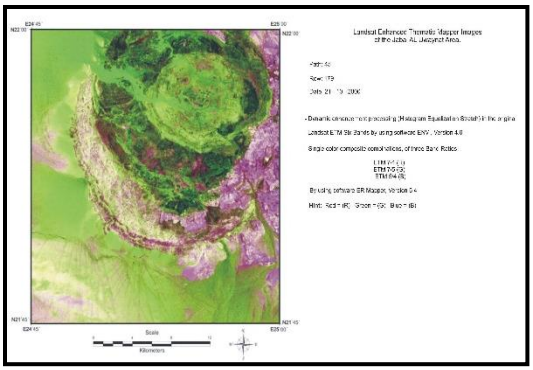


Figure 15: Single color composit combinations, of three Band Ratios ETM 7/4, ETM 7/5 and ETM 5/4

Table 1: Three band ratios applied in Jabal AL Uwaynat

ETM 7/4	(R)
ETM 7/5	(G)
ETM 5/4	(B)
ETM 5/7	(R)
ETM 4/5	(G)
ETM 4/3	(B)
ETM 5/6	(R)
ETM 5/3	(G)
ETM 3/2	(B)

7.

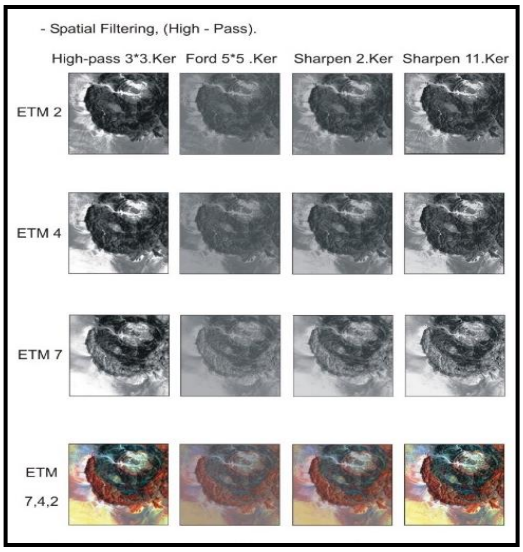


Figure 16: Landsat (ETM 7,4,2) images resulting from application of algorithm spatial filtering High – Pass applied in Jabal AL Uwaynat

7-Another technique was carried out here with Landsat ETM prepared in the form of High - Pass and Low - Pass, and the results were suitable and efficient technique for Jabal AL Uwaynat. (Figs. 16 and 17)

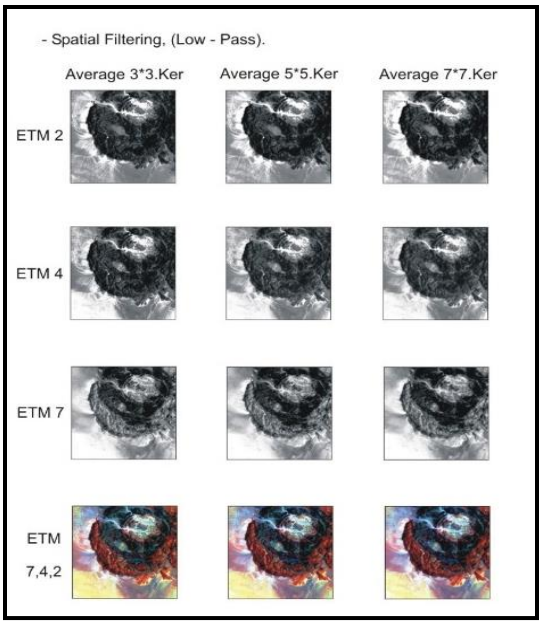


Figure 17: Landsat (ETM 7,4,2) images Resulting from application of algorithm spatial filtering Low – Pass applied in Jabal AL Uwaynat

8. Principle Component Transformation and Intensity – Hue – Saturation Color Space Transformation has Been identified terrain features, but they are not the best and suitable techniques for discrimination terrain features of the study area. (Fig. 18)

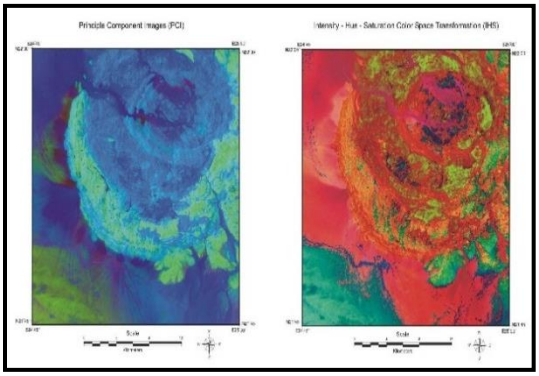


Figure 18: PCI and IHS applied in Jabal AL Uwaynat

Conclusions

Significant results have been obtained for the Jabal AL Uwaynat region of southeastern Libyan.

A study was carried out here with Landsat ETM prepared in the form of different processed images through an interactive program, using a reference image and a color composite of Histogram Equalization Contrast Stretch bands.

In particular, the color composite of the three-color combinations (ETM 7,4,2, and ETM 5,4,3) and three color ratio combinations (Fig.14) revealed interesting details, concerning the update structural (Fig.10) lithological

information (Fig.7) and geomorphic landforms analysis (Fig.9) of the terrain features of Jabal AL Uwaynat.

Acknowledgments

My appreciated to Petroleum Research Centre for give us the chance to do many research studies and my thanks also extended to all colleagues in Geophysics Section at petroleum Research Centre for help us and providing necessary data.

References

Derek, F., Salem, L., Michael. P., an R.A. Cliff., 1987: The Rock - Forming Minerals of the Jabal Arkun and Jabal Al Uwaynat Alkaline Ring Complexes of SE Libya In: The Geology of Libya (eds.) M.J. Salem an M.T. Busrewil Fac. Sci., Univ. Al-Fateh, Tripoli, VII, 2540-2544.

EL-Mehdi, B; Turki, S. M. and Suwesi K. S. (2004).Short Note and Guidebook on the Geology of Al Kufrah Basin AL Uwaynat Area. *IRC*, Tripoli, 67p.
Hunting Geology and Geophysics Ltd.
(1974). Geology of Jabal Al Uwaynat area.
Libyan Arab Republic. Unpublished rep. *Ind. Res. Cent*., Tripoli, Libya, 86p.

Industrial Research Centre (2007). Joint Geological Mapping Project Sheet, Jabal AL Uwaynat
(NF 35-9) Scale 1:250.000, Tripoli, Libya, 99p.

Lillesand T. and Kiefer, R. W. (1999).
Remote Sensing and Image Interpretation. 4th Edition, John Willey and Sons, Inc. New York, 607p.

Sabins F. E. (1997). Principles and Interpretation. 3rd. Edition. W. H. Freeman and Company, New York, 449p.