Lineament Extraction Using Remote Sensing Data mid Iraq

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Abstract

Lineaments are considered evidence for the existence of subsurface structures, so it was in this research work on the geological interpretation of the study area during the extraction of these lineaments. Mosaic have been work of three satellite of the panchromatic band (8) for Landsat-8 for the region confined between longitudes 44° 35' 22.27" East to 44° 59' 3.97" East and latitudes 32° 48' 57.49" North to 34° 6' 27.27" North and area estimated at (18659.45 km^2). The lineament considered very important indicator to determine the general and local tectonic trends and areas of fractures in rocks. Four programs have been used in the work are (ENVI5.1, PCI-Geomatica 2014, ArcGIS10.2.2 and Rockwork16).

It has also been three geospatial applications which analyzes (height, density and direction) in order to estimate lineaments. Used manual and automatic methods to extract lineaments. When using the manual method found that the lineaments be greatest, this difference between two methods is due to use of Sobel operator to enhance the digital image in the manual way .Extracted lineaments of both methods was more density when the folds and local fractures areas and concentrated towards the NW-SE.

Keywords: Lineament extraction, mid Iraq, Landsat-8, lineament density.

الخلاصة

تعتبر الملامح الجيولوجية الخطية هي دليلا لوجود تراكيب تحت سطحية، لذلك تم في هذا البحث العمل على تفسير جيولوجية منطقة الدراسة من خلال استخراج هذه الملامح. تم عمل فسيفساء لثلاثة مشاهد فضائية للفرقة البانكروماتية (8) للتابع الصنعي (Landsat-8) للمنطقة المحصورة بين خطي طول "44° 35' 22.27 شرقاً الى "44° 59' 3.97 شرقاً ودائرتي عرض "32° 48' 57.49 شمالاً الى "34° 6' 27.27 شمالاً و بمساحة تقدر بـ (18659,45 كم^2). حيث تعتبر الملامح الجيولوجية الخطية مؤشرا مهما جدا لتحديد الاتجاهات التكتونية العامة والمحلية ومناطق الكسور في الصخور. تم استخدام اربع برامج في العمل وهي كلا من (ENVI5.1, PCI-Geomatica 2014, ArcGIS10.2.2 and Rockwork16).

تم تطبيق ثلاثة تحليلات جغرافية مكانية وهي (الطول، الكثافة والاتجاه) وذلك من اجل تخمين الملامح الجيولوجية الخطية. استخدمت الطريقتين اليدوية والآلية لاستخراج الملامح الجيولوجية الخطية، وعند استخدام الطريقة اليدوية وجد ان الملامح الجيولوجية الخطية تكون اكثر كثافة يعزى هذا الاختلاف بين الطريقتين بسبب استخدام مؤثر سوبل في تحسين الصورة الرقمية في الطريقة اليدوية. وقد كانت الملامح الجيولوجية الخطية المستخرجة في كلا الطريقتين اكثر كثافةً عند مناطق الطيات والكسور الموضعية وتتركز باتجاه شمال غرب – جنوب شرق.

الكلمات المفتاحية: الملامح الجيولوجية الخطية، وسط العراق، التابع الصنعي (8)، كثافة الملامح الجيولوجية الخطية

Introduction

Lineaments are defined as mapable linear surface features, which differ distinctly from the patterns of adjacent features and presumably reflect subsurface phenomena [O’Leary, 1976]. Earth surface linear features have been studied theme for geologists through many years [Lattman and Nickelsen, 1958]. The importance of geologic structures especially lineaments such as joints, fractures and faults cannot be underestimated. This is because they act as reservoir both for oil, water and gas and also for the deposition of important ores. One of the main features of geological interpretation of satellite imagery has been the recognition of lineaments varying in length from a few kilometers to hundreds of kilometers [Onyedim and Ocan, 2001]. Remote sensing techniques are usually adopted in studying lineaments because they give an opportunity of synoptically studying the feature without actually coming into contact with them, especially at the regional level. Satellite remotely sensed data has been widely used as source of information for geologists to map lineaments at district and regional scales. The lineament is a mappable linear or curvilinear feature of a surface whose parts align in a straight or slightly curving relationship [Hung, 2005]. They may be an expression of faults, joints or other line weakness. The lineament may be has a geomorphological implication, i.e. major structural ridges, cliffs, terraces and aligned segments of a valley are typical geomorphological expressions of lineaments. Differences in vegetation, moisture content, and soil or rock composition account for most tonal contrast which are used to extract the linear feature [O'Leary ,1976]. Satellite images and aerial photographs are extensively used to delineate lineaments for different purposes, such as defining geological structures and tectonic fabrics [Neawsuparp and Charusiri, 2004]. Since satellite images are obtained from varying wavelength intervals of the electromagnetic spectrum, they are considered to be a better tool to discriminate the lineaments and to produce better information than conventional aerial photographs [Casas et al, 2000].the aim of this study is comparing between the automatically and manually (visual interpretation to estimate the lineaments) lineaments extraction

Study Area

The study area is located in Mesopotamian Fore deep Basin, Middle Iraq between Longitudes 43°35' 22.70" E to 44° 59' 3.97" E and Latitudes 32° 48' 57.49" N to 34° 6' 27.27" N, within area approximately equal 18659.45 km2 as shown in (Figure 1) and (Figure 2).The study area is located in the region east of the Euphrates River.

Geology of the study area

The study area is part of the Arabian Basin in a regional extent and specifically within Mesopotamian Fore deep Basin. Locating this studied area in the Arabian Peninsula Basins map prepared by the U.S.Geological Survey [Pollastro, 1999] with special emphasis on Iraqi region of northeastern Arabian Peninsula figure (1), The study area could be graded tectonically northeastward toward the Zagross Fold Belt and westward toward the boundary with the Widian Basin of Interior Platform while its southward extensions are the Mesopotamian Fore deep Basin that contain deposits of the Tethys ocean during the Jurassic and Cretaceous Periods. Tethys Ocean was of mainly dysoxic– anoxic palaeo environments along the equator and of tectonically unrest [Sharland, 2001] that permitted preservation of high organic matters and development of highest world oil and gas reserve in the Arabian Region. See (Figure 1).

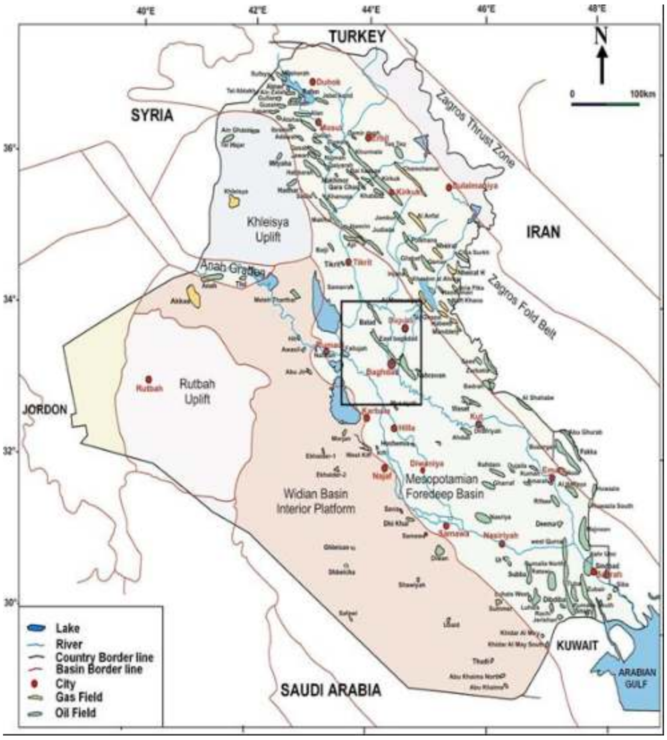


Figure (1-1a) Location map of Iraq showing basins and oil fields with study area in the middle of Iraq [Iraqi Geological Survey and Mining, 2010]

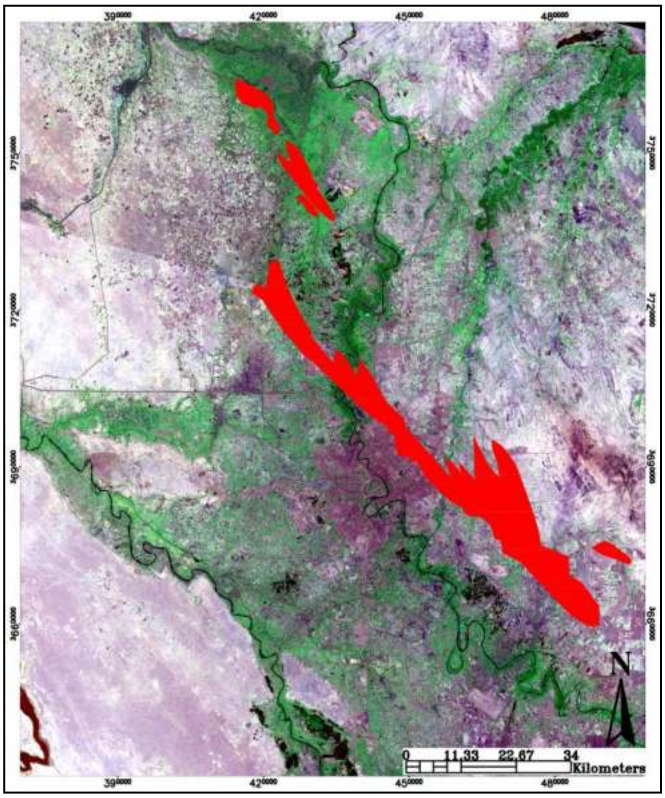


Figure (1-1b) Landsat 8 false color composite image showing study area with oil fields located within the region

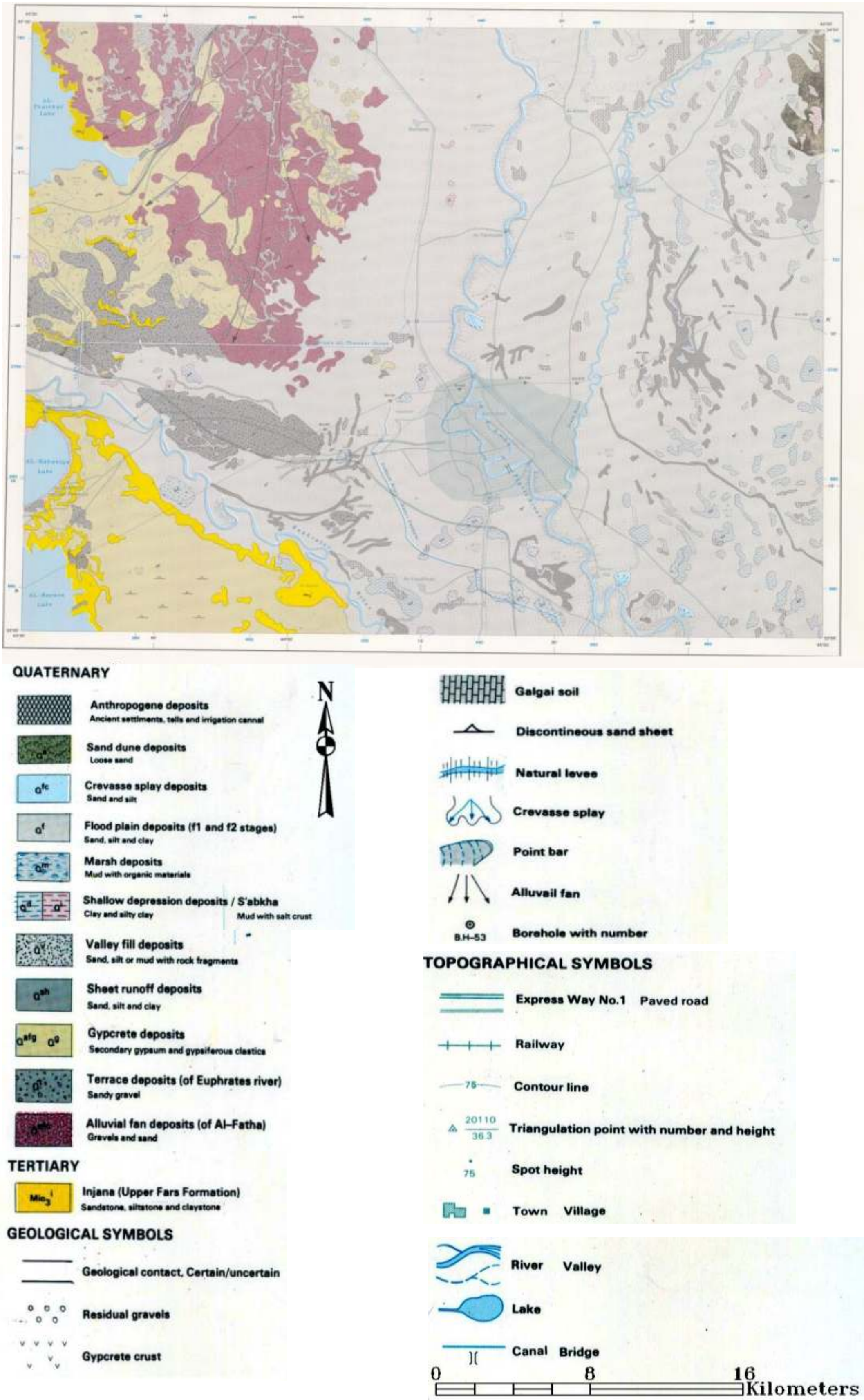


Figure (1-1c) Geological map of studied area [Iraqi Geological Survey and Mining, 1994].

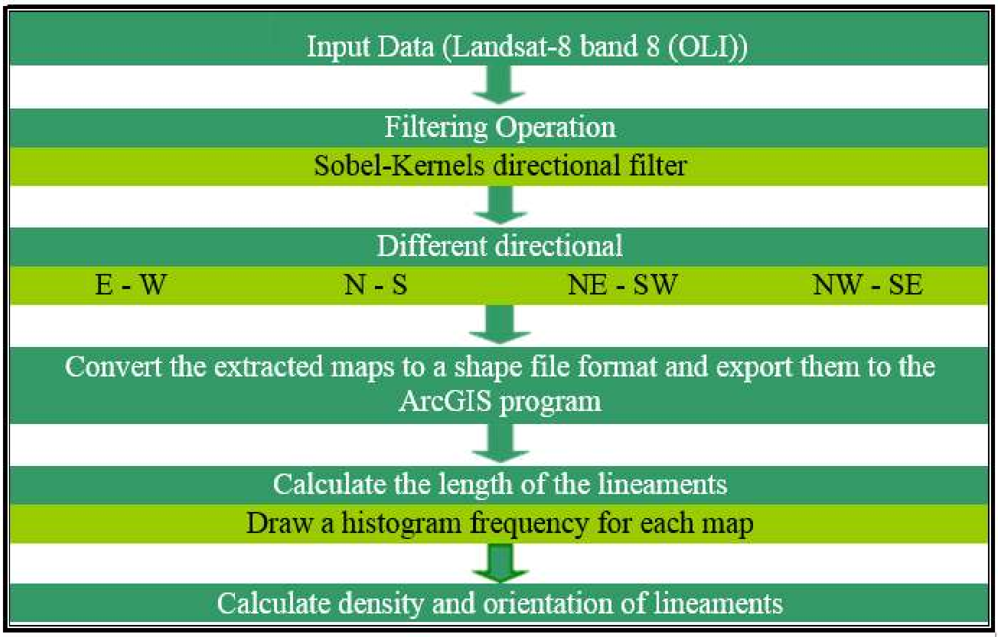
Materials and Methodologies

Landsat-8 Operational Land Imager (OLI) images consist of nine spectral bands with a spatial resolution of 30 meters for bands 1 to 7 and 9. The resolution for band 8 (panchromatic) is 15 meters [Landsat-8 metadata file]. Landsat-8 (OLI) was chosen because of its spectral discrimination of a variety of characteristics that are required for the study. A total of three Landsat scenes wholly cover the study area. Band 8 (0.50 - 0.68 micrometers); panchromatic, is useful in the extraction of geological formations and rock features. Previous lineament extraction studies using Landsat had made use of TM, ETM and ETM+ sensors; the corresponding panchromatic band in OLI was used in this research. Three Landsat scenes, band 8, fully covered the study area acquired in different months and/or years. The Landsat -8 data used in the study are listed in (Table 1). It is geo-referenced to the UTM coordinate system; Zone 38 North and resampled using nearest neighbor resample technique.

Table (1) Landsat 8 data acquisition

Raw	Path	Date of acquisition
36	169	22 / 9/ 2014
37	169	22 / 9/ 2014
37	168	15/ 9/ 2014

The main flow diagram which is applied for the lineament extraction and analysis is given in (Figure 2).



(Figure 2) Flow diagram explain the stages lineaments extraction and analysis.

Input Data

The first stage of the methodology is selection of initial input data for lineament extraction. Although the lineaments can be extracted from several data such as aerial photographs, geophysical data etc., in this study the satellite image is preferred for the application.

Lineament Extraction

The second stage of the methodology is extraction of lineaments from satellite images and final map generation. This is the main stage in the application. Lineament extraction in this study is performed in two ways:

- Manual lineament extraction.
- Automated lineament extraction.

Manual lineament extraction

In manual extraction method, the lineaments are extracted from satellite image by using visual interpretation. The lineaments usually 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, 1990]. Some general features, however, help to identify the lineaments that can be listed as follows as already described in the literature:

- Topographic features such as straight valleys, continuous scarps.
- Straight rock boundaries.
- Systematic offset of rivers.
- Sudden tonal variations.
- Alignment of vegetation.

According to [Koike, 1995] a continuous straight valley is the most helpful feature as a primary identification criterion in image processing for lineaments because a satellite image has no direct information on the topography of the area.

There are several image enhancement techniques that can contribute to manual lineament extraction. This study will use the filtering operation in the preparation of the final lineament map.

Filtering operation

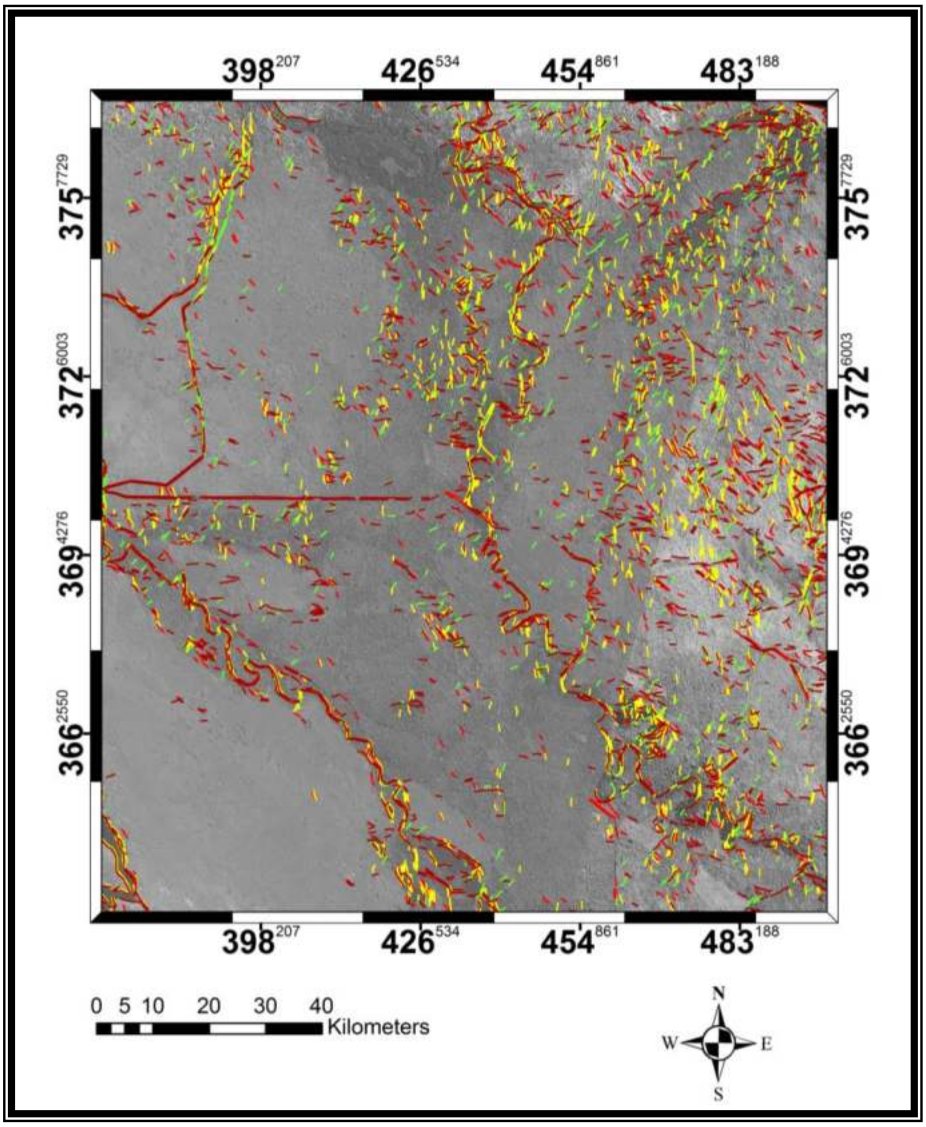
One of the characteristic features of the satellite images is a parameter called spatial frequency which is defined as the number of changes in brightness value per unit distance for any particular part of an image [Sarp, 2005]. If there are very few changes in brightness value over a given area in an 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, 2005]. 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 sharpen the boundary that exists between adjacent units.

The main disadvantage of the filtering method is that it cannot effectively extract lineaments in low-contrast areas where features extended parallel to the sun directions and in mountain shadows [Koike, 1995].In this study, Directional Gradient-Sobel filter is applied to the Landsat-8 (OLI) band 8 in N-S, E-W, NE-SW and NW-SE directions to increase frequency and contrast in the image. Directional filtering has been used to enhance, extract and classified the oriented lineaments of the study area. Directional filters are applied to image using a convolution process by mean of constructing a window normally with a (3×3) pixel box of Sobel- kernels filters (Table 2). This type of filter was used in order to get a high accuracy in extraction of oriented lineaments because the directional nature of Sobel-kernels generate an effective and faster way to evaluate lineaments in four principal directions [suzen, 1998]. Four filtered images have been produced by ENVI5.1 Imagine software related to the directions N-S, E-W, NE-SW and NW-SE.

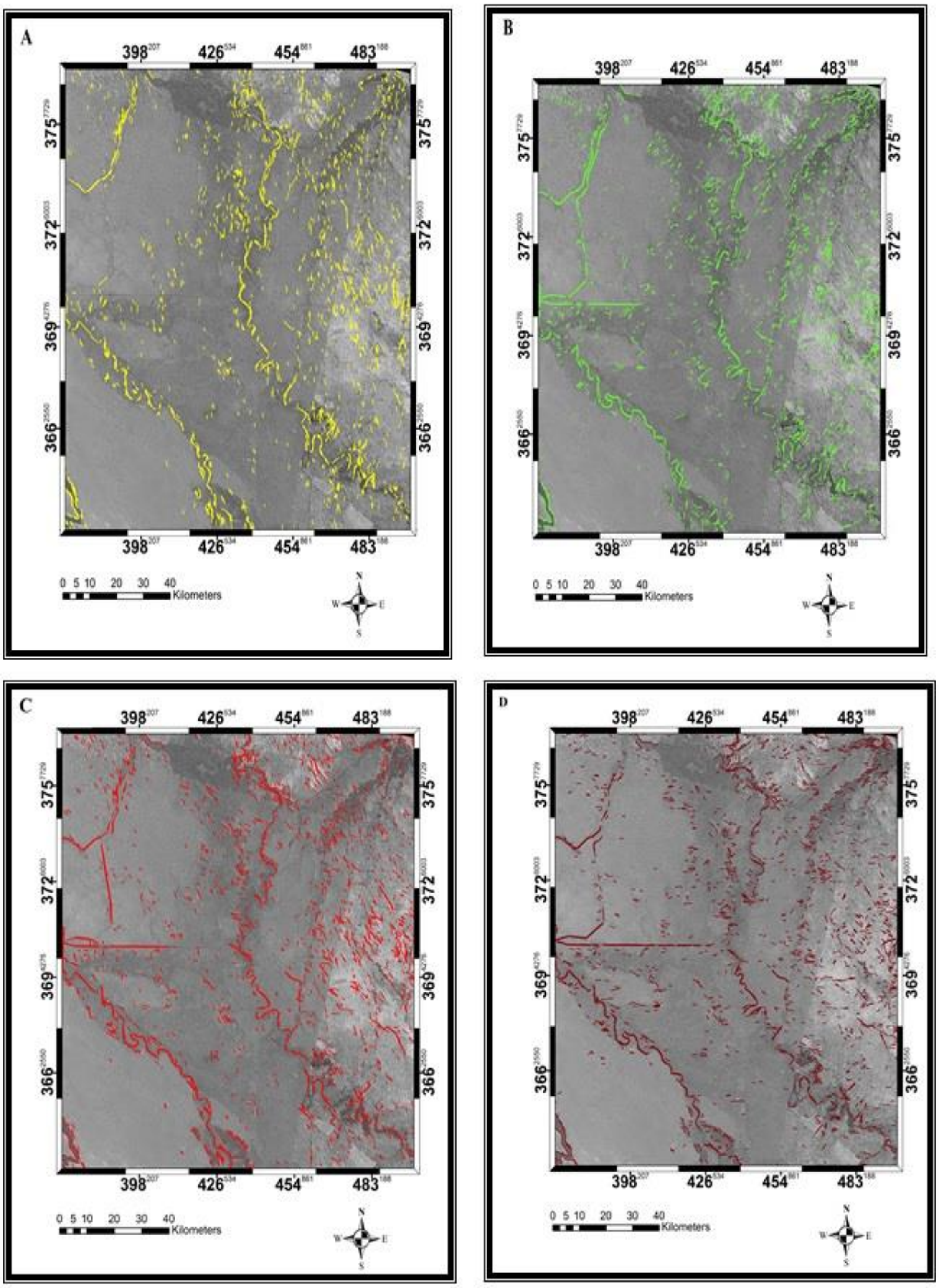
Table (2) Sobel - kernels in four principle trends

N - S			NE - SW			E - W			NW - SE		
-1	0	1	-2	-1	0	-1	-2	-1	0	1	2
-2	0	2	-1	0	1	0	0	0	-1	0	1
-1	0	1	0	1	2	1	2	1	-2	-1	0

The results of manual extracted lineament map are shown in Figure (3) and (4) Lineaments are extracted from satellite images using automated extraction techniques in order to compare with the manually extracted lineaments. The main advantages of automated lineament extraction over the manual lineament extraction are its ability to uniform approach to different images; processing operations are performed in a short time and its ability to extract lineaments which are not recognized by the human eyes.

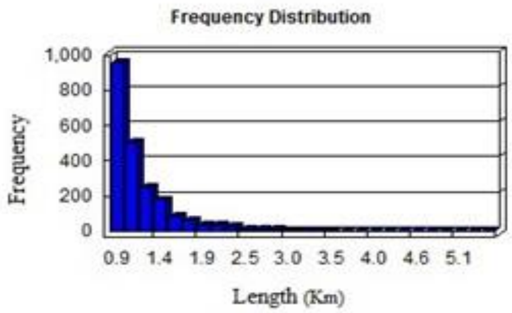


(Figure 3) Total number of the manually extracted Lineament.



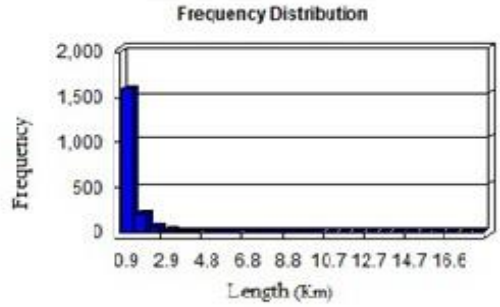
(Figure 4) Manually extracted Lineament overlapped over the filtered images of the study area at four directions (A) N-S, (B) NE-SW, (C) NW-SE, (D) E-W. The number of the lineaments identified in these four maps is considerably different.

The result lineament map for Sobel filters and its frequency histogram is shown in Figure (5). It has been noticed that the (N-S) lineament map has higher number and (E-W) has higher length compared with the other. According to the parameters values which are used in this study, the maximum length of the lineaments is (20 Km) recorded in the (E-W) direction. In addition, the maximum frequency of lineaments is (2143) recorded in the (N-S) direction which is about (26 %) of the final map.



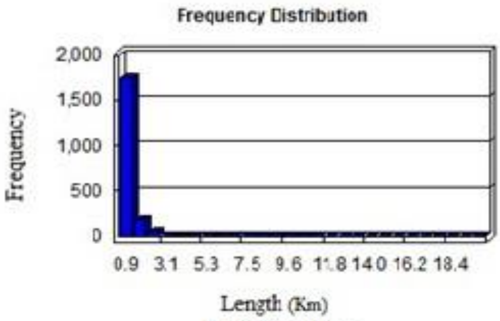
Count	2143
Minimum Length (km)	0.9
Maximum Length (km)	2.52
Sum (km)	2665.48
Mean (km)	1.24
Standard Deviation	0.42

N-S Direction



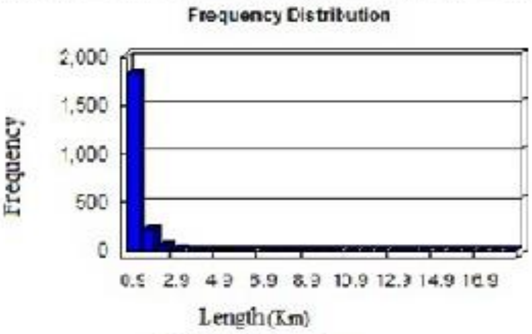
Count	1874
Minimum Length (km)	0.9
Maximum Length (km)	17.97
Sum (km)	2413.21
Mean (km)	1.29
Standard Deviation	0.73

NE-SW Direction



Count	1996
Minimum Length (km)	0.9
Maximum Length (km)	20.01
Sum (km)	2542.14
Mean (km)	1.27
Standard Deviation	0.71

E-W Direction



Count	2122
Minimum Length (km)	0.9
Maximum Length (km)	18.48
Sum (km)	2712
Mean (km)	1.28
Standard Deviation	0.74

NW-SE Direction

(Figure 5) Frequency distribution and basic statics at four principle directions of Sobel-kernel filter

Automated Lineament Extraction

The main advantages of automated lineament extraction over the manual lineament extraction are its ability to uniform approach to different images; processing operations are performed in a short time and its ability to extract lineaments which are not recognized by the human eyes.

Available softwares provide different algorithms for automated extraction. Three common algorithms are Hough transform, Haar transform and Segment Tracing Algorithm (STA) [Koçal, 2004]. The Hough transform is a technique which can be used to separate features of specific shape within an image. It is required that the specific feature must be defined in some parametric form. The Hough transform is most commonly used for the detection of lines, circles, ellipses, etc. The main advantages of the Hough transform are that it is relatively unaffected by gaps in lines and by noise [Wang, 1990].

Haar transform used by Majumdar and Bahattacharya (1988) for extraction of linear and anomalous patterns in the image. This method provides a domain in which a type of differential energy is concentrated in local regions. The transform has both low and high frequency components and therefore can be used for image enhancement [Koçal, 2004]. The Segment Tracing Algorithm (STA), which is developed by [Koike, 1995], is a method to automatically detect a line of pixels as a vector element by examining local variance of the gray level in a digital image. The automated lineament extraction in this study is performed by the LINE module of Geomatica software. The logic of this method is similar to STA. A brief explanation of the algorithm of this module will be given here. This information is provided from the Geomatica users' manual (2014).

The automated lineament extraction operations are applied on Landsat-8 (OLI) scene by using PCI Geomatica 2014 software line option. Band 8 of the image with a spatial resolution 15*15 meter is selected for automated lineament extraction considering the purpose of this study; since this band is useful for discrimination of lineaments and other geological features such as mineral and rock types and is also sensitive to vegetation moisture content [Sabins, 1996].

The extraction process is manipulated changing the six parameters. Several lineament maps are generated using different threshold values. The most suitable threshold values are selected (below) considering these lineaments as fault lines. General properties of faults are taken into consideration such as the length, curvature, segmentation, separation and so on in order to determine the threshold values. The parameters in this application are selected as follows in (Table 3).

Table (3) Suggested parameters values

Parameters	Suggested value
Filter radius (RADI)	10
Gradient threshold (GTHR)	75
Length threshold (LTHR)	30
Line fitting error threshold (FTHR)	3
Angular difference threshold (ATHR)	1
Linking distance threshold (DTHR)	40

The automatically extracted lineament map and its basic statistics are illustrated in (Figure 6) and (Figure 7) respectively. The results of the manual extraction and its basic statistics are also given in these figures to compare the two maps.

The Results and Discussion

Lineaments interpretation

So as to take out the most suitable lineaments concerning the region of study structural tectonic setting, optimum values for PCI parameters are suggested (Table 2).In manual extracted, prior four filtered images (Figure 3) are utilized as an input datum to the line modular with a view to calculate and estimate the length, orientation, numbers, and density of the lineament to each one of these input data. (Figure 4) describe the lineament map through the four input data with different directions. In this case, the lineaments analysis is conducted through the process of analyzing geospatial information like the length, density, and direction of this lineaments to the extent possible to extract information on the distribution and nature of these structures

Analyses of length

Figure (5) shows the relationship between the lineaments in each one of the four trends in the number (frequency) and length.

Identified (8135) total number of geological lineaments digitally. Length per unit area was calculated and then digitally represented in unit kilometer.

Automated and Manually Extracted

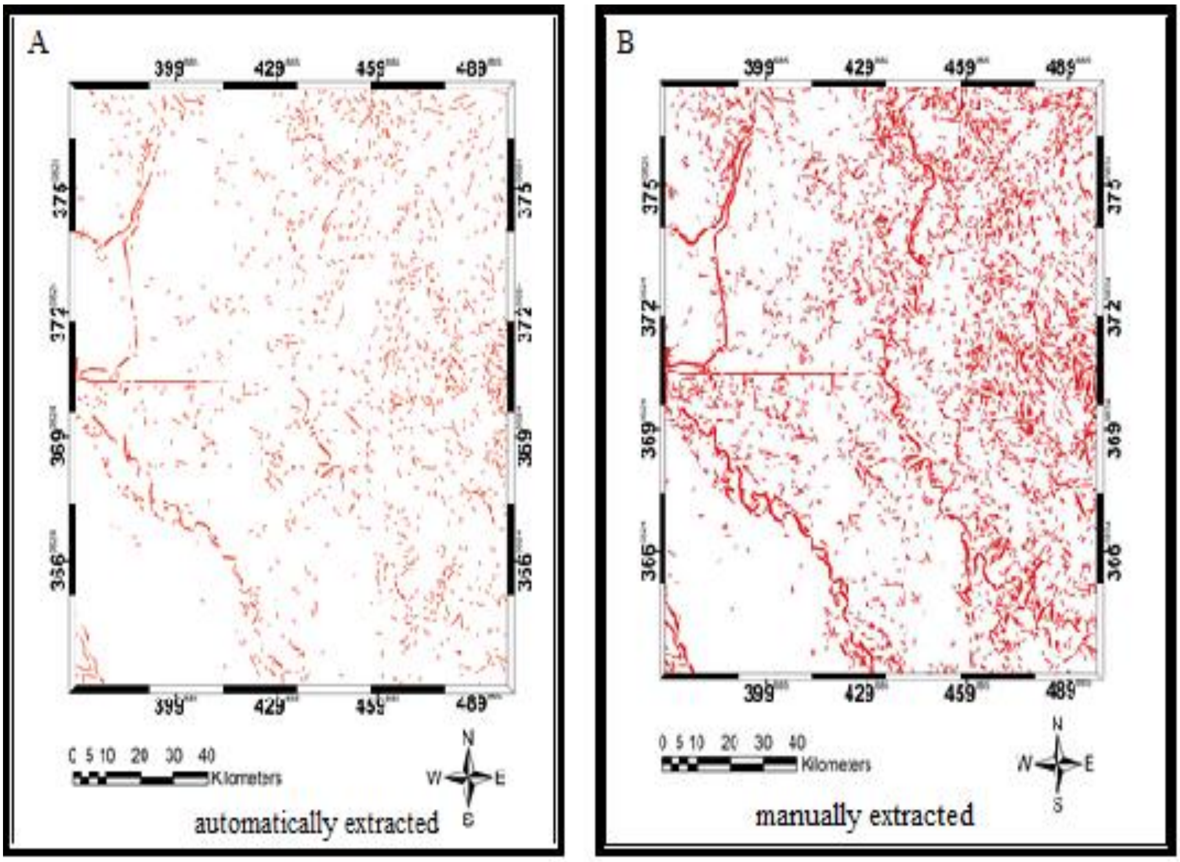
-From Figure (7) the frequency of manually extracted lineaments is greater more than 4 times of the automatically extracted ones (8135 versus 1849). The most important factor for this is that the lineaments in manually one are shorter in length so that a few of them could be combined to form one line in automatically extracted map. Although the linking distance threshold is assigned as 1200 m (40 pixels), the program could not combine segmented lines see Figure (6).

-In addition to the frequency of the lineaments is higher in manually one, the total length of all lineaments is still higher than the lineaments (10332.83 km versus 2385.54 km) identified by automated methods. This feature is best illustrated by the mean lengths of automatic and manual lineaments which are 1.29 km and 1.27 km, respectively.

-Spatial distribution of the lineaments in both maps Figure (6) is considerably different. In the manually one the frequency of the lines seems to be higher in the eastern and northeast parts of the area particularly in the close vicinity of Baquba and east of Baghdad. In the manual one, on the other hand, In addition to the areas mentioned, along the Tigris and Euphrates rivers and their extensions (that fit the Tikrit-Amara Fault Zone and Ramadi-Musayib Fault Zone).

-The pattern of the two maps in general look similar.

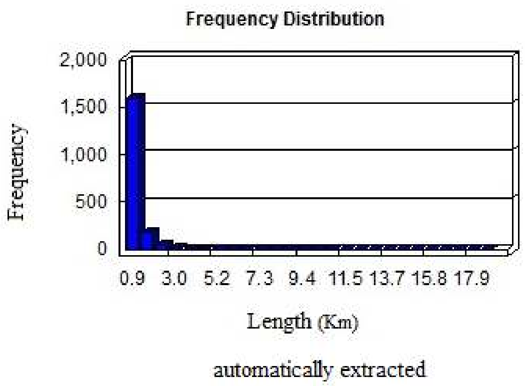
-Length of the maximum lineament is detected by automated one is 19.35km which is a proper length for the faults in the area. This length, however, is 20.01 km for manual one which is quite reasonable.



(Figure 6) Lineament maps: A) Automatically extracted; B) Manually extracted.

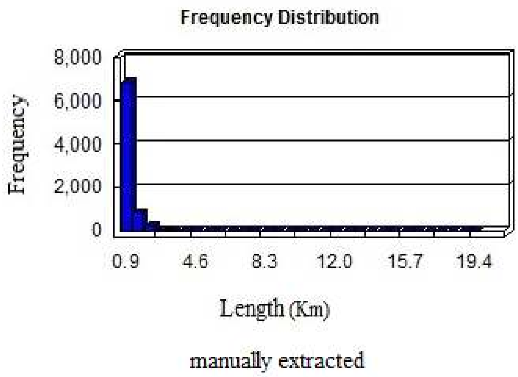
A

Count	1849
Minimum Length (km)	0.9
Maximum Length (km)	19.35
Sum (km)	2385.54
Mean (km)	1.29
Standard Deviation	0.71



B

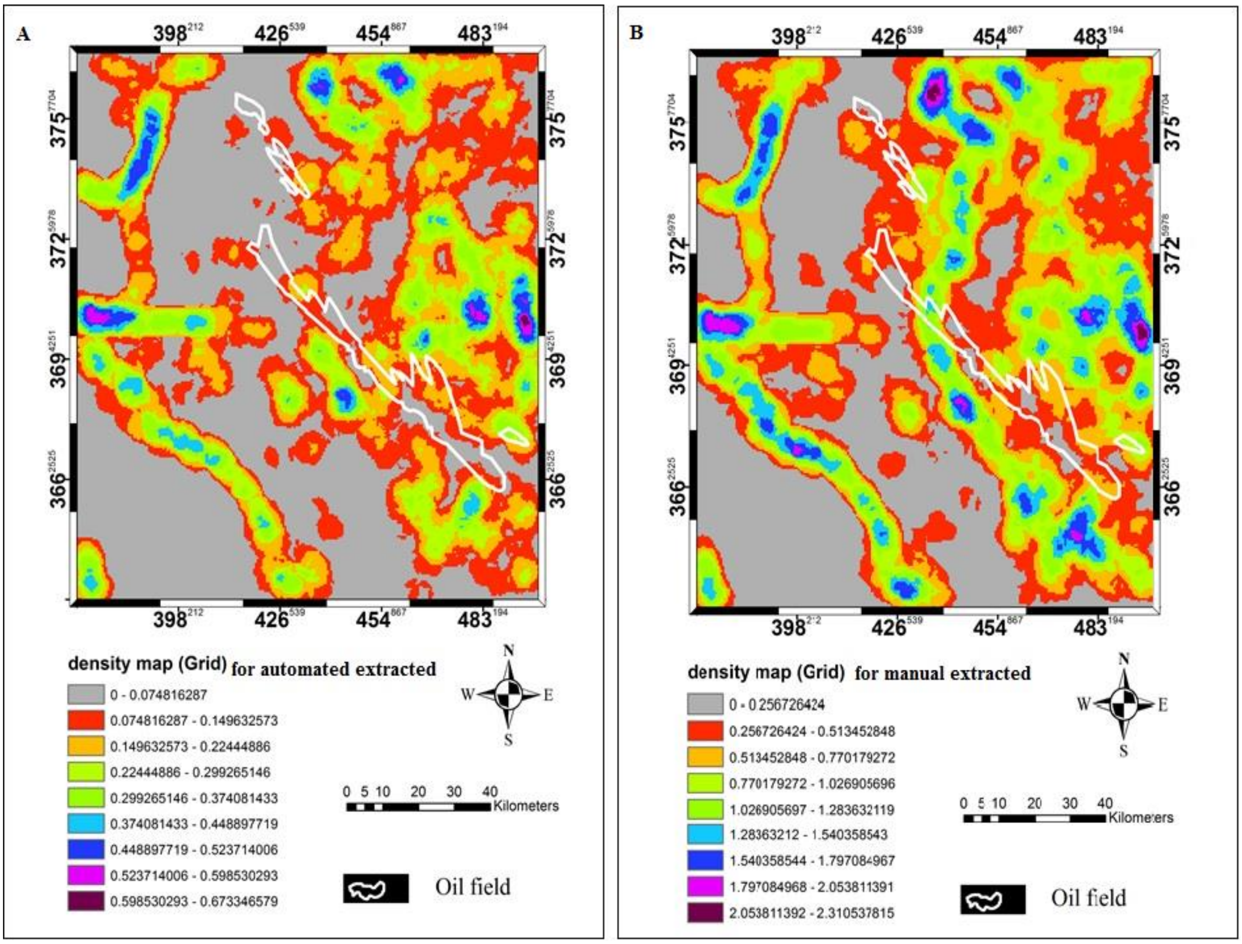
Count	8135
Minimum Length (km)	0.9
Maximum Length (km)	20.01
Sum (km)	10332.83
Mean (km)	1.27
Standard Deviation	0.67



(Figure7) basic statistics: A) Automatically extracted; B) Manually extracted lineaments.

Analysis of lineaments density

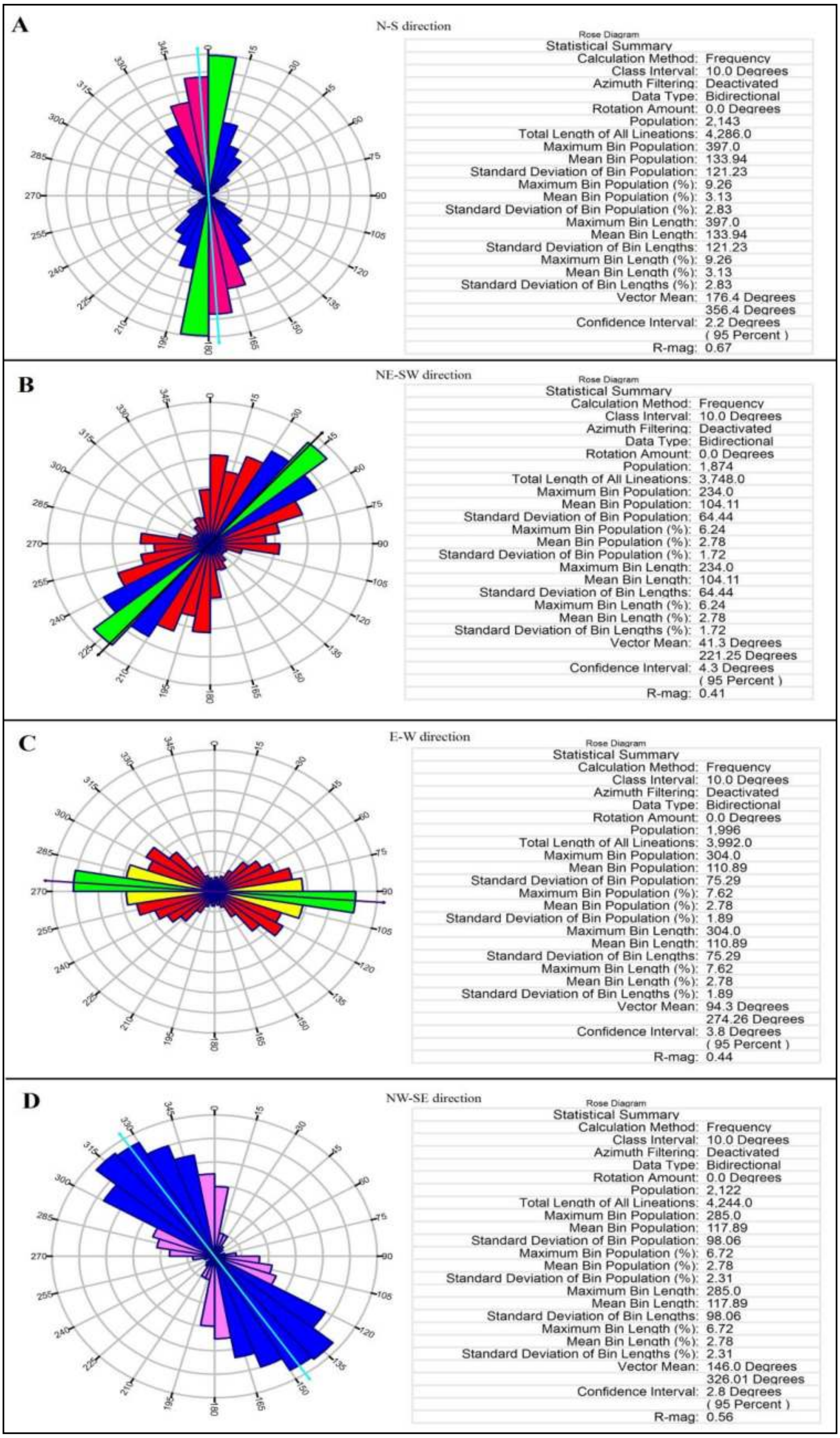
Density of lineament can be calculated from the number of the lineament per unit area [Hung, 2000], after that is Output a map showing the concentration lineaments per unit area. In this study, the lineament density is created using ArcGIS 10.2.2 program by counting lines per unit area digitally (No. of lines/km^2) and then plot in the grid centers for his using the same program. Density map of lineaments of the four trends is created and displayed in Figure (8) by grids for manually and automated. The high density of lineaments is existing in the areas inside the major structures as the anticlines.



(Figure 8) Lineaments Density maps of the overall lineaments: A) Automated extracted; B) Manual extracted

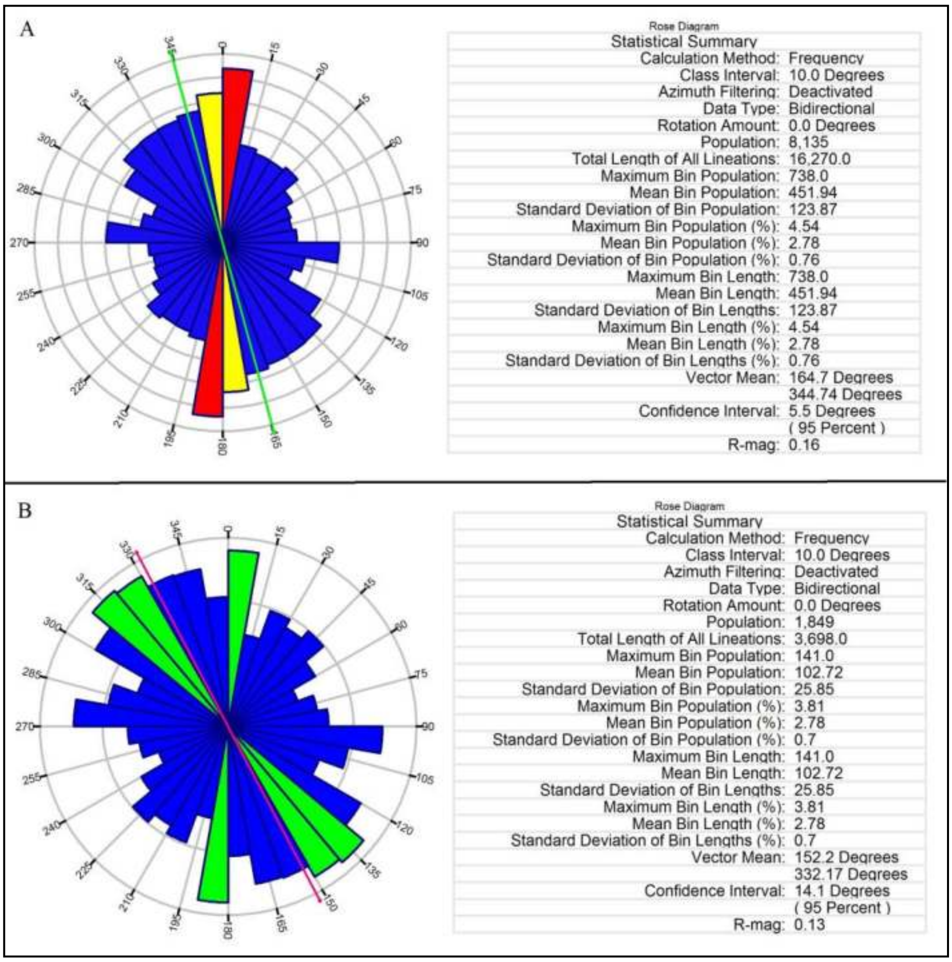
Direction analysis

Directions of lineaments are usually analyzed by rose diagram in all studies which are specialized in these structures. In manually extraction, these diagrams display the orientation frequencies of the extracted lineaments overall the particular area in the results lineaments maps for Sobel filters. A rose diagram created from the RockWorks16 Software. It was used to extract the lineament orientation in the studied area. Orientation of the lineaments for different lineament maps are compared using the rose diagrams Figure (9) noted to four principal directions. Also noted that the rose diagram displays four orientations but in various domains, while, the dominance directions in the trends are N-S, NW-SE.



(Figure 9) Rose diagrams prepared from lineaments extracted. A) N-S orientation; B) NE-SW orientation; C) E-W orientation; D) NW-SE orientation

Two diagrams in Figure (10) show rose diagram for manually and automatically lineaments which have great similarities as being concentrated in NW-SE direction. Comparison of two maps indicates that the manually and automated extracted lineament map is more similar in terms of their segmentation, their spatial distribution and their orientation except length of the lineaments.



(Figure 10) Rose diagrams prepared from: A) Manual extraction; B) Automated extraction

Conclusions

This study could be regarded as an effective method for the extraction and analysis of linear geological features over large areas. Landsat - 8 panchromatic band has very helpful characteristic. In optimum conditions these characteristics enhance the image interpretation especially in structure geology. Sobel kernels edge enhancement technique was applied on the Landsat image with different kernel (windows). However, the comparison of the extracted lineaments map with the geospatial analysis performing by Geographic Information Systems (GIS) such as density, length and orientation will contribute to the understanding the tectonic relationship between the lineaments and the structural elements in the study area. Of extract lineaments with the geospatial data (length, direction and density) can Identify the crack regions for both manual and auto extraction of lineaments. Used manual and automatic methods to extract lineaments. When using the manual method found that the lineaments be greatest, this difference between two methods is due to use of Sobel operator to enhance the digital image in the manual way .Extracted lineaments of both methods was more density when the folds and local fractures areas and concentrated towards the NW-SE.

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