Fractures System Analysis of Nukhaib Area in Western Desert of Iraq Using Landsat Image Data

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Abstract

Landsat ETM+ image data and one scene of digital elevation model (DEM) are used in the Nukhaib area. The image is geometrically corrected and has a resolution of 30 meter which can easily detect the lineaments in the study area. Three different software packages are used in digital processing of Landsat image data, interpretation and drawing lineaments, calculating their lengths and numbers, and to contour them. The image, which occupies bands 2, 3, and 4, has been stretched across the 0-255 range, in order to enhance the image contrast. Two methods are used to interpret the lineaments; filtering operations method which enhances the small scale features while maintains the large scale features, and color composites method which is used to enhance the image digitally and makes it easier to identify linear patterns of lineaments. The final map for the study area is generated from these two techniques and showed that there are 89 lineaments, with lengths between 452.94 and 19193.39 meter. The frequency rose diagram is extracted from the final map. This diagram represents the statistical directional distribution of lineaments, and showed that the northwest direction is the primary direction in the Nukhaib area which is the same direction of the dominant forces in the western desert of Iraq.

الخلاصة

استخدمت في هذه الدراسة بيانات الارتفاعات الرقمية وصورة فضائية من القمر لاندسات مصححة هندسيا ولها دقة 30 متروالتي بأمكانها تحديد التراكيب الخطية في المنطقة, وقد تم استخدام ثلاثة برامج لغرض المعالجة الرقمية للصورة الفضائية وان هذه الصورة تشغل الحزم 2 و 3 و 4 والتي تم تمديدها من 0 الى 255 من اجل تمييز الظواهر بصورة واضحة. استخدمت طريقتان لتفسير التراكيب الخطية وهما طريقة الترشيح التي تقوم بتوضيح المظاهر الصغيرة وتحافظ على الكبيرة,والطريقة الثانية هي طريقة الصور الملونة المركبة والتي تستخدم من اجل تعزيز الصورة رقميا وتسهل من عملية تحديد انظمة التراكيب الخطية, ومن هاتين الطريقتين رسمت الخارطة النهائية والتي بينت بأن هنالك 89 كسرا بأطوال تتراوح مابين 452.94 و 19193.39 متر, ومن الخارطة النهائية تم الحصول على مخطط روز التكراري الذي يمثل كيفية انتشار التراكيب الخطية والاتجاهات السائدة لها في المنطقة, ومن تحليل هذا المخطط تبين ان الاتجاه الرئيسي في منطقة الدراسة هو الشمال الغربي والذي يتفق مع اتجاه القوى السائدة في الصحراء الغربية من العراق.

Introduction

The study area is located between latitudes 31°45´- 32°15´ North and longitudes 41°55´- 42°30´ East, and covers an area of 3151 square kilometers, it is located in the western desert of Iraq (Figure 1) within the Rutba Subzone (Figure 2), which is part of the uplifted area of the Rutba-Jezira zone. The zone is part of the stable shelf of Iraq (Jassim & Goff, 2006). The land surface rises gradually from east to west to a maximum elevation of 383 m. above sea level (Figure 3). The climate of the Nukhaib area is semi-arid, with dry and hot summer and cold and low rain winter. There are big diurnal changes in temperature, even daily variation of 36°C. The mean annual rainfall is very low (75 - 150) mm, increasing westwards, whereas the mean annual evaporation ranges from (3000 - 3500) mm, therefore the remained small quantity of water acts in chemical weathering such as leaching, solution and hydration (Hamza, 2007).

Previous Studies;

Al-Amiri (1978) has done a structural study of the western desert of Iraq using Landsat satellite imagery, and determined the lineaments in the area. Al-Azzawi (1988), has studied the tectonics of the area west of the Euphrates River using satellite imagery and geological information. Abdul-Qadir (2002) has used the data from Resrs-01#3 satellite for optimal utilization of groundwater resources in the Iraqi western desert. Al-Jaf (2008) used the integration between remote sensing and GIS to study the geological features and the mineral deposits in the Iraqi western desert. Al-Muthen (2009) studied the regional structures of Ga'ara area in the Iraqi western desert using Landsat image data. Jahjah (2001) has done a study to define the geological Formations in part of Diala Province using data from the Thematical Mapper (TM) sensor. Akman and Tüfekçi (2004) have studied an area west of Turkey using ASTER data to determine the lineaments and their directions in the area.

Aim Of The Study

The aim of this study is to interpret Landsat image of Nukhaib area in order to map fracture trace systems and analyze them statistically.

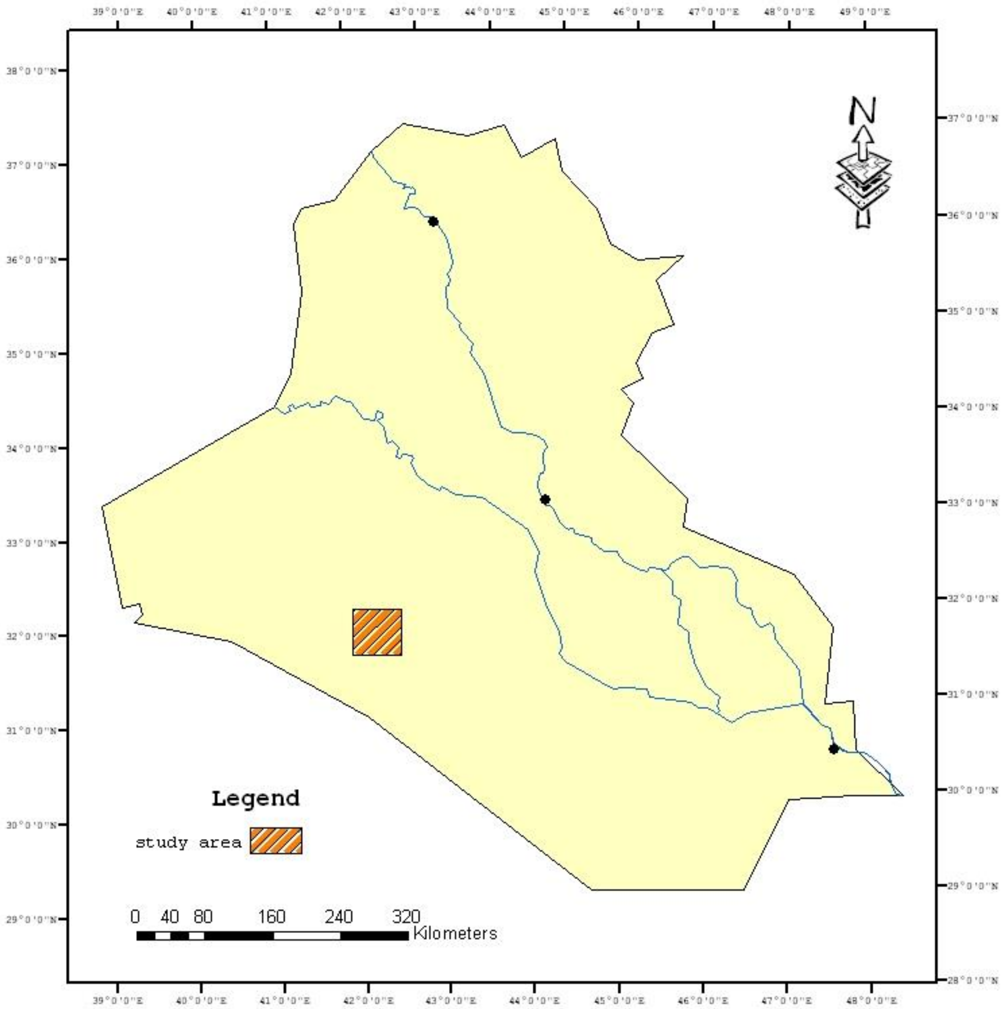
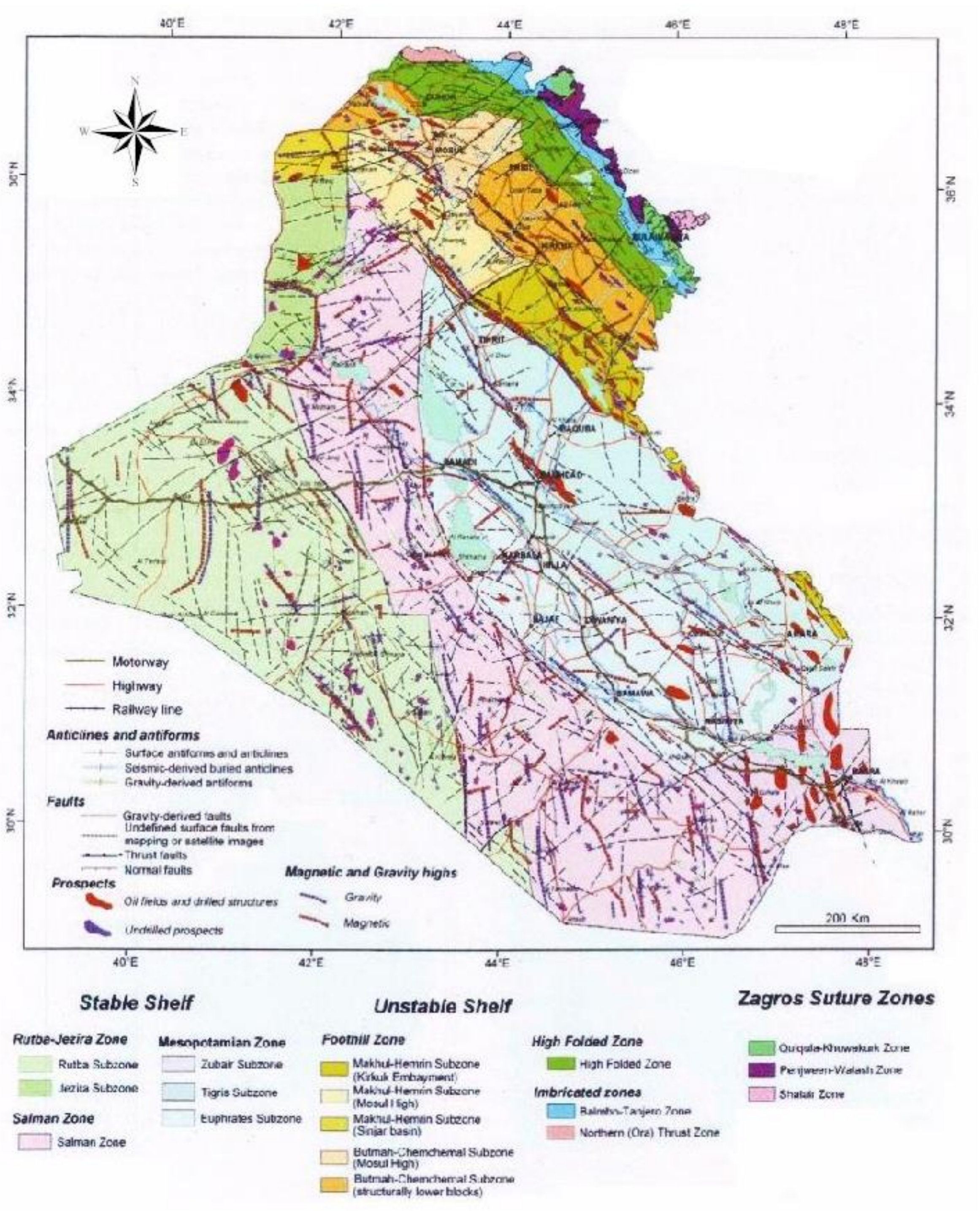


Figure 1: Location map of the study area.


Motorway
Highway
Railway line
Anticlines and antiforms
Surface antiforms and anticlines
Seismic-derived buried anticlines
Gravity-derived antiforms
Faults
Gravity-derived faults
Undefined surface faults from mapping or satellite images
Thrust faults
Normal faults
Prospects
Oil fields and drilled structures
Undrilled prospects
Magnetic and Gravity highs
Gravity
Magnetic
200 Km
Stable Shelf
Unstable Shelf
Zagros Suture Zones
Rutbe-Jezira Zone
Rutba Subzone
Jezira Subzone
Salman Zone
Salman Zone
Mesopotamian Zone
Zubair Subzone
Tigris Subzone
Euphrates Subzone
Foothill Zone
Makhul-Hemrin Subzone (Kirkuk Embayment)
Makhul-Hemrin Subzone (Mosul High)
Makhul-Hemrin Subzone (Sinjar basin)
Butmah-Chemchemal Subzone (Mosul High)
Butmah-Chemchemal Subzone (structurally lower blocks)
High Folded Zone
High Folded Zone
Imbricated zones
Northern (Ora) Thrust Zone
Shalair Zone

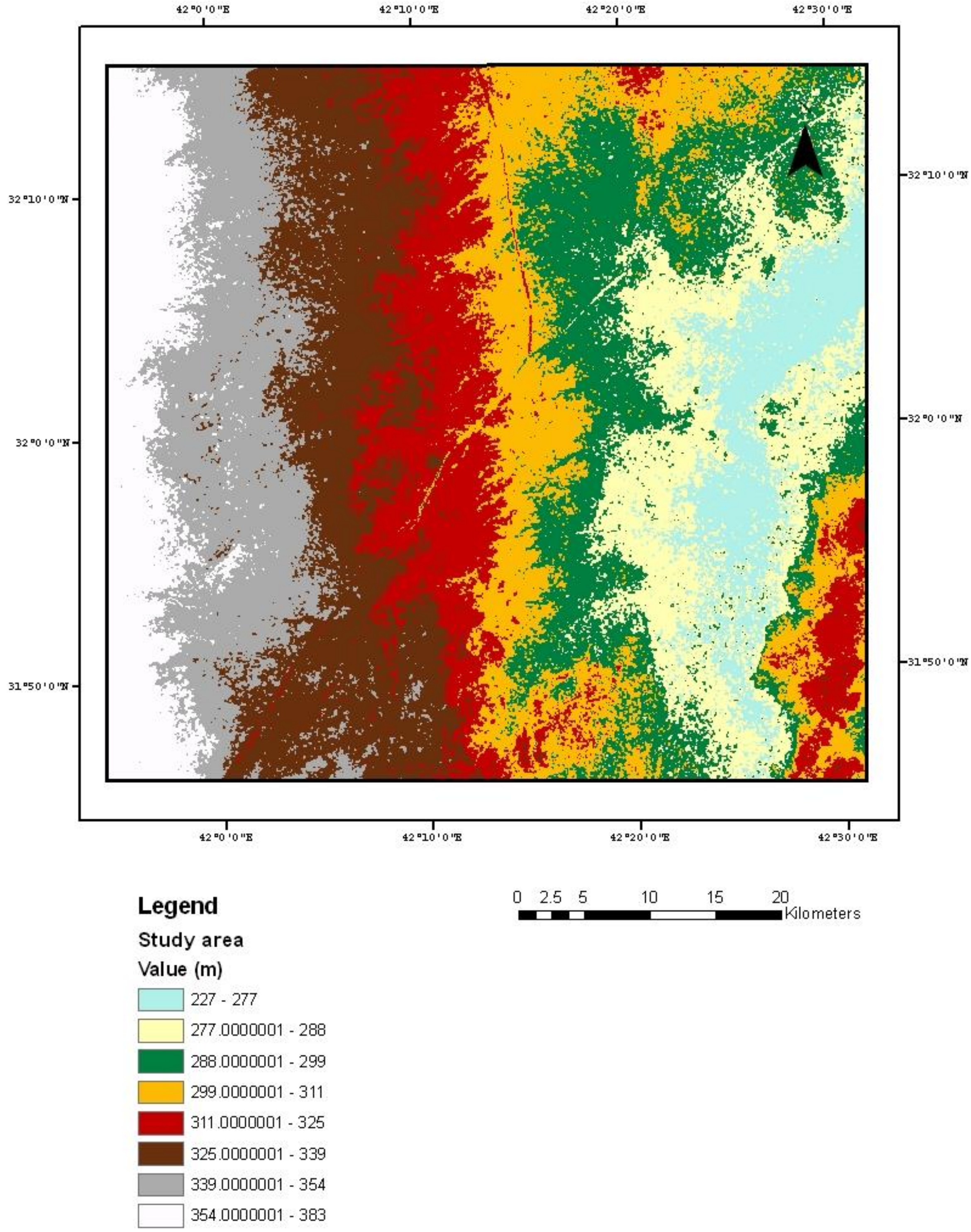


Figure 3: Elevation map of study area generated from DEM data (resolution 30 m).

Stratigraphic Succession In Nukhaib Area:

The geologic formations in Nukhaib area are shown in (Figure 4). In order to facilitate the description of the exposed geological formations in the Iraqi Western Desert; they are divided according to age and each formation is described in a systematic style; starting with the exposure areas, lithology, and age, (Sissakian, 2007).

1- Umm Er Radhuma Formation (Middle - Late Paleocene):

The Umm Er Radhuma Formation crops out widely in the eastern part of the Iraqi Western Desert. It crops out south of Al-Sahin, along the Iraqi - Saudi Arabia borders and extends northwards till north of wadi Ubaidh, also extends northwestwards to Muger Al-Na'am vicinity, crossing Al-Bireet, Jdaidat Ar'ar, Al-Nukhaib and extends further northwestwards till wadi Al-Meera, where Cretaceous rocks crop out. Umm Er Radhuma Formation consists of anhydritic and dolomitic limestones, mostly dull, white or buff, microcrystalline and porous. Chert occurs in the higher part of the formation (Bellen *et al.*, 1959). The following ages were claimed by different authors: Paleocene - Early Eocene (Bellen *et al.*, 1959), Paleocene (*Buday et al.*, 1980) Middle - Late Paleocene (Al-Mubarak and Amin, 1983).

2. Dammam Formation (Middle - Late Eocene):

The Dammam Formation is exposed only in the eastern part of Iraqi Western Desert. It is exposed in Al-Sahin vicinity and extends northwards to Garat Al-Shatub, crossing Al-Breet, Al-Lusuf and Al-Jithoom vicinities. Its exposures cross wadi Ubaiyidh for about 50 Km, northwards till 10 Km southeast of Garat Al-Shutub (Figure3). It is also exposed in some deep cut valleys, as isolated outcrops, like Ghadaf, Thumail, and Hauran. The Dammam Formation, in the type locality, consists of "whitish grey, porous dolomitized limestone. The limestones are sometimes chalky. At or near the base of the drilled section a persistent grey - green waxy shale body is encountered (Bellen *et al.*, 1959). The age of the Dammam Formation is another matter of controversy between different authors. According to Bellen *et al.* (1959) the age in the supplementary type section is Middle Eocene. However, they have not excluded the possibility of being Early - Late Eocene. The age in H1 Oil pumping vicinity (along wadi Hauran) is Early - Middle Eocene (Tyrack and Youbert, 1975); in Shithatha vicinity is Middle Eocene (Al-Mehaidi *et al.,* 1975); in the eastern part of the Western Desert is Early - Middle Eocene (Early Ypresian - Late Lutetian) (Al-Mubarak and Amin, 1983); the age of the Dammam Formation (regionally) is Middle Late Eocene (Lower Lutetian - Priabonian) (Jassim *et al.*, 1984).

3. Zahra Formation (Pliocene - Pleistocene):

The Zahra Formation has considerable coverage areas in the Iraqi Western Desert. It is exposed in the eastern part, from Al-Sahin vicinity and extends north northwestwards in a patchy character crossing Khibrat Shinana, Al-Nukhaib, Al-Habbariyah till wadi Ghadaf. The Zahra Formation, in the type locality consists of "whitish and reddi limestone, locally sandy, red and purple sandy marls and calcareous sands" (Bellen *et al.,* 1959). Al-Mubarak and Amin (1983) described the Zahra Formation as cyclic deposits usually (1-10) cycles are developed, except in the southern part of Nukhaib Graben, where it consists of 26 cycles. The presence of a tongue of limestone similar to those of Zahra Formation in Dibdibba Formation suggests that the two formations are laterally equivalent at least in parts. Late Miocene or younger age is claimed by Bellen *et al.* (1959).

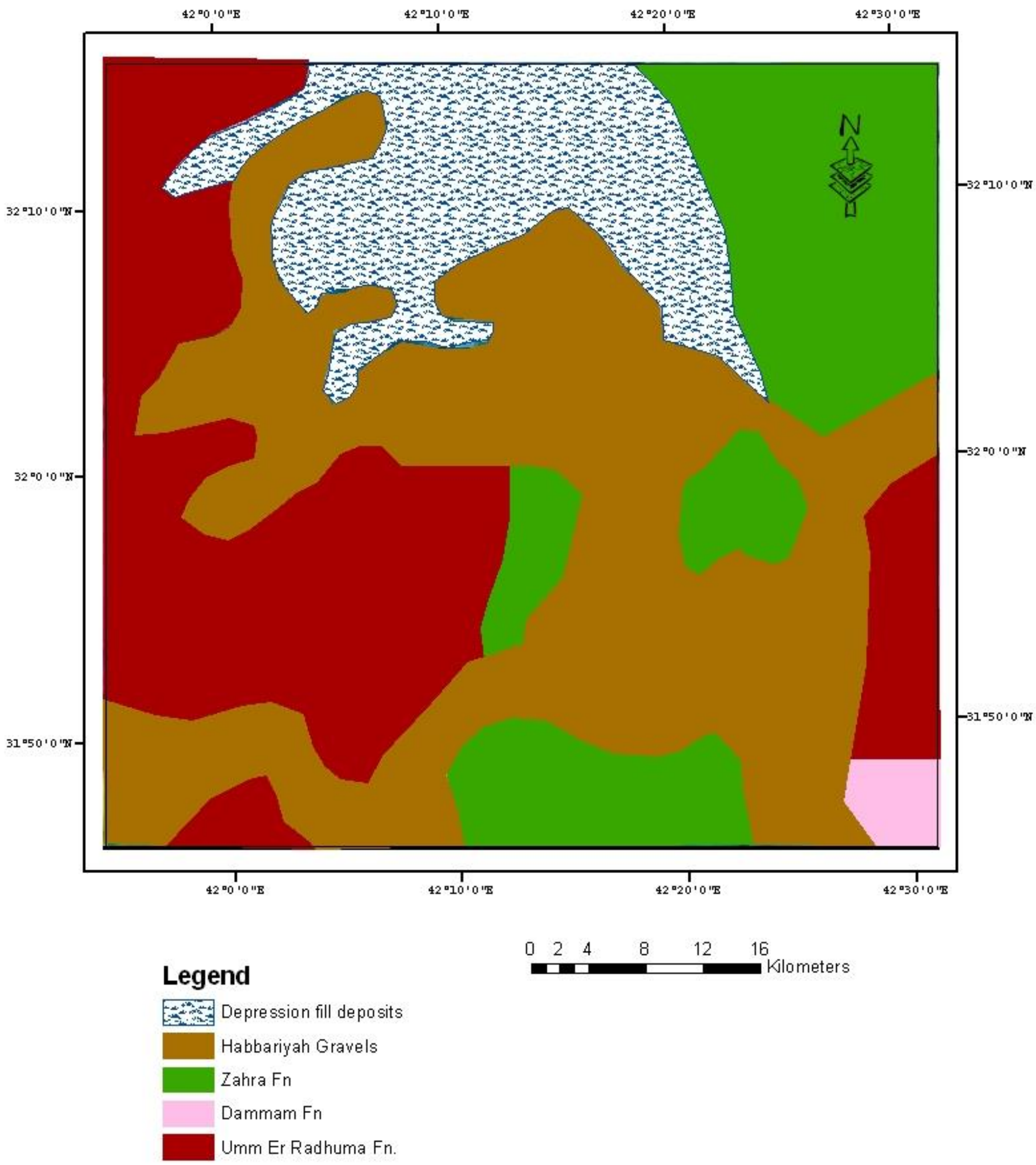


Figure 4: Geological map of the study area (modified by Sissakian, 2000).

4. Habbariyah Gravels (Pleistocene)

Al-Mubarak and Amin (1983) introduced the Habbariyah Gravels for the first time. These are well developed in the middle part of the Iraqi Western Desert. They are composed of loose, rounded to sub rounded limestone pebbles with few chert, the size of the pebbles ranges from (12 - 20) cm, the thickness of this level ranges from (5 – 6) m exceptionally reaches (8-12) m, in the northern bank of wadi Ghadaf. This horizon is capped by calcrete layer, semi bedded, with few pebbles and thickness of (0.5 - 1.5) m. The second (higher) gravelly layer is composed of loose, rounded to sub rounded dolostone, limestone and chert pebbles, the size of the pebbles ranges from (0.5 - 3.0) cm, with thickness of (1 - 3) m but occasionally may reach (4 - 5) m. The source and origin of the pebbles are obscure.

5. Depression Fill Deposits (Holocene):
These are restricted mainly to the Northern part of study area, forming usually flat areas, which called playa and locally as "Faidhah" or "Khibrah" .The deposits are mainly of clay and silt, rich in $S0_4$. The thickness is (0.5 - 1.5) m and may exceed, whereas the average area is less than 1 Km^2 to more than few tens of square kilometers.

Geomorphological Units In Nukhaib Area:
The landforms of Nukhaib area are grouped in three major units related to the agents and processes contributing to their development. The units are:

1. Units of Structural - Denudational Origin

Plateaus:
Plateaus form one of the widest landforms of the study area, because of its structural position within the Stable Shelf. The plateaus are surfaces formed during past geological periods on variable rocks. Some of the plateaus represent contact surfaces between geological formations; others are formed on members within geological formations (Hamza, 2007).
The plateau on Zahra Formation is bordered by Al-Qusair Fault and Al-Habbariyah Depression. The width of the plateaus is about 60 Km, in the south and about 25 Km, in the north. The surface of the plateau is level and dissected by short shallow karst valleys. The middle part of the plateau is rich in small size karst depressions; therefore it is isolated as karst landform.

Questas and Hogbacks:
This type of landforms is well developed in the area south of Al-Nukhaib Depression (Shithatha Quadrangle, sheet N1-38-13, scale 1: 250 000). The features are exposed in ring shapes, representing remnants of domes, which are formed of rocks of Zahra Formation; the features cover an area that reaches about 70 km in width.
Relics of hogbacks occur in the upper reach of Wadi Tabal and Wadi Thumail basins (Tabal Quadrangle, sheet N1-37-16, scale 1: 250 000). The features reflect short and long folds composed of rocks of Hartha and Tayarat formations.

2-Unit of Denudational Origin:

Depressions:
Large size depression in the study area is the AL- Habbariyah depression. The most important element in development of the depression is the existence of faults along which denudation is very effective.
Al-Habbariyah Depression is developed in the southeastern part of the Western Desert. It is younger in age than the Ga'ara Depression, as evidenced by the exposures of Zahra formation on their both sides. The depression is formed by denudation along N - S trending faults and enlarged by reiteration of their cliffs. The depression is (35 x 70) Km in dimension. It is filled by fine and coarse sediments. The fine sediments were laid down by the wadis, which cross the depression, whereas the coarse materials are gravels of alluvial fans, which extend along the western side of the depression. The depression is surrounded by cliffs in the east which are of medium height, while those in the west are lower.

3-Units of Fluvial Origin:

Alluvial Fans:
Alluvial fan topography is common in the study area. The fans are merged together in form of bajada. The surface of the bajada shows local breaks in slope indicating stages of fans. The stages are consequence of climatic changes.

In Al-Habbariyah Depression, three stages of alluvial fans are developed .The stages differ from each other in degree of dissection. The higher two stages are highly dissected and separated from each other by a cliff. The two stages are probably of Pleistocene age. The third stage (youngest) is of smooth surface and might be of Early Holocene age.

Infilled depressions:

Infilled depressions are common on surfaces of all plateaus. They are of variable sizes, ranging from few square meters up to few hundred square kilometers. The depressions vary also in age. They have started to develop since Late Cetaceous. The depressions are either erosional or solutional in origin. The infilling materials of the depressions consist generally of fluvial materials with subordinate influence of eolian activity. The old depressions are infilled by collapsed material, from the surrounding rims, consists of rock fragments and blocks mixed with soil (Hamza, 2007).

Tectonic Setting Of Nukhaib Area:

The study area is a part of the western desert of Iraq, which lies on the stable part of the Arabian platform where Mesozoic and Cenozoic rock units are exposed and slopping gently north and east towards the unstable part of the platform (Buday and Jassim, 1987). The Stable Shelf covers most of central, southern and western of Iraq, it is divided into three major tectonic zones; the Rutba-Jezira zone, the Salman zone, and the Mesopotamian zone (Figure 2). The stable shelf is tectonically stable and little affected by Late Cretaceous and Tertiary deformation. The orientations of the structures in this tectonic unit were influenced by the geometry of the underlying basement blocks and faults, Paleozoic epirogenic events and Mesozoic arching (Jassim and Goff, 2006).

The N - S trending faults are restricted to the southern part of the Western Desert. Al-Mubarak and Amin (1983) described them as a set of normal faults with long traces (80 - 150) Km and clear vertical displacement. The fault system form a north - south trending, 160 Km long and (70 - 80) Km wide graben known as "Nukhaib Graben". Al-Bassam *et al.* (1997) presented an extended discussion concerning the geology and origin of Nukhaib Graben, using different geological, geophysical, geochemical and hydrogeological data. They pointed out that the graben is formed above the basement high (granitic intrusion and salt dome), and that the graben bounding faults displaced the Mesozoic and Cenozoic stratigraphic sequences. Other faults such as the NW- SE, NE - SW and E -W trending is also recorded by many workers (e.g. Al-Amiri, 1978; Al-Mubarak and Amin, 1983, and Al-Bassam *et al.,* 2004). With limited data available, however, many of these faults can not be verified or discussed in detail.

Data used in this study:

The Landsat Enhanced Thematic Mapper Plus (ETM+) sensor, launched in 2000, is a development of the TM sensor. The Landsat 7 ETM+ sensor offers several enhancements over the Landsat 4 and 5 Thematic Mapper sensors, including increased spectral information content, improved geodetic accuracy, reduced noise, reliable calibration, the addition of a panchromatic band and improved spatial resolution of the thermal band (Lillisand & Kiefer, 2000) are shown in table 1.

Table 1: Spectral and spatial resolution of the common Landsat ETM+ sensor (Walsh, 2003)

Landsat 1 – 7		
Sensor	**Spatial Resolution (metric) 1000 m**	**Band Wavelength or Frequency Detection**
ETM+	**Bands 1-7: 30 m** **Band 6 at 60 m** **Pan. 15 m**	**Band 1: blue, 0.45-0.52μm** **Band 2: green, 0.52-0.60μm** **Band 3: red, 0.63-0.69μm** **Band 4: near IR, 0.76-0.90μm** **Band 5: mid IR, 1.55-1.74μm** **Band 6: thermal IR 10.40-12.50μm** **Band 7: mid IR, 2.08-2.35μm** **Pan: 0.52 - 0.90 μm**

Characteristics of data used in this study:

Satellite image of the area is the main data used in this study. It is used for the interpretation of fracture lineaments. Considering spatial resolution of the available satellite images and the size of the study area, Landsat ETM+ image is selected for this study. This image has a resolution of 30 m which can easily detect the fracture lineaments. The study area is covered by one scene of Landsat ETM+ (Figure 5), and one scene of Digital Elevation Model (DEM) of the Shuttle Radar Topography Mission (Figure 6).

Software used in this study:

During this study three different software packages are used since there is not single software that will process all steps in the analyses. These are ERDAS IMAGING (version 9.0), ArcGIS (version 9.1) and ROCK WARE 2006. All lineament interpretation including Filtering operations and Color Composite are carried out using ERDAS IMAGING software. ArcGIS is used for analysis operations of the interpretation lineaments and output. ROCK WARE software is used in drawing Rose diagram to the interpretation lineaments from ETM+ image during this work.

Methodology:

1- Principal Components Transformation (PCT):

In order to merge data sets the Principal Components Transformation model is used (Walsh, 2003). This technique is applied to increase the spatial resolution of images from 30 m to 15 m.

2- Histogram equalization:

The histogram equalization technique is a non-linear stretch. In this method, the digital number values are redistributed on the basis of their frequency. More different gray tones are assigned to the frequently occurring digital number values of the histogram. A histogram of the resulting image will thus appear flat. In theory (i.e., Information Theory), this will lead to an image that carries the maximum amount of information for any given number of classes. However, this does not imply that the resulting image is more meaningful (Walsh, 2003).

The image of the study area occupies the digital values from 73 to107 for band 2, 123 to 185 for band 3, and 105 to 153 for band 4 before stretching; the digital number has been stretched across the 0-255 range, which resulted in an overall increase in image contrast.

The images before and after stretching for bands 2, 3, and 4, are shown in figures 7, 8, and 9, respectively.

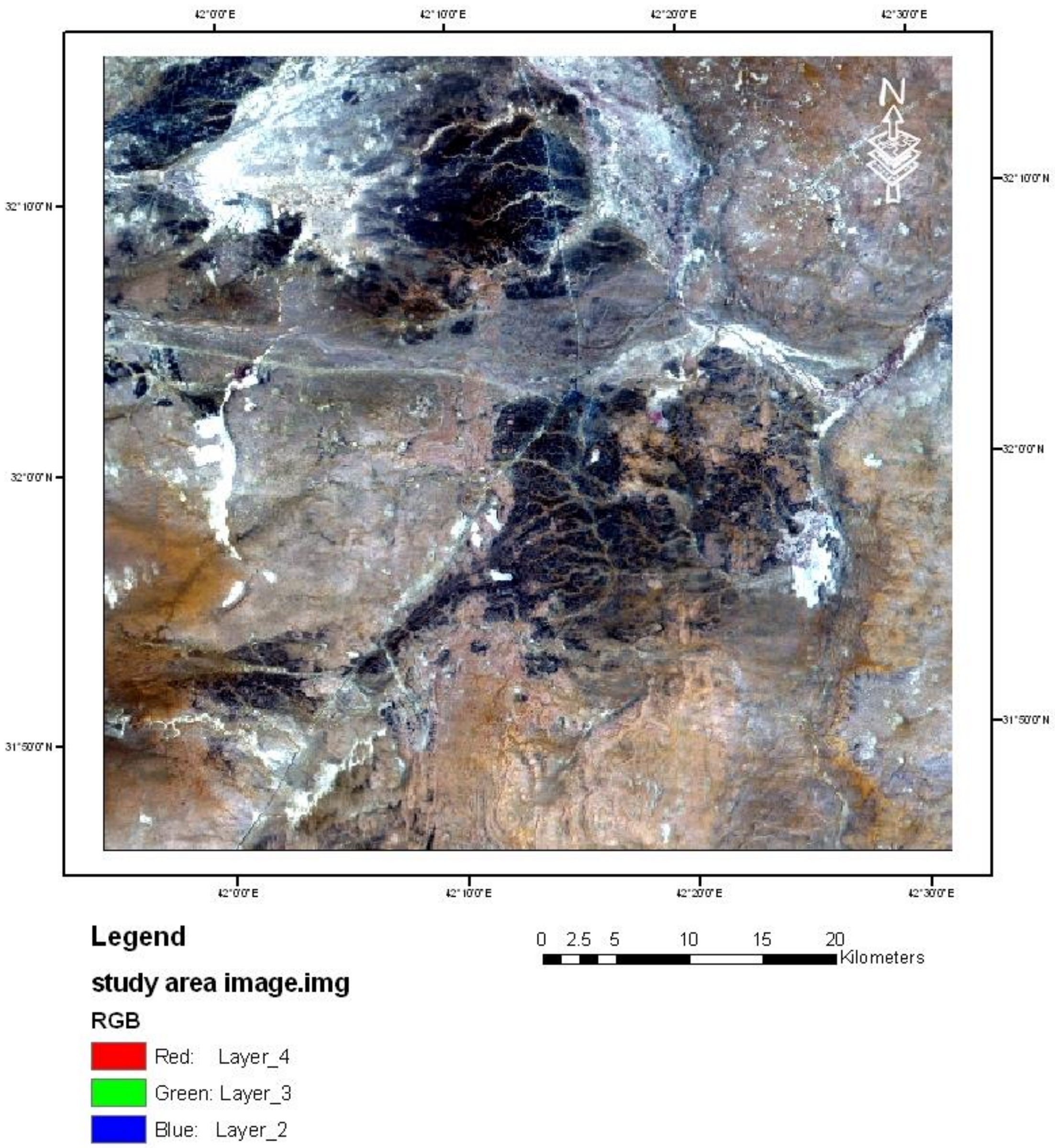


Figure 5: Landsat ETM+ image of the study area.

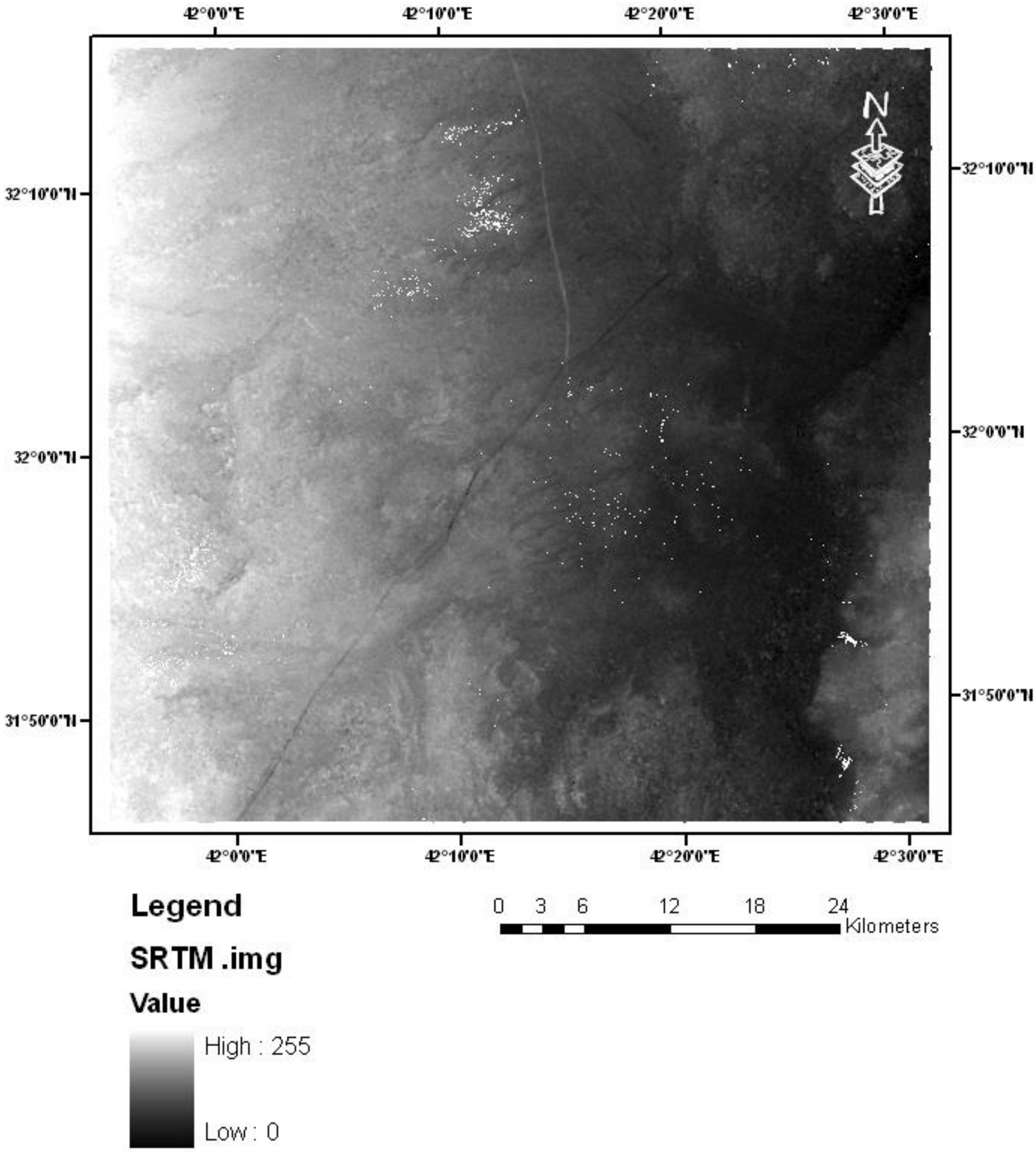


Figure 6: Digital Elevation Model (DEM) of the study area.

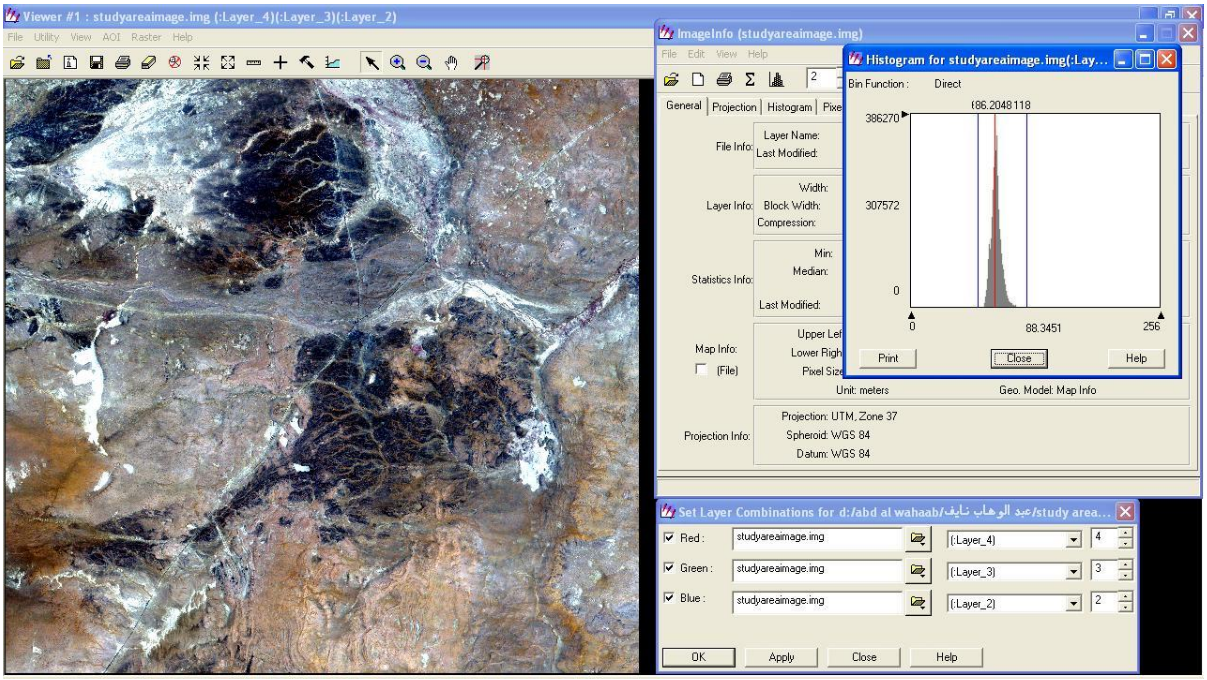


Image and histogram before stretching

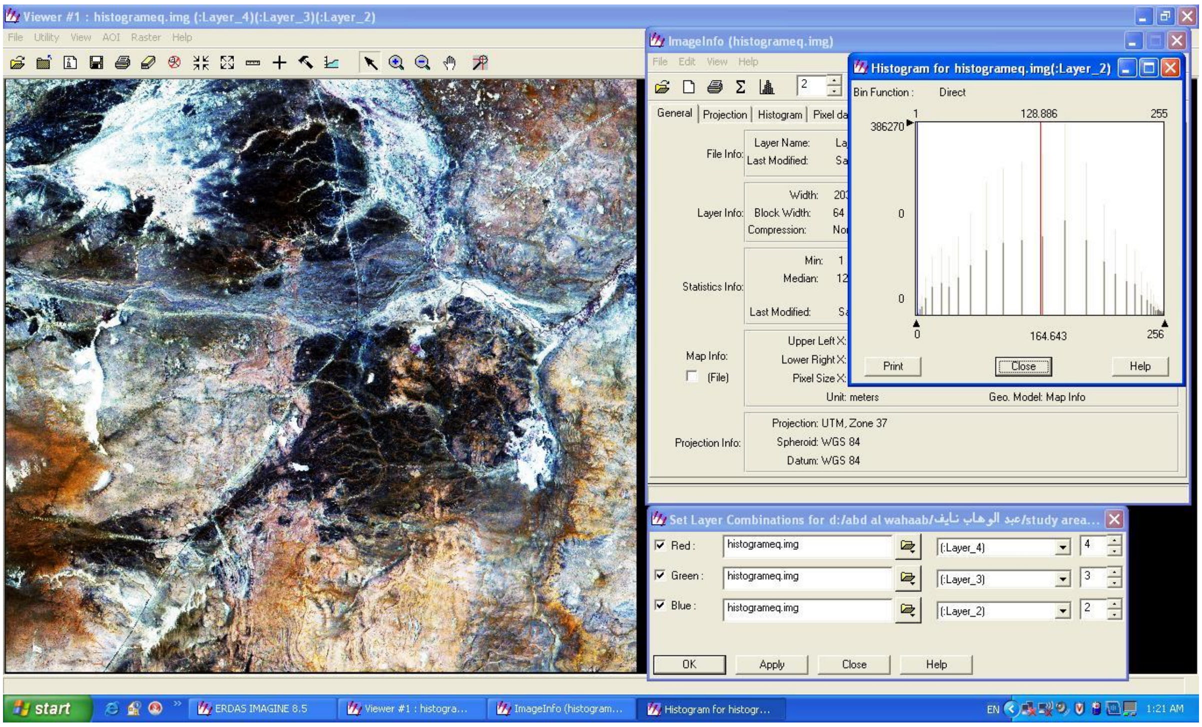


Image and histogram after stretching

Figure 7: The images and histograms of band 2 before and after stretching.

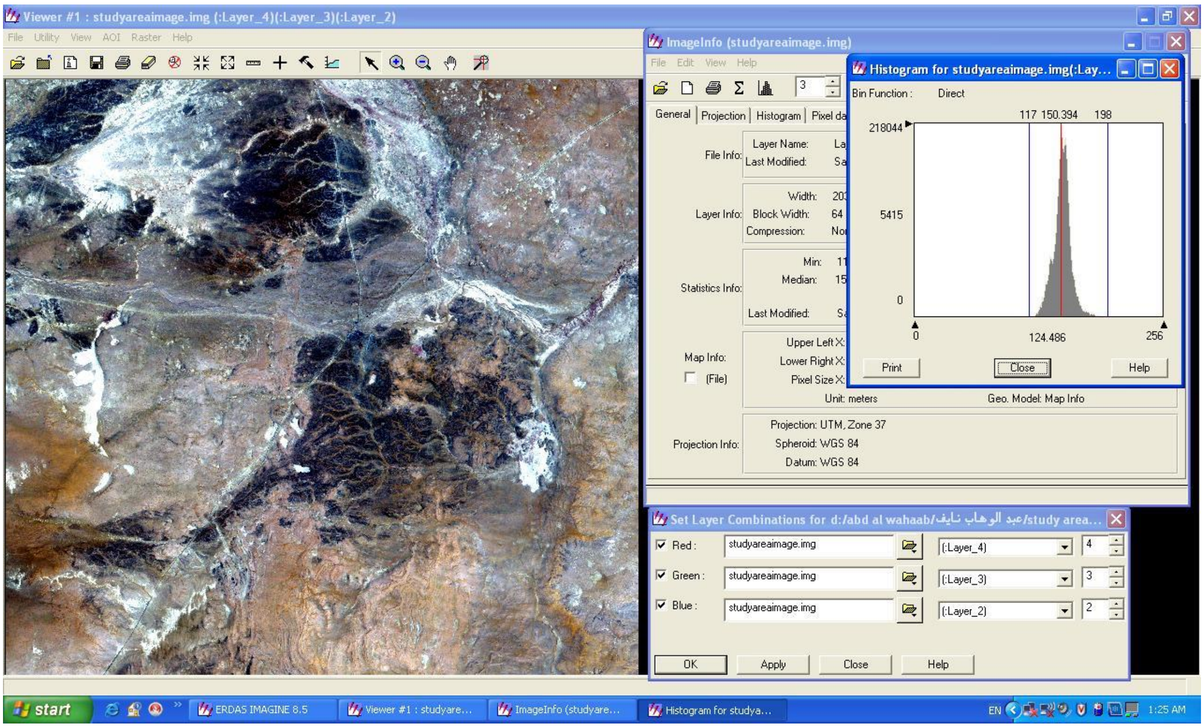


Image and histogram before stretching

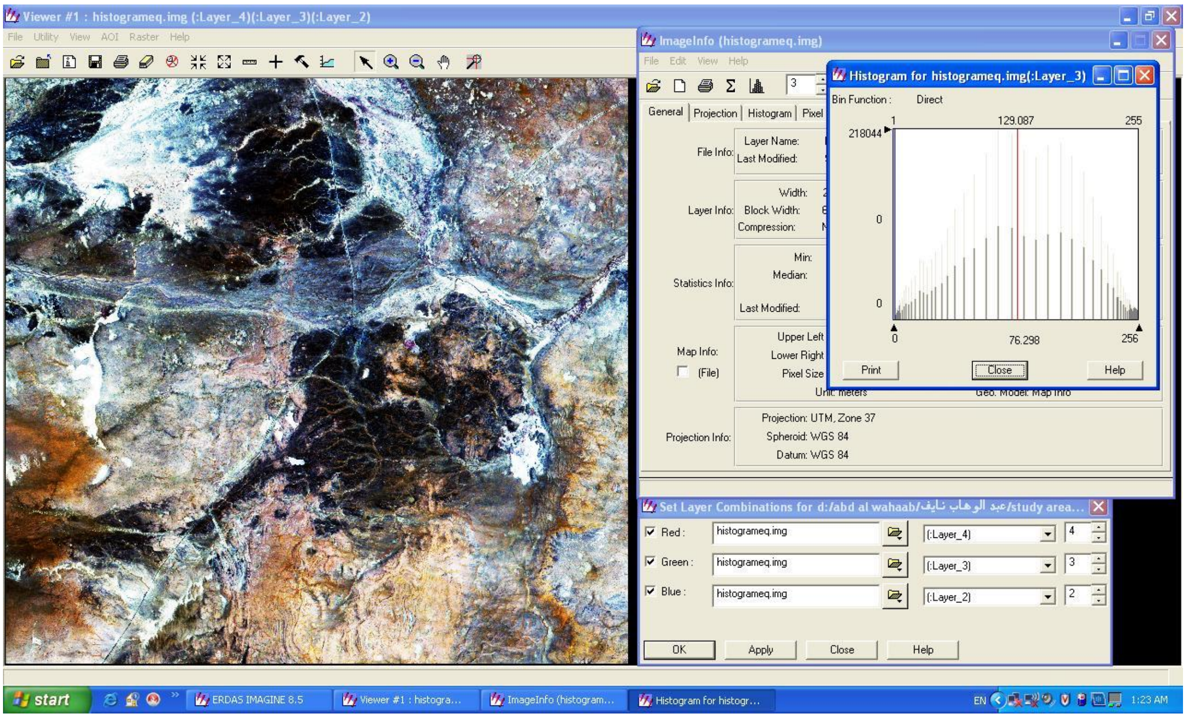


Image and histogram after stretching

Figure 8: The images and histograms of band 3 before and after stretching.

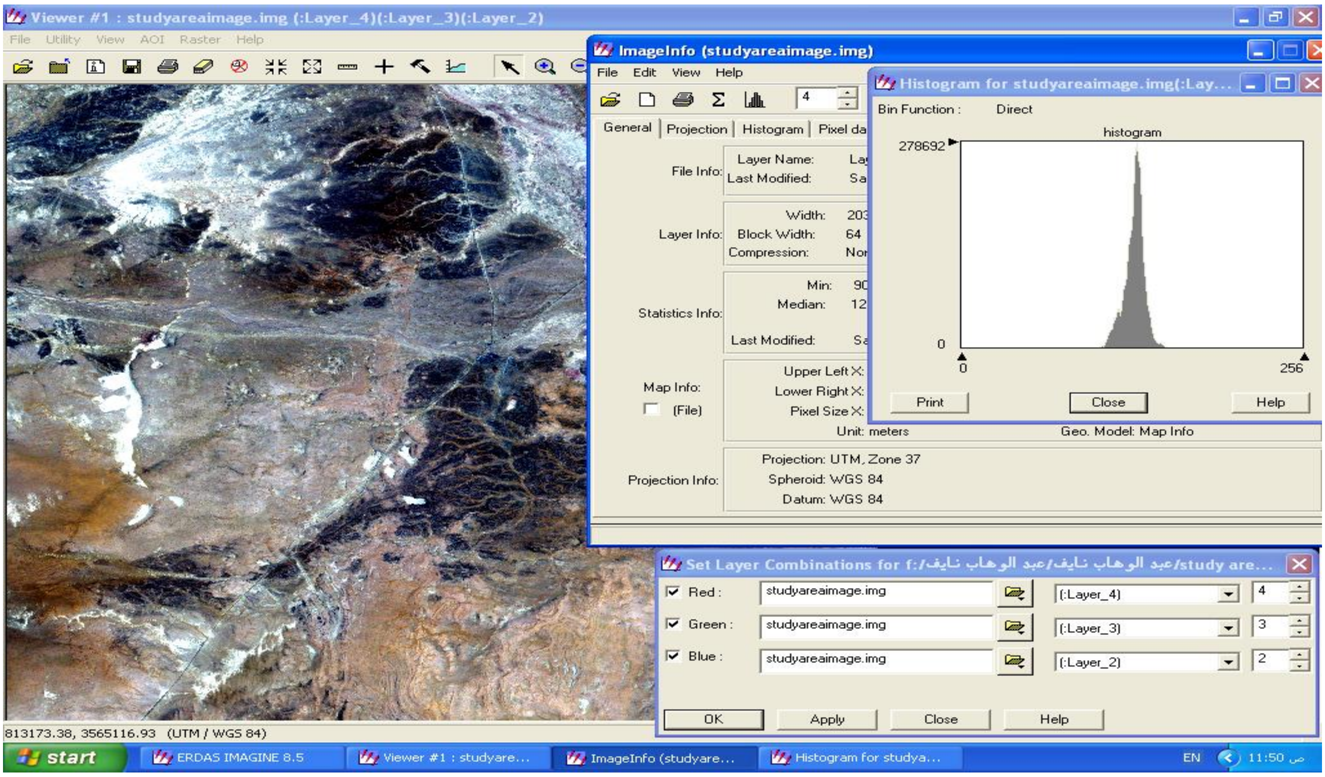


Image and histogram before stretching

Image and histogram after stretching

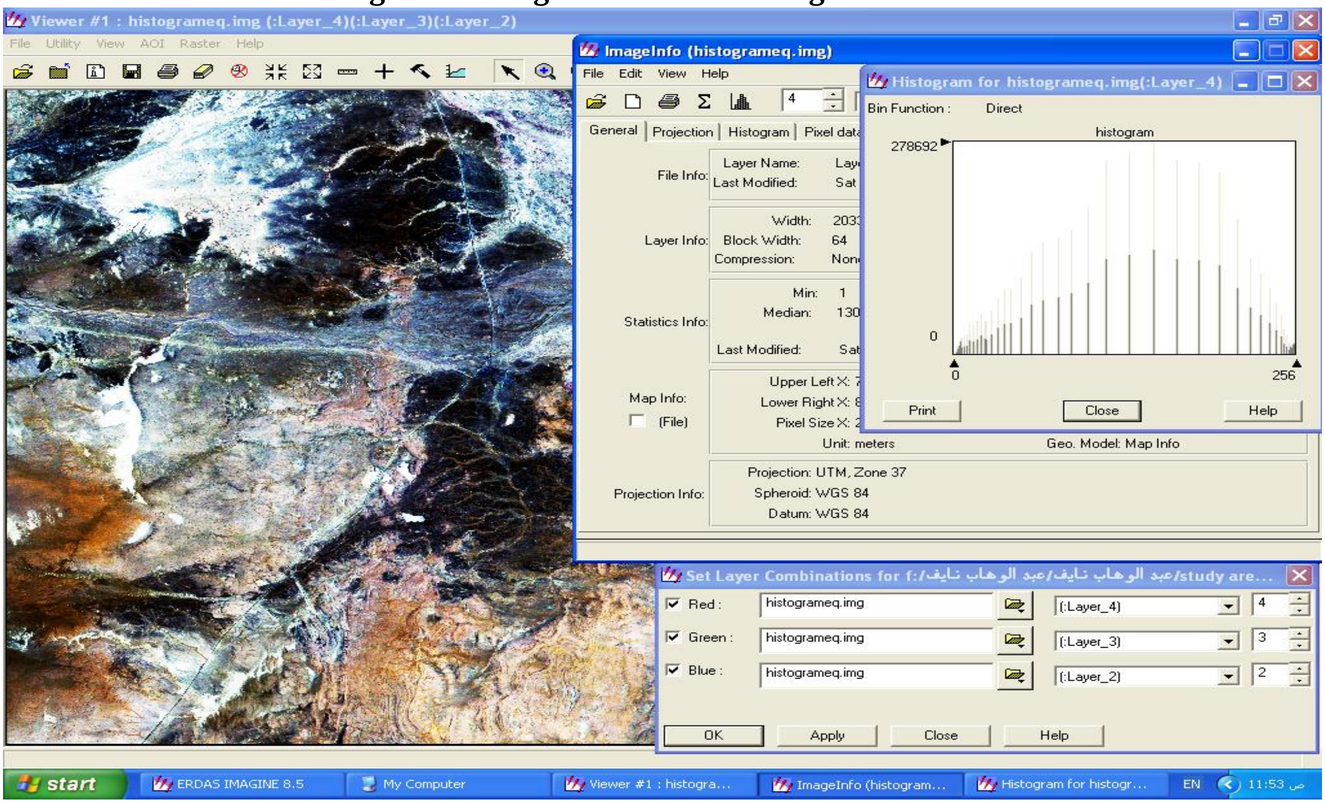


Figure 9: The images and histograms of band 4 before and after stretching.

Lineaments Detection:

Lineaments are tonal or topographic linear features which can be recognized on maps and images and represent areas of structural weakness. They are considered as the main key in mapping of regional structures and studying the regional tectonic analysis in order to use them in the mineral and petroleum explorations, and in the hydrological structural studies.

The lineaments are extracted from satellite image by using visual interpretation after digital image processing. The lineaments almost appear as straight lines or "edges" on the satellite images which in all cases contributed by the tonal differences within the surface material. The knowledge and the experience of the user is the key point in the identification of the lineaments particularly to connect broken segments into a longer lineament (Wang et al., 1990). Some general features, however, help to identify the lineaments can be listed as follows:

-Topographic features such as straight valleys and continuous scarps.

-Abrupt change in direction of drainage.

-Straight rock boundaries.

-Sudden tonal variations.

There are several image enhancement techniques that can contribute to manual lineament extraction. In this study two of commonly known techniques were used in the preparation of the final lineament map. These are filtering operations, and the color composites.

1- Filtering operations:

One of the characteristic features of the satellite images is a parameter called spatial frequency which is defined as the number of changes in brightness value per unit distance for any particular part of an image. If there are very few changes in brightness value over a given area in an image, this is referred to as a low-frequency area. Conversely, if the brightness values change dramatically over short distances, this is an area of high frequency detail (Jensen, 1996). Therefore, filtering operations are used to emphasize or deemphasize spatial frequency in the image. This frequency can be attributed to the presence of the lineaments in the area. In other words, the filtering operation will be sharpening the boundary that exists between adjacent units.

The high pass filter selectively enhances the small scale features of an image (high frequency spatial components); while maintaining the large-scale features (low-frequency components) that constitute most of the information in the image (Sarp 2005).

The results of the high pass filters kernel 3*3, 5*5, 7*7 are given in Figures 10, 11, and 12. One map is prepared from these images (Figure 13), which shows that thirteen lineaments are extracted. Figure 14 shows the frequency histogram resulted from high pass filtering and shows that there are 13 lineaments with minimum length of 2704.693 meter and maximum length of 19398.684 meter, which means that it only detects the lineaments with medium and long lengths.

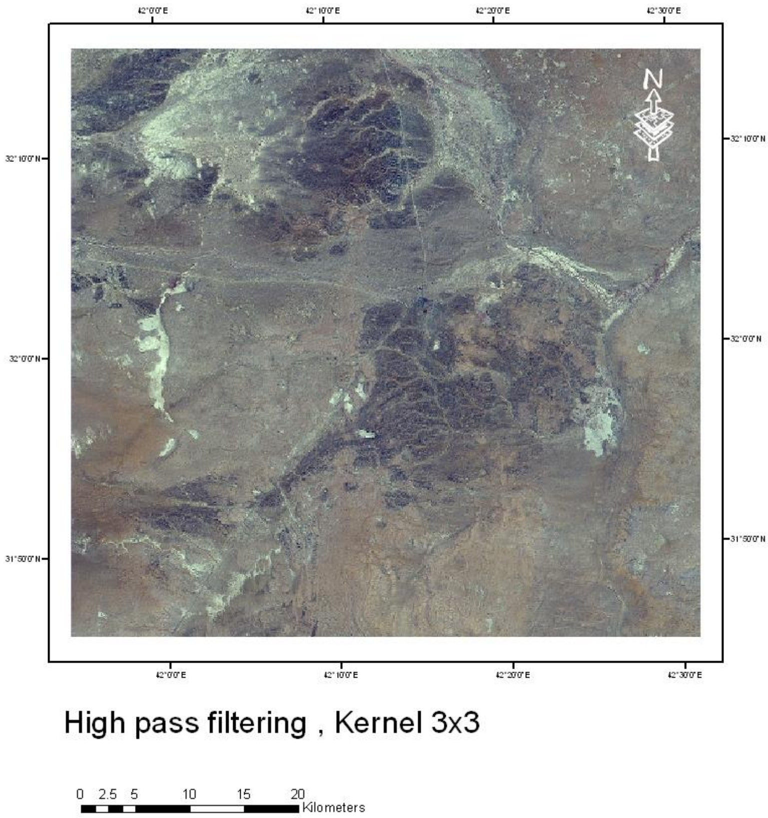


Figure 10: High pass filtering image, kernel 3*3.

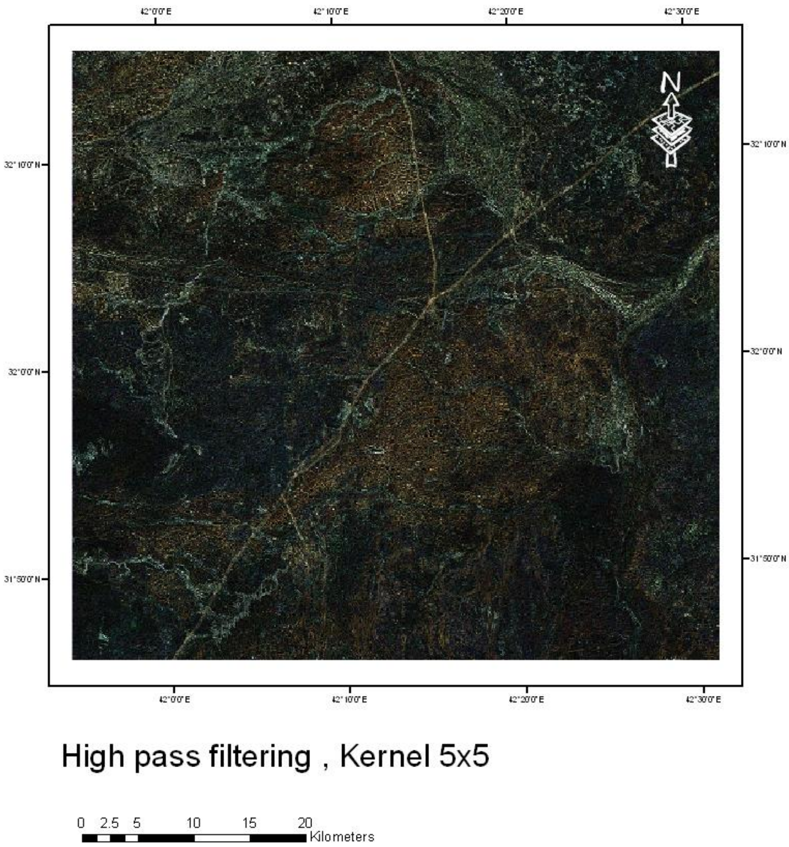


Figure 11: High pass filtering image, kernel 5*5.

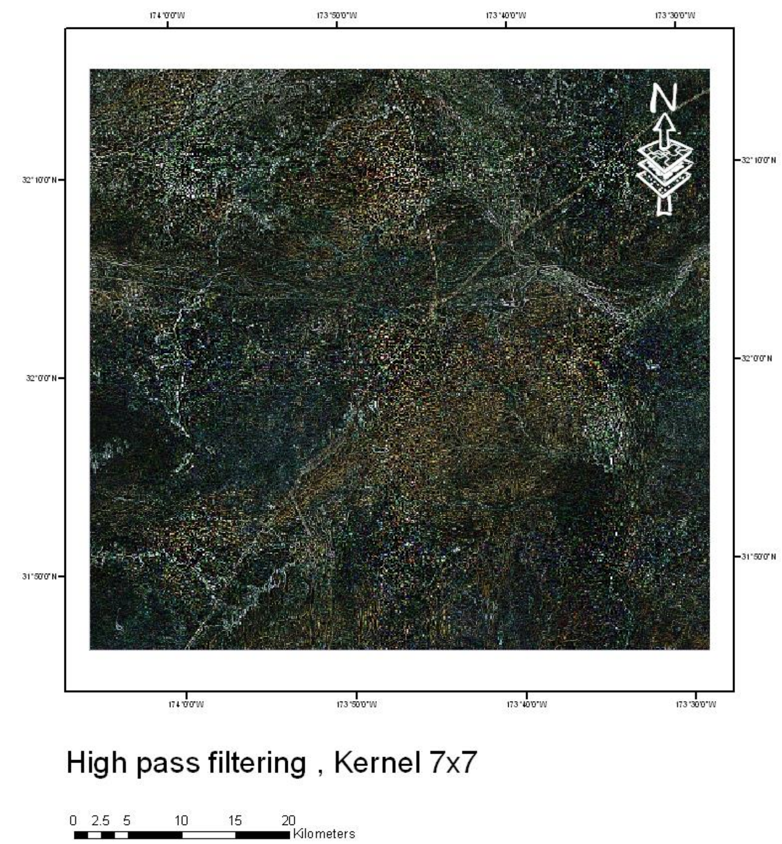


Figure 12: High pass filtering image, kernel 7*7.

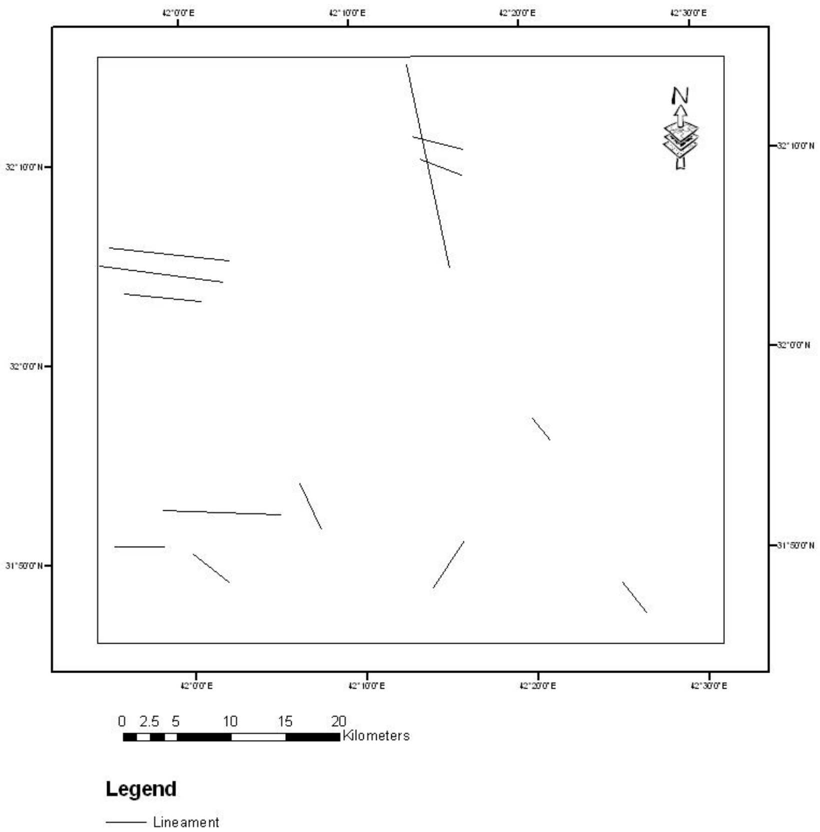
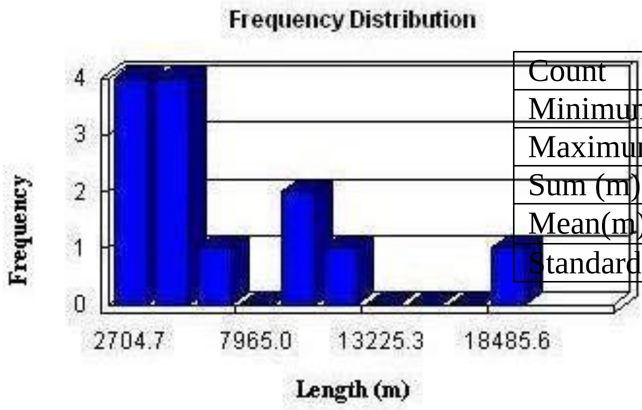


Figure 13: Lineament map of high pass filtering.



Count	13
Minimum Length (m)	2704.693
Maximum Length (m)	19398.684
Sum (m)	94604.527
Mean(m)	7277.27
Standard Deviation	4577.322

Figure 14: Length- frequency distribution of lineaments from high pass filtering.

2- Color composites (CC):

Color composite is another multi-band spectral technique which is applied in the study to enhance the images digitally and makes it easier to identify linear patterns of lineaments. Color composites are one of the most basic forms of images that are used for first-order analysis of remotely sensed data. Spectral data stored in separate bands are integrated by combining them into one band, so that strong spectral anomaly is displayed and the image becomes more interpretable (Zumsprekel and Prinz, 2000). Color composites are created by combining three raster images (bands). One band is displayed in shades of red and the other two are displayed in shades of green and blue.

False color images are produced for lineament interpretation 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 utilizing three bands 4, 3 and 2 (in red, green, and blue, respectively). This false color combination made it easier to identify linear patterns of vegetation, geologic formation boundaries, river channels, and geological weakness zones. The result of the process is shown in figure 15.

From the visual interpretation of the false color composite, 75 lineaments are extracted as shown in (Figure 16). The length and frequency distribution of manually extracted lineaments are illustrated in figure 13, which shows the minimum length of lineaments is 461.366 meter and the maximum length is 5086.669 meter. It shows that the color composites technique detects the short and medium length lineaments only.

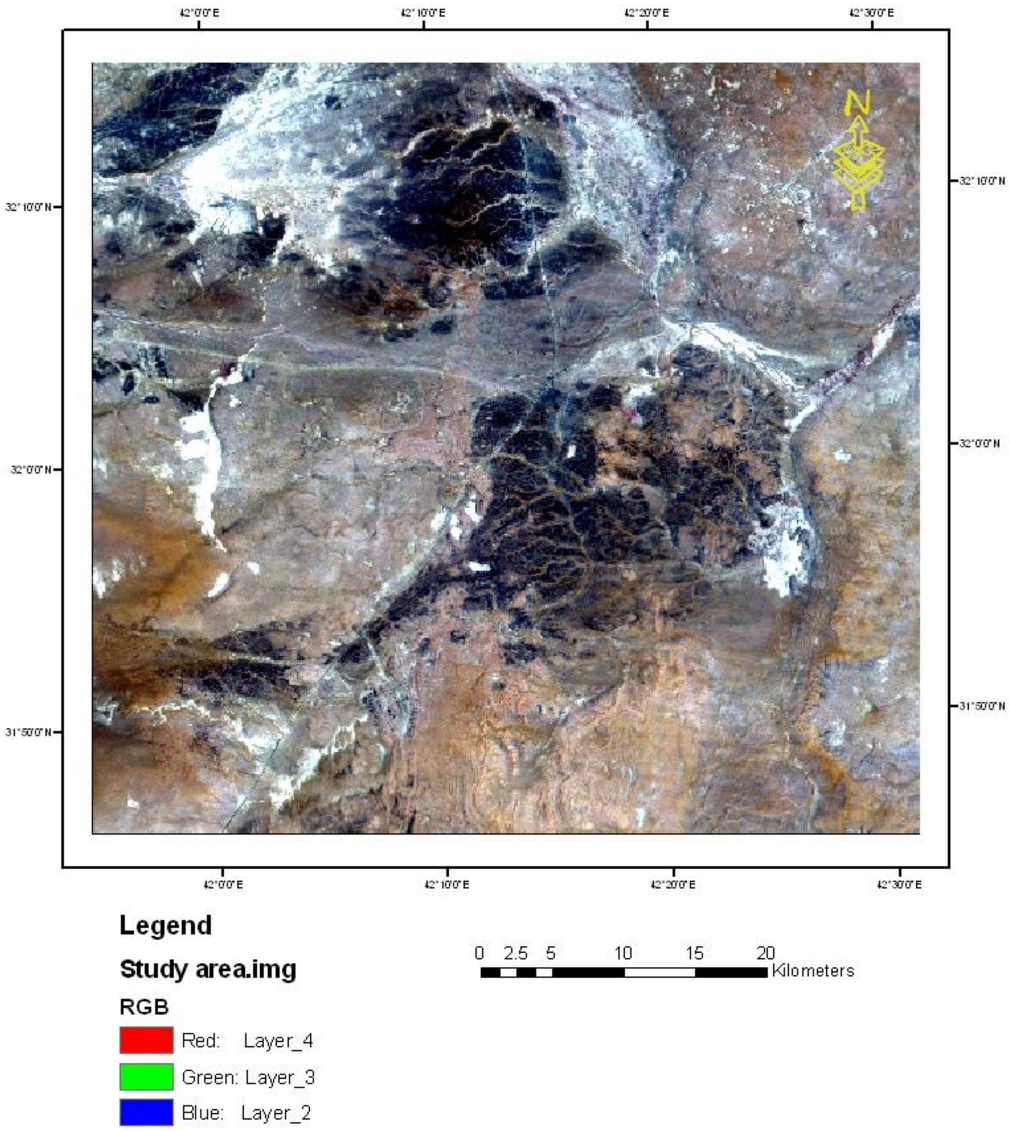


Figure 15: Color composite of the band 4 (Red), 3(Green), 2 (Blue).

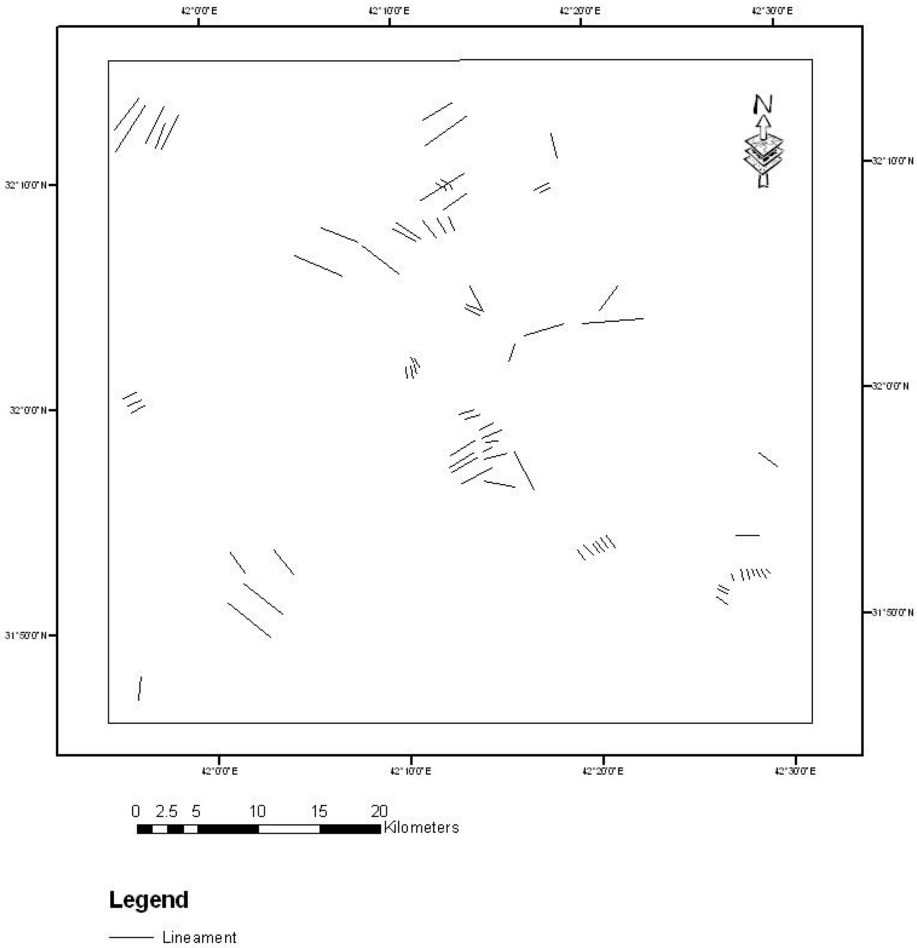
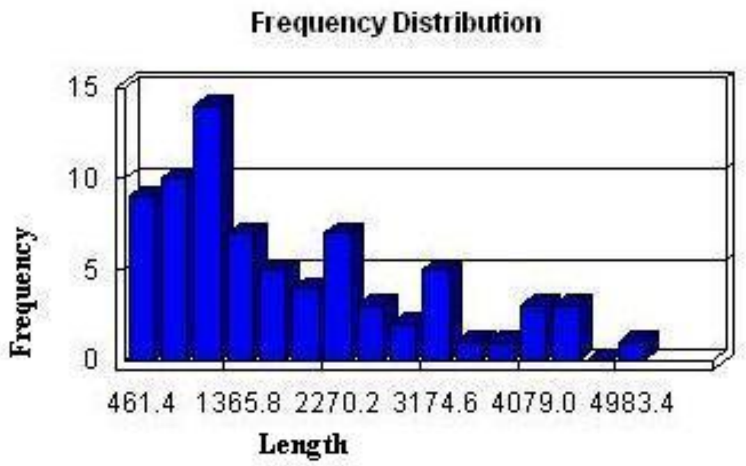


Figure 16: Lineament map interpretation from color composites.



Count	**75**
Minimum Length (m)	**366.461**
Maximum Length (m)	**5086.669**
Sum (m)	**146582.73**
Mean(m)	**1954.436**
Standard Deviation	**1168.005**

Figure 17: Length frequency distribution of lineaments from color composites.

The Final Map:

The final map is generated after adding all lineaments, which are obtained from the filtering operations and color composites techniques, and those that correspond to the roads are erased (Figure 18). The histogram and basic statistics of this map are illustrated in figure 19. The total number of lineaments generated by the different methods is 89 (Appendix No.1), which shows their lengths and directions. The resulted histogram shows that the minimum length of lineaments is 452.9407 meter and the maximum length is19193.391 meter.

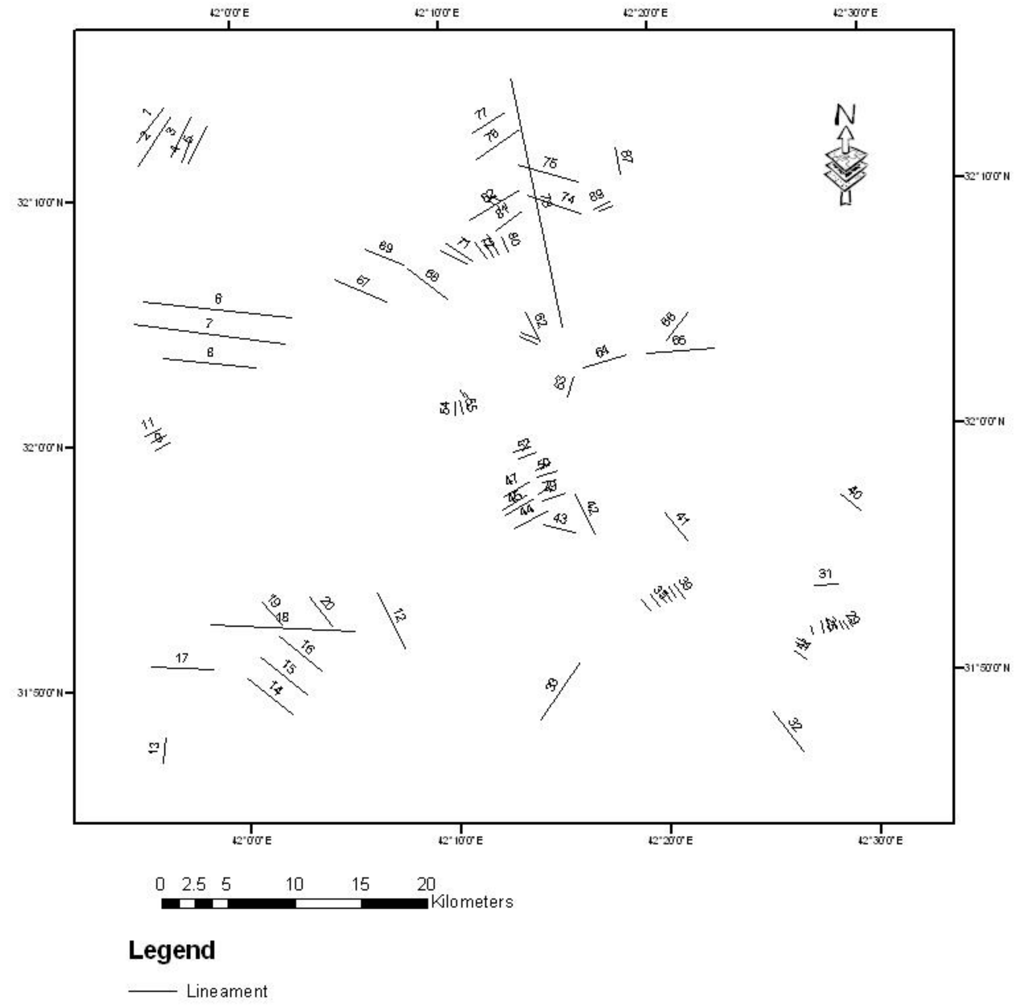
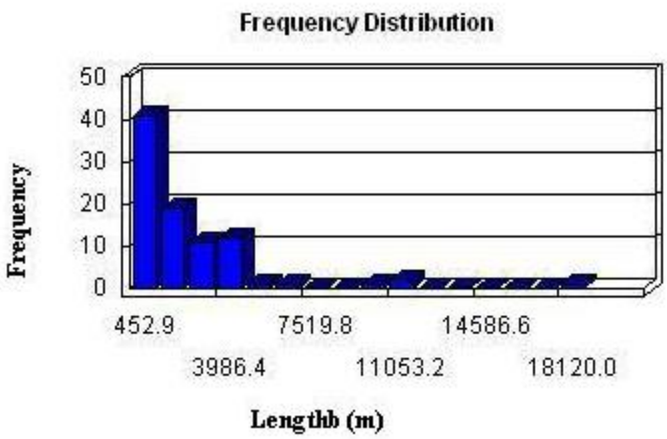


Figure 18: The final map of lineaments in the study area.



Count	**89**
Minimum Length (m)	**9407.452**
Maximum Length (m)	**19193.391**
Sum (m)	**243569.23**
Mean(m)	**2736.733**
Standard Deviation	**2764.316**

Figure 19: Length frequency distribution of lineaments from the final map.

Lineaments Classification:

Lineaments are classified according to the classification of El-Etr (1974), which is based on the lengths of the lineaments, into three types. The lineaments with length less than 2 km are represented by blue color, and those with length from 2-10 km are represented by red color, while the lineaments with length more than 10 km are represented by black color (Figure 20).In the study area there are 46 lineaments with lengths less than 2 km, 39 with lengths 2-10 km, and 4 with lengths more than 10 km (Appendix 1).

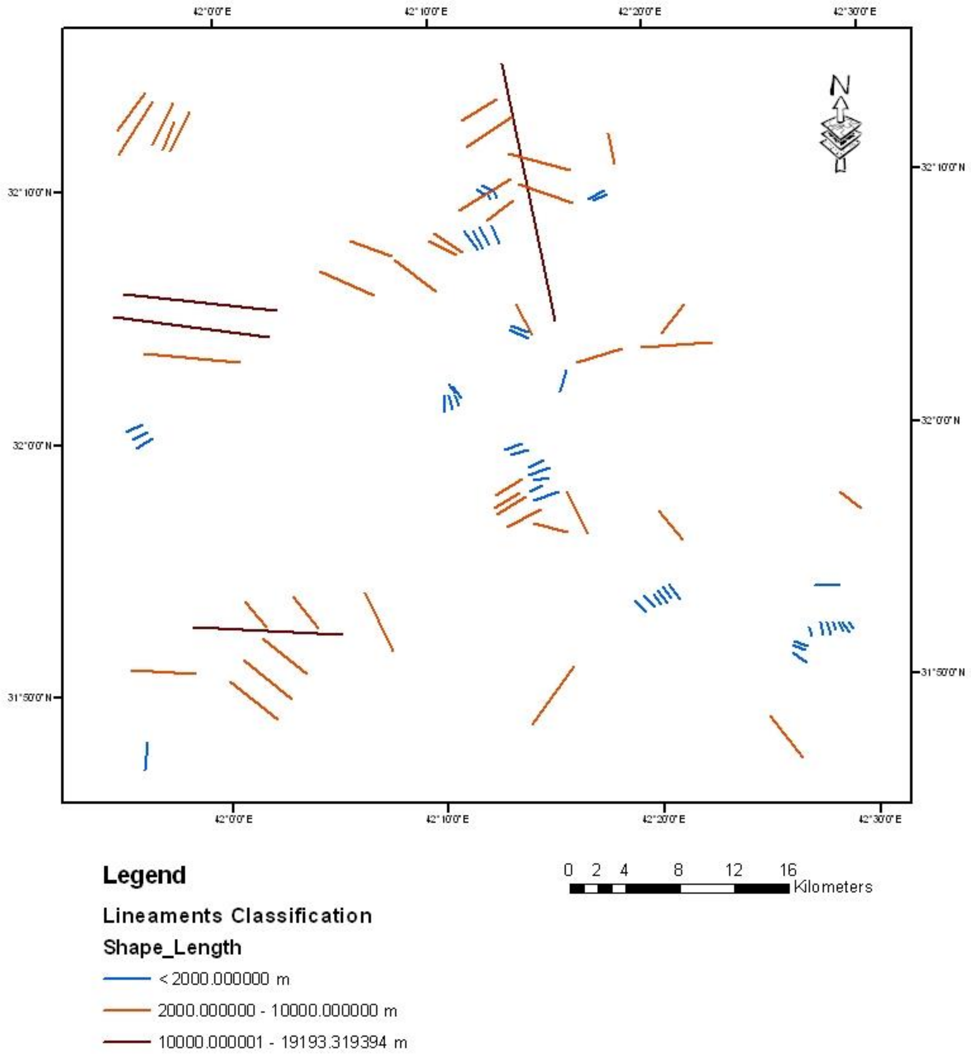


Figure 20: Classification of Lineaments in the study area

Frequency Rose Diagram:

The frequency rose diagram, which represents the statistical directional distribution of lineaments, is extracted from the final map using the ROCK WARE 2006. This diagram shows that the primary direction is N40W. The secondary directions are (N15W, N55E, and N55W) as shown in figure 21; the lineaments sets are almost perpendicular to each other, which is a phenomenon that occurs in nearly flat lying sedimentary rocks such as in Nukhaib area. Altogether 89 lineaments are detected and digitized in the whole study area.

This rose diagram shows that the maximum frequency of lineaments lies in the N40W direction, so the primary direction of lineaments in the Nukhaib area is northwest, which is the same direction of the dominant force in the western Iraqi desert according to Al-Amiri (1978), Al-Jaf (2008) and Al-Muthen (2009).

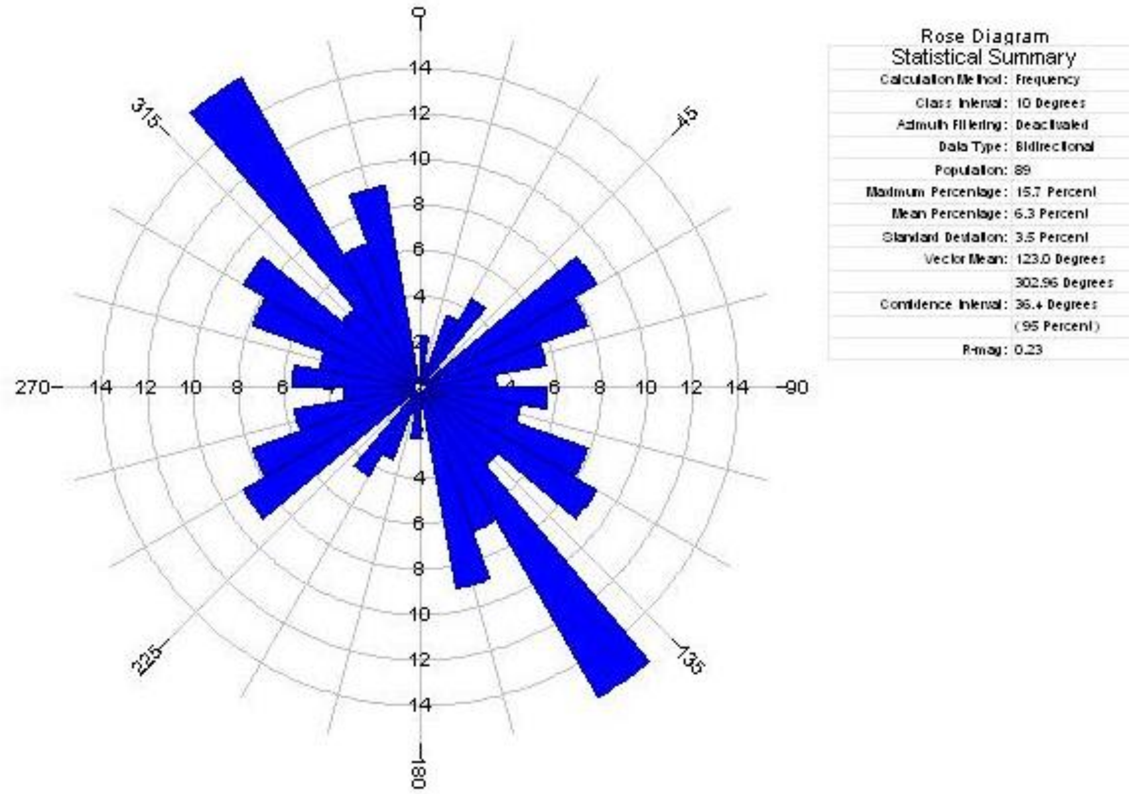


Figure 21: Frequency rose diagram for the study area.

Conclusions

1- Remote Sensing is a powerful tool for geological and tectonic study in desert areas like Nukhaib area where the rocks are well exposed and field visit is difficult. Digitally enhanced Landsat ETM+ bands with spatial resolution of 30 m, 15 m in panchromatic, data and digital elevation models (DEM) with spatial resolution of 30 m are used in the interpretation of lineaments.
2- The highest and lowest elevations in the study area, which are derived from the digital elevation model (DEM) data, are 383 m, and 227 m, respectively.
3- Combination of different image enhancement techniques such as, filtering, and color composites (CC) are proved to be effective and suitable for lineament identification.
4- The frequency rose diagram of the total lineaments in the study area showed two major orthogonal systems of fractures, the first system consists of two sets occur in N40W direction and N55E direction. The second system consists of two sets of fractures in N15W and N55W directions, the lineaments interpreted on satellite images assumingly represent surface traces of deep fractures probable on the basement rocks. The analysis of the frequency rose diagram of the lineaments showed that the northwest direction is the primary direction in the study area which is the same direction of the dominant force in the western Iraqi desert.

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Appendix

Appendix No. 1: Nos. , lengths, and directions of lineaments in the study area.

No.	Length (m)	Direction	No.	Length (m)	Direction
1	3423.95435390000	53	21	1234.61358984000	145
2	4563.20381135000	57	22	1012.41438531000	157
3	3458.97368966000	64	23	1066.04296699000	155
4	2191.88611455000	68	24	722.50293280500	104
5	3206.16168318000	65	25	1000.05538476000	101
6	11293.40399990000	174	26	965.21250301200	106
7	11544.59971040000	173	27	664.96139932500	108
8	7104.69848701000	175	28	778.35680132000	121

9	1357.45908817000	30	29	851.63811102200	127
10	1304.86268578000	27	30	596.82104704600	130
11	1342.12300628000	25	31	1928.83367956000	2
12	4697.24488688000	115	32	3879.56167498000	127
13	1996.08724205000	84	33	5259.52222437000	55
14	4431.29019348000	141	34	1155.50264493000	132
15	4546.99787003000	141	35	1205.37266178000	132
16	4263.07103651000	141	36	955.21509771800	128
17	4785.29494339000	177	37	1172.71783369000	130
18	10953.93095510000	177	38	1089.21400317000	126
19	2435.06274695000	131	39	1411.74003102000	128
20	2943.71427357000	129	40	2027.85409910000	141

41	2790.14355357000	129	66	2735.62461037000	52
42	3408.51962503000	118	67	4398.20184971000	157
43	2553.41807513000	167	68	3814.28503330000	143
44	2903.74200130000	28	69	3271.66868490000	159
45	2492.80176942000	31	70	2262.77880875000	153
46	2202.34611631000	31	71	2478.19152400000	147
47	2265.28558067000	31	72	1726.11386930000	128
48	1002.23628476000	32	73	19193.31939450000	102
49	1901.06506022000	18	74	4218.87988870000	161
50	1615.66319519000	19	75	4694.69989746000	165
51	1262.19830838000	27	76	4017.47474887000	35

52	1419.34176805000	17	77	2985.15167754000	32
53	1338.76353530000	18	78	1483.16486554000	122
54	1157.51226838000	89	79	1508.06772121000	121
55	1068.40447746000	102	80	1364.09219288000	112
56	767.76536206300	107	81	2429.61980932000	36
57	1044.65494374000	128	82	4416.44080194000	32
58	745.12484431400	127	83	452.94070819600	113
59	1137.73020795000	7	84	505.25988477800	113
60	1499.81973514000	155	85	778.41514382300	156
61	1367.70439228000	160	86	652.16699742000	147
62	2487.99999442000	117	87	2231.92801848000	103
63	1659.33851572000	72	88	1101.97824382000	23
64	3434.45767074000	17	89	1360.24348279000	26
65	5140.31971386000	4			