INTERNATIONAL JOURNAL OF ENHANCED RESEARCH IN SCIENCE TECHNOLOGY & ENGINEERING

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

Automatic Extraction and Geospatial Analysis of Lineaments and their Tectonic Significance in some areas of Northern Iraq using Remote Sensing Techniques and GIS

Rayan Ghazi Thannoun
Remote Sensing Center / Mosul University, Iraq
rayan.ghazi@yahoo.com

Abstract: The geological structural features such as lineaments have been took much interest in the geological studies lately, because it is considers as a very important structural and geological indicator to determine general and local tectonic trends and fractures zones in the rocks, especially in the areas which are characterized that are covered extremely by the soils. The principle objective of this study is to design a suitable methods for automatically and digital lineament analysis and use the results in the tectonic induction. Consequently, an adaptive approach for tectonic lineaments extraction were used and it is includes (five steps). Throughout this study, panchromatic Landsat band-8 was used for auto extraction under user- suggested parameters values within PCI geomatica software. Three geospatial analyses are applied in order to evaluate the lineaments, These are: length, density and orientation analysis. The results have indicated that, 1.The Lineaments in the area have two main trends in the NE-SW and N-S directions and a subordinate E-W and NW-SE trend. 2. The total number and length of the lineaments is more in the dominant trend (NE-SW). 3. Most of the faults and major lineaments are located very close to the locations with high values of lineaments density. 4. Geospatial analysis of lineaments are give a good correspondence with the arrangement of the main tectonic forces of the studied area.

Keywords: Automatic extraction lineaments, geospatial analysis, directional filters, PCI geomatica.

Introduction

Earth surface linear features have been study theme for geologists through many years. The old term lineament, introduced at the beginning of the 20th century. Hobbs(1911) is one of the first geologists used lineaments and realized that this features are the result of zones of weakness or structural displacement in the crust of the earth, also, Hills (1953) is one of first geologist considers lineaments as a worldwide pattern in features such as faults, fractures and major relief forms (Lattman and Nickelsen, 1958). A 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 a 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 et al. 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). In this context, characteristics of lineaments such as trend, length and density are indicate to the zones and trends of high permeability rocks (Masoud and Koike, 2011). Since satellite images are considered to be a better tool to discriminate the lineaments and to produce better information than conventional aerial photographs (Casas et. al., 2000). Lineaments can be shown in both aerial photographs and in satellite images as a discontinuity that is darker or lighter in color in differentiation with the surrounding area. The principle objective of this study is to design a suitable method for auto-extraction and digital lineament analysis and then use the results in the tectonic induction. The advantage of the proposed method is its capability for applying in the areas which their outcrops characterized that are covered extremely by the soils (such as the area under study). Consequently, the soils hiding the underlying structural elements like joints and this lead to complicate study the tectonic setting of this area. 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.

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

Study area, position and geologic setting

The area under investigation covers about (1100 km2) and located at the north west of Mosul city between (Lat. 36°44'49.818"N and 36°34'36.783"N) and (Long. 42°23'14.534"E and 42°52'46.283"E) (Fig. 1). Several structural elements with their lithological units are exposed at the surface along this area. Ain-Zala, Ravan, Butmah and Qusair anticlines represent these structural elements which characterized that are asymmetrical, cylindrical anticlines, and their fold axis trend towards East-west (Ain -Zala and Butmah), West, North West- East, South East (Ravan and Qusair). The lithological units are exposed in these structures include Fatha and Injana formations and also Quaternary deposits (Geosurv-Iraq, 1995) (fig. 1). The stratigraphic units of Fatha formation (Middle Miocene) at the studied area contain of green marl, limestone and gypsum at the lower member of the formation and red claystone, marl, limestone, gypsum and siltstone at the upper member. Injana formation (upper Miocene) in the same area contains outcrops of sandstone, siltstone and claystone. The Quaternary deposits includes residual soil, slope and valley filling deposits.

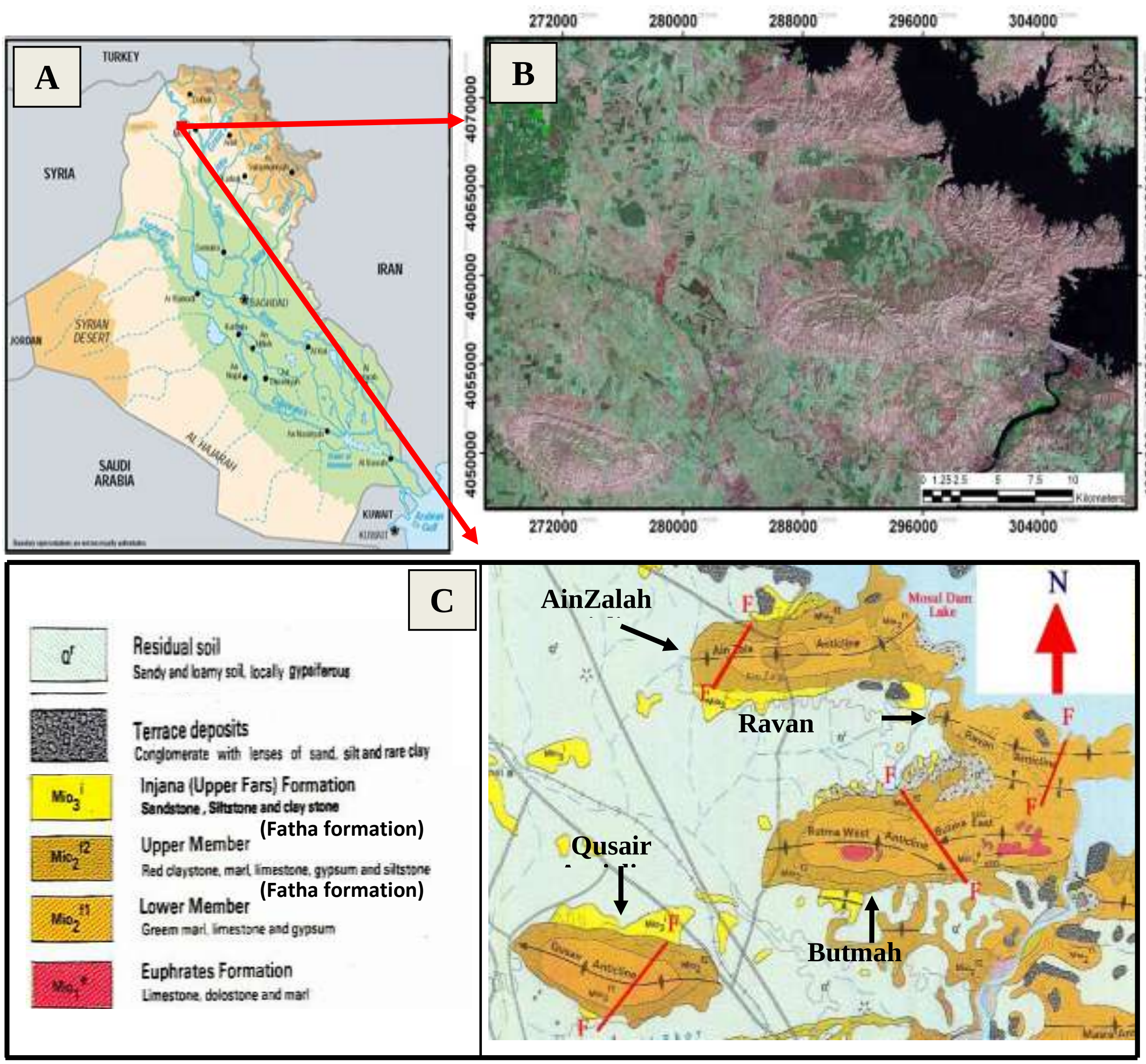

Figure 1: **A.** Simplified map of Iraq showing study area. **B.** Landsat ETM+ false color composite image. **C.** Geological map modified from (Geosurv-Iraq, 1995)

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

Methodology

The major flowchart which are applied for the lineament Extraction and analysis is given in (Fig. 2). The methodology of this research composed of five successive steps:

1) The first step is the selection of the suitable band of Landsat ETM+ for lineament auto extraction and geospatial analysis.

2) The second step is the applying some of image processing methods to enhance the edge and direction of lineaments

3) The third step depend on the techniques for extracting the lineaments by using a sufficient values of PCI geomatica LINE module parameters software.

4) The fourth step is the evaluation of lineament map with their directions by calculation geospatial analysis like density and the lengths of these feature.

5) The fifth step includes evaluate the tectonic setting of the area depending on the results of the suggested method in this paper.

Data used and techniques

The data utilized in this research is a subset of panchromatic spectral band (Band 8) of Landsat-7 ETM+ data set (Row 35/Path 170), dated 13 Jun 2001. Panchromatic band has favored in lineament analysis as a consequence of its improved spatial resolution (15 meter). This panchromatic band also is geo-referenced to the UTM coordinate system, Zone 38 North based on 1:50,000 scale topographic maps with acceptable root mean square error. False color composite image(7Red, 4Blue and 1Green) of landsat-7 ETM+ data set (Row35/path 170) also used for representing the auto extraction and geospatial lineaments analysis results. In this study, there are two techniques have been used. First is related to the software's, second involves the image processing to perform edge enhancements. The most widely used software for the automatic lineament extraction is the LINE module of the PCI geomatica. Also, Using (ENVI 4.6) software a number of processes (like digital filtering) have been done to the panchromatic band in order to get the high efficiency of extracted lineaments. Geographical Information Systems (GIS) software (ArcGIS 9.3) is utilized to perform Geospatial analysis and prepare final maps of lineaments.

Auto-extraction Procedures

This parts involves the procedures which have been used to extract lineaments from Landsat panchromatic band and geospatial analysis.

1. Edge enhancement: 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 sharpen the boundary that exists between adjacent units (Sarp, 2005).In this study, Directional filtering has been used to enhance, extract and classified the oriented lineaments. The direction was chosen depending on the structural and tectonic features of the area, however, 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 1).This type of filter was used in order to get a high accuracy in auto 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 et al.,1998).

Table 1: Sobel - kernels in four principle directions

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

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

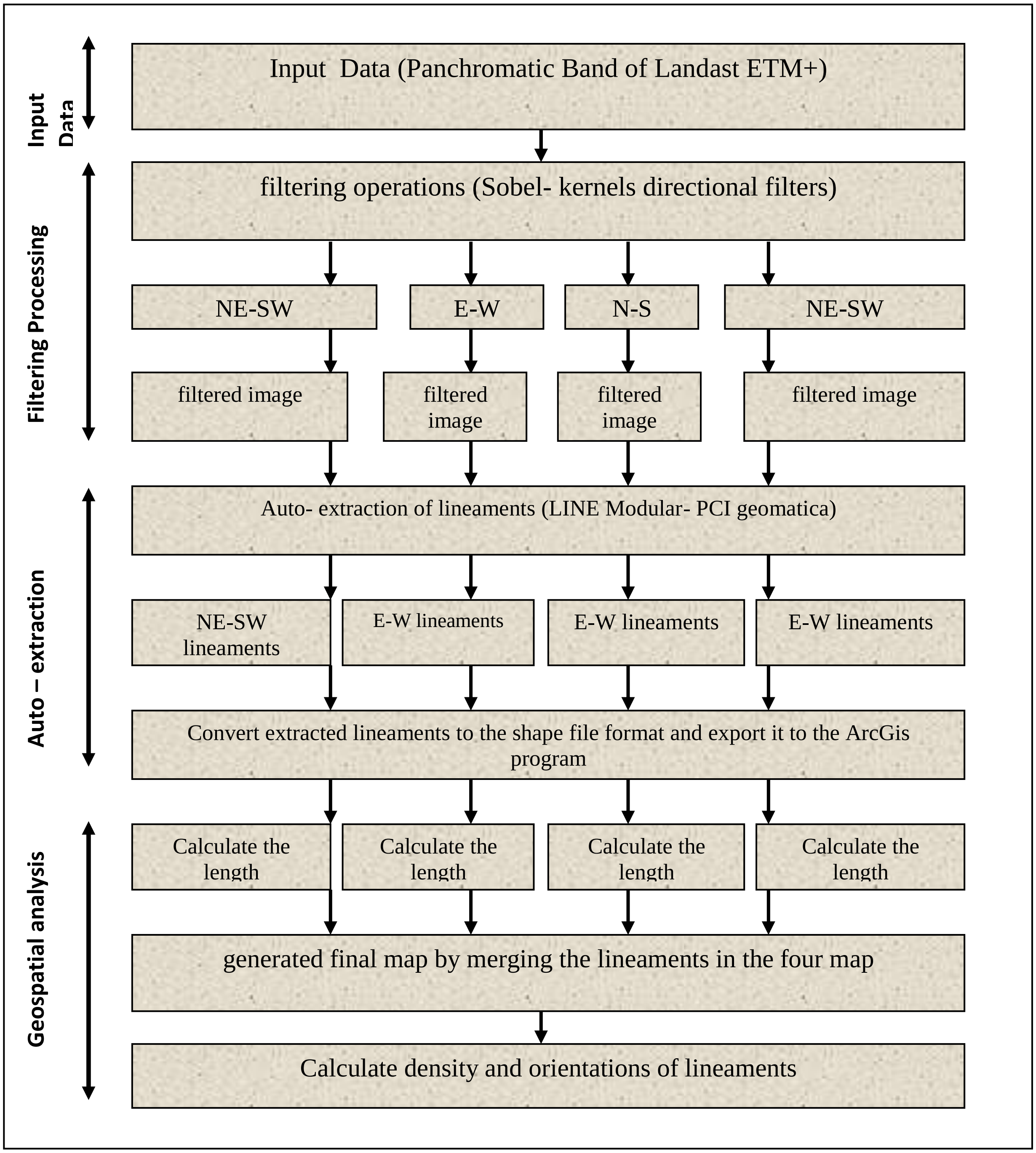

Figure 2: Flowchart shows steps of the study

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

as shown in (Fig. 3), four filtered images have been produced by ENVI software related to the directions N-S, E-W, NE-SW and NW-SE, which are used as an inputs images for auto extraction methods.

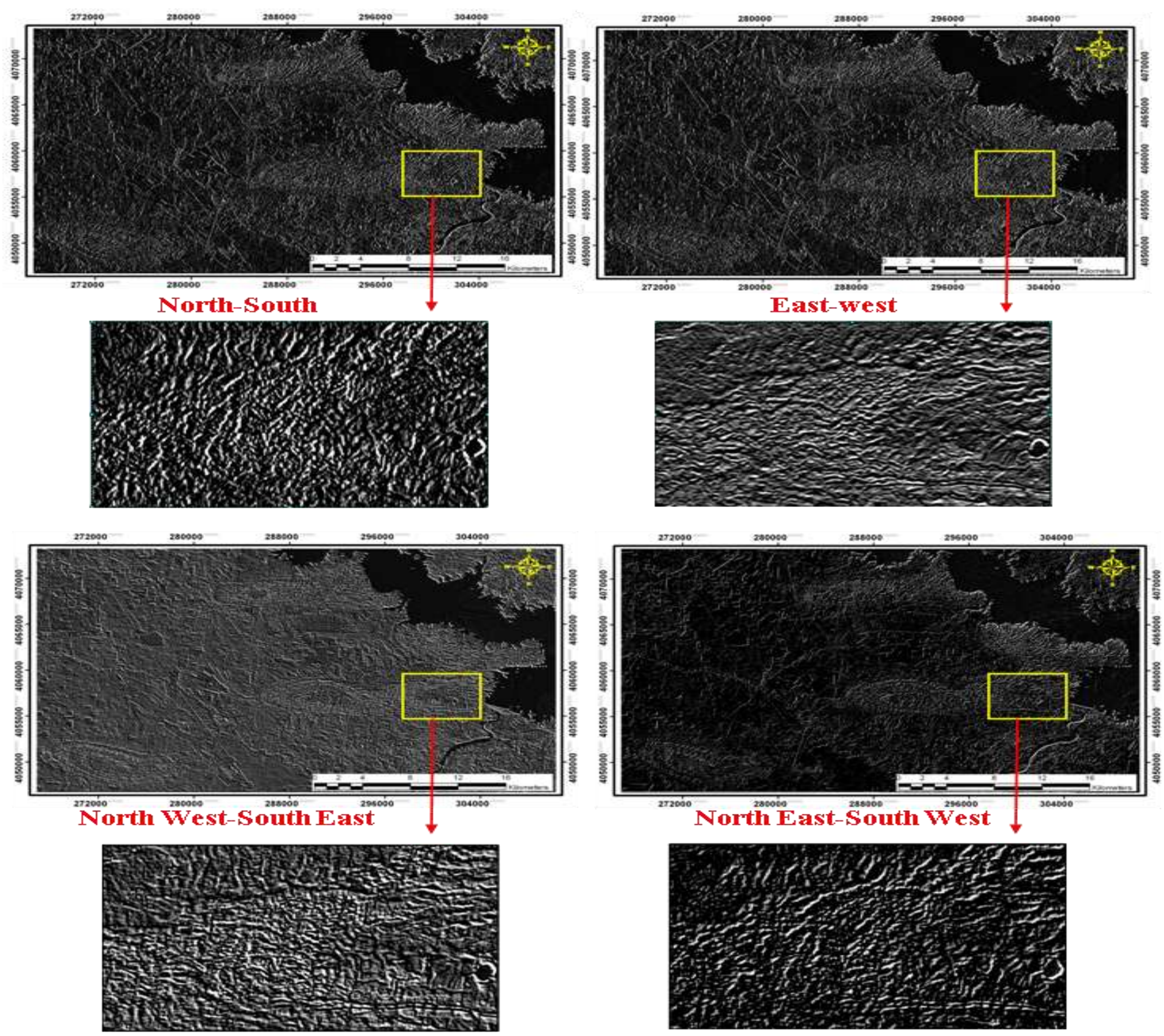

Figure 3: Filtered images in N-S ,E-W, NW-SE, NE-SW, directions

2. Auto extraction parameters

Numbers and lengths of extracted lineaments depends on the input parameters values which are represent optional digits of the LINE modular in PCI geomatica software. The algorithm of this modular consists of three stages: edge detection, thresholding, and curve extraction. however, LINE module extracts lineaments from an image and convert these linear feature in vector form by using six optional parameters(RADI, GTHR, LTHR, FTHR, ATHR and DTHR) . These parameters explained briefly according to the (Sarp, 2005):

RADI (Filter radius): This parameter specifies the radius of the edge detection filter (in pixels). It roughly determines the smallest-detail level in the input image to be detected. The data range for this parameter is between 0 and 8192.

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

GTHR (Gradient threshold): This parameter specifies the threshold for the minimum gradient level for an edge pixel to obtain a binary image. The data range for this parameter is between 0 and 255.

LTHR (Length threshold): This parameter specifies the minimum length of curve (in pixels) to be considered as lineament or for further consideration (e.g., linking with other curves). The data range for this parameter is between 0 and 8192.

FTHR (Line fitting error threshold): This parameter specifies the maximum error (in pixels) allowed in fitting a polyline to a pixel curve. Low FTHR values give better fitting but also shorter segments in polyline. The data range for this parameter is between 0 and 8192.

ATHR (Angular difference threshold): This parameter specifies the maximum angle (in degrees) between segments of a polyline. Otherwise, it is segmented into two or more vectors. It is also the maximum angle between two vectors for them to be linked. The data range for this parameter is between 0 and 90.

DTHR (Linking distance threshold): This parameter specifies the minimum distance (in pixels) between the end points of two vectors for them to be linked. The data range for this parameter is between 0 and 8192.

3. Lineaments digitizing saving

Extracted lineaments converted to the shape file in order to export it to the ArcGis program which is contains specialist tools for the geospatial analysis and data processing.

Lineaments maps and geospatial analysis

In order to obtain the most appropriate lineaments related to the tectonic setting of the studied area, optimum values for LINE modular parameters are suggested (Table 2). Previous four filtered images (fig. 3) are used as an input data to the line modular in order to calculate and estimate the length, orientation, numbers, and density of the lineament to each one of these input data (i.e. four filtered images).

Table 2: Suggested parameters values

Parameters	Suggested Parameters values
Filter Radius	5
Edge Gradient Threshold	75
Curve Length Threshold	10
Line Fitting Error Threshold	2
Angular Difference Threshold	20
Linking Distance Threshold	1

(Fig. 4) demonstrates the lineaments map over the four input data with different trends. In this context, lineaments are analyzed by three process of geospatial analysis in order to extract further information related to distribute and nature of these structures. Geospatial analysis process are includes: length, density and orientation analysis.

1. Length analysis

The relationship between the lineaments in each one of the four maps in number (frequency) and lengths is shown in (fig. 5). A total of (3463) geologic lineaments (for all directions) were identified digitally. Length per unit area for each line is completely calculated digitally and then represented the value of length (in meter) by attributes table in the data base as a new field.

As shown in (fig. 5), It has been noticed that the (NE-SW) lineament map have higher number and length compared with the other. According to the parameters values which are used in this study, the maximum length of the lineaments is (2916m) recorded in the (NE-SW) direction. In addition, The maximum frequency of lineaments is (810) recorded in the same direction which is which is about (50 %) of the final map.

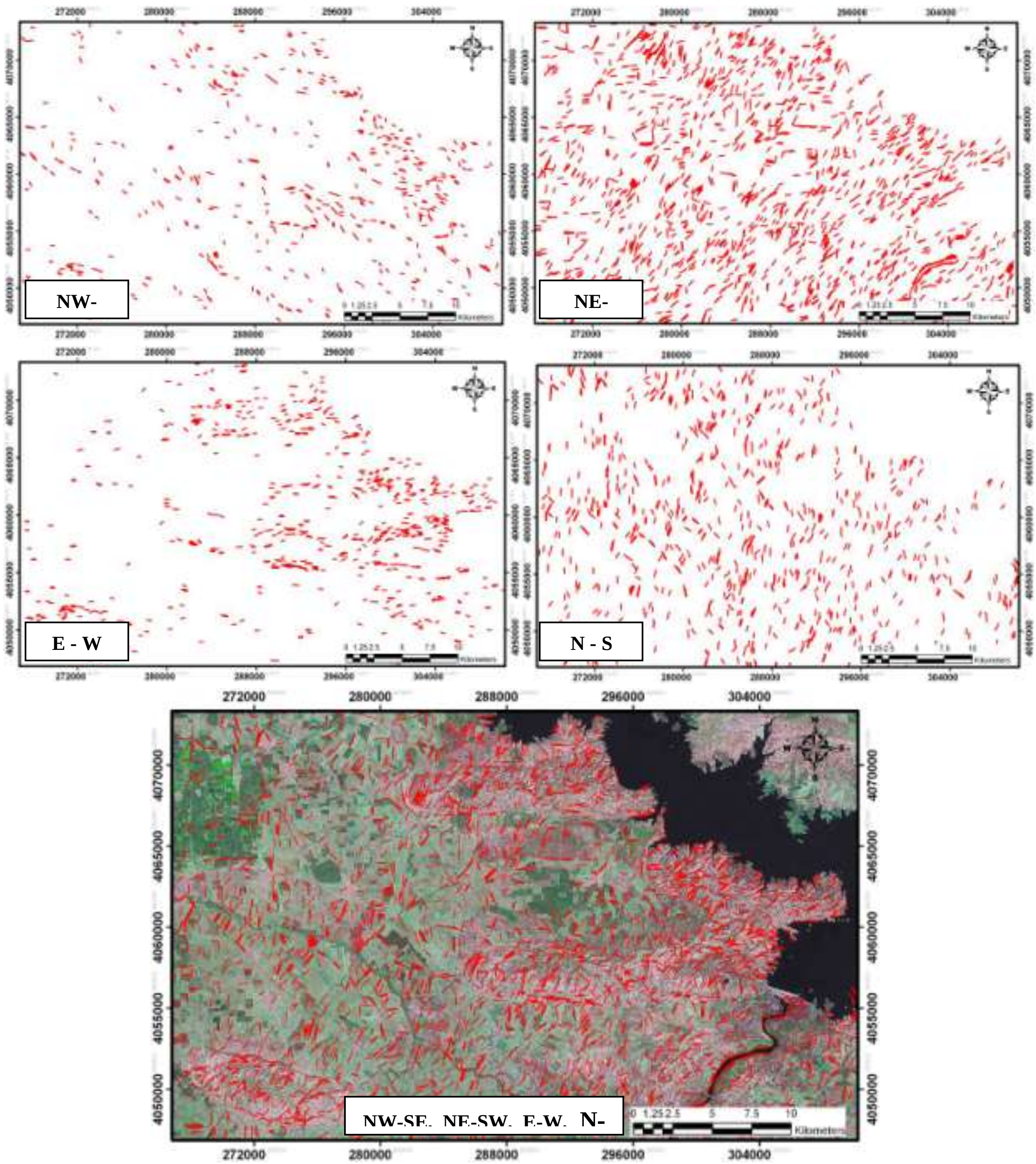

Figure 4: Lineaments maps with four principal trends

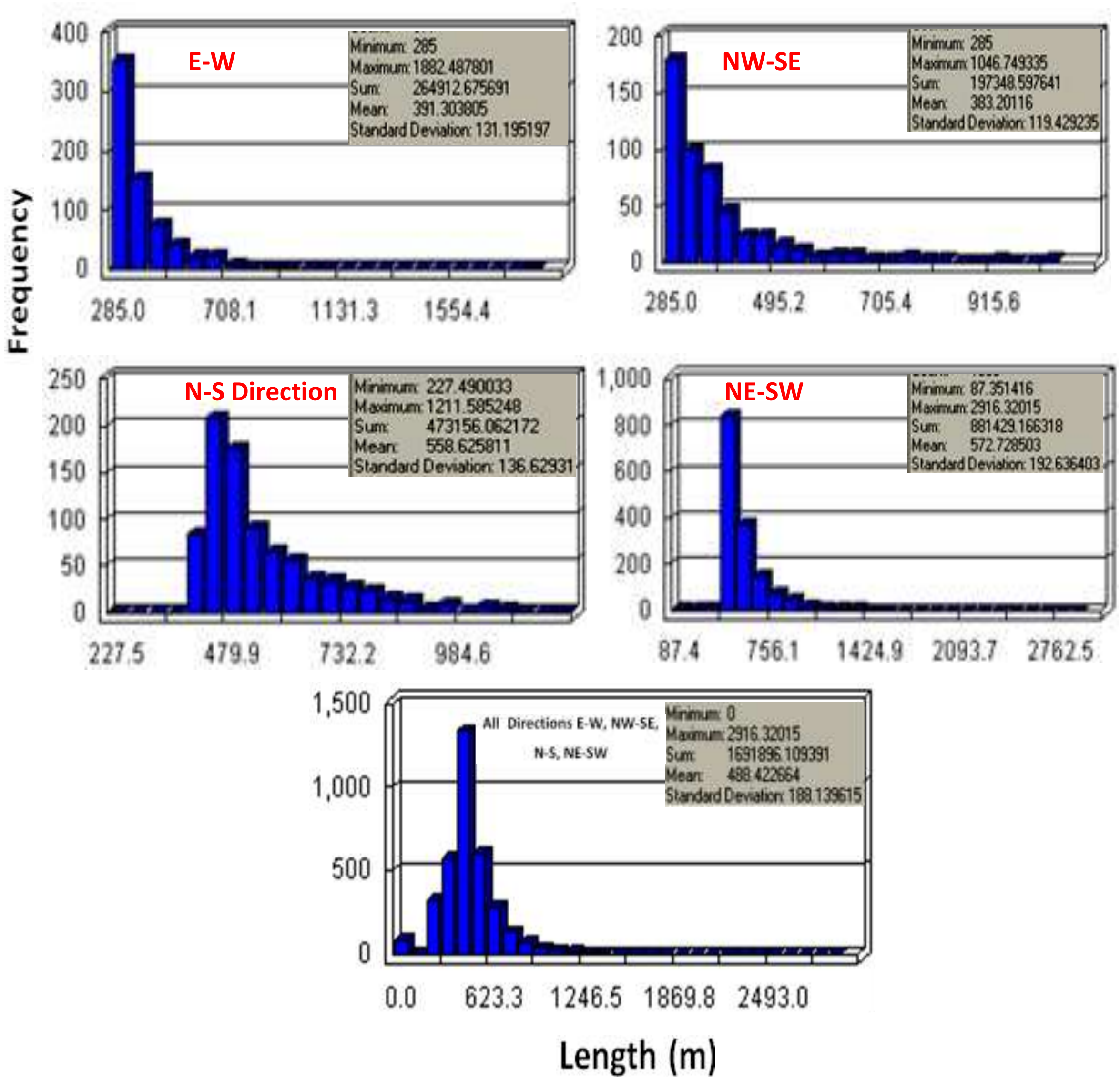

Figure 5: Frequency distribution and basic statics of the lineaments

2. Density analysis

This analysis calculates the frequency of the lineaments per unit area (Hung et al., 2005), and then produce a map showing concentrations of the lineaments over unit area. In this study, the lineament density is created by spatial analyst tool in (ArcGis 9.3) program by counting lines digitally per unit area (number/km2) and then plotted in the respective grid centers and contoured using the same tool. Lineaments density map of the overall lineaments (the four directions) is produced and shows in (fig. 6) by grids and contours. The high density of lineaments are located in the areas within inside the main structures (i. e. anticlines). Meanwhile , it is clear that most areas adjacent to the main faults has also a high density of lineaments. However, The ranges of lineament numbers are varied between (2 to 7 per/km2).

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

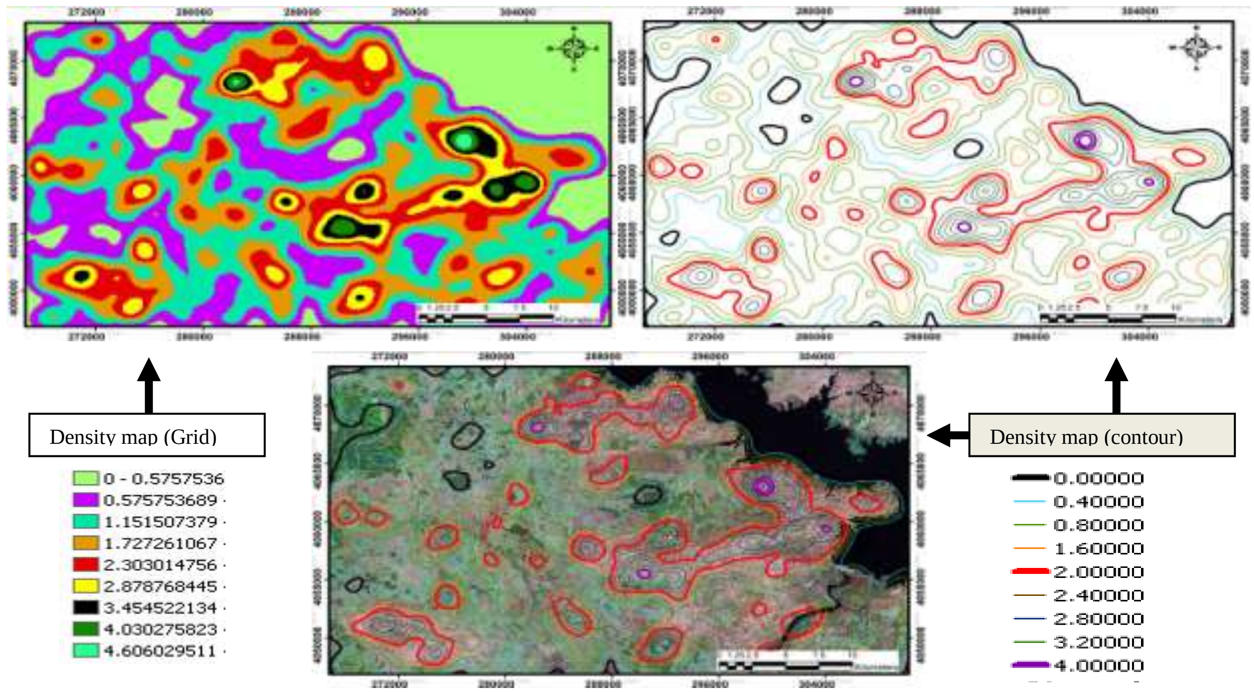

Figure 6: Lineaments Density map of the overall lineaments by grids and contours

3. Orientation analysis

Lineaments orientations are usually analyzed by rose diagram in all researches which are dealing with these structures. In auto-extraction, this diagram shows the directional frequency of the extracted lineaments over the specific area. A rose diagram tool from the (ArcView3.2) was used to derive lineament directions in the selected part in the studied area.

As shown in (fig. 7), The rose diagram shows four directions (i.e. NE-SW, N-S, E-W and NW-SE) are noticed but in different ranges, however, the dominance trends in the directions are include: NE-SW, N-S. The rose diagram on lineament indicated also that the more than 80% of the lineaments falling in NE-SW.

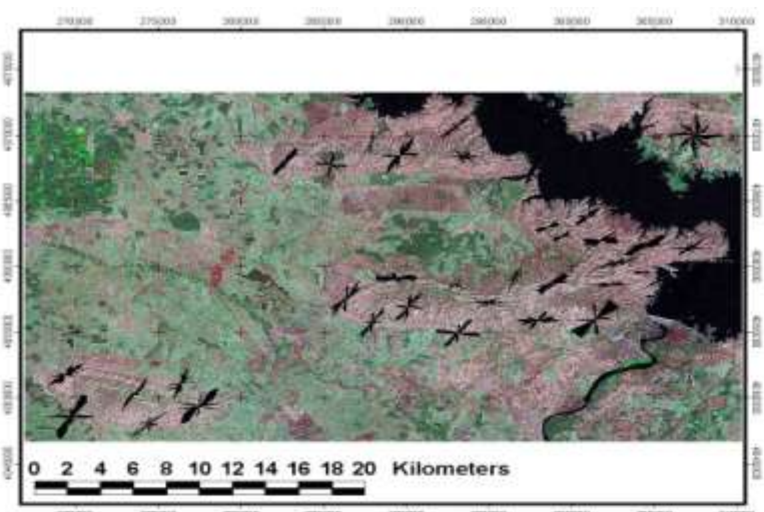

Figure 7: Rose diagram illustrating all lineament trend over the FCC Landsat image of some selected zones of the studied area

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

Tectonic and Structural interpretation of Auto-extracted lineaments

Throughout this study, panchromatic band-8 was analyzed for automatic lineaments extraction under user suggested parameters values within LINE module of PCI geomatica software. The extracted lineaments showing all possible linear features that can be represented fractures zones. In the studied area, lineaments have been created as a result of two factors. The one by composing major structural units which are represent the recent phase of folding in the Iraqi foreland zone according to the (Al-Azzawi, 2003). The second, these features also, might be accompanied with a major faults in this area. Depending on these two factors, the numerous lineaments detected are characterized by variety in trend, length and density. Trends of these feature are (NE-SW), (N-S), (E-W) and (NW-SE). The (NE-SW) is the most frequent trend and has also a longer length. The most maximum length (in NE-SW trend) is recorded in the eastern part of Qusair anticline specifically, along the strike slip fault trace. the fault trend is (NE-SW) and fault's slip of the fatha formation outcrops (Middle Miocene) reach to (520m) (field measurement). The tectonic style of the principal structural extracted lineaments of the area under investigating can be detected by tectonic setting of the Arabian plate and Eurasian plate. The collision between this two plates in (Eocene) (Numan , 1997) lead to forming compressive stress with (NE-SW) and (N-S) depending the location of plate boundary. Force which are result from the trend (N-S) is mostly coincident with the extracted lineaments. In this context, the compressive forces are recently still active (Al-Azzawi, 2003), and Since, the folds axis are mostly oriented in (E-W) .

However, the major force acting perpendicular to the fold axis, Similarly the lineaments are extracted coincident to the major and local force directions which are consider as an indication to the tectonic activity effect of the terrain morphology. The arrangement of stress is shown in (fig. 8), (σ1) (Maximum principal stress axes) coincides with major force (N-S trend). However, the directions of the shear planes(Faults) are compatible with the (NE-SW and NW-SE). whereas, the (N-S) lineaments are represent tension fractures which are parallel to the main force (i. e. N-S). In this context, (E-W) lineaments are considers also tension fractures formed by releasing the stress during folding process. The previous analysis may be interpreting the distribution of the all lineaments trends in the study area. In addition, the continuity of alpine orogeny and its effect to the Arabian plate, may be lead to rejuvenate and activate the major fault in this area, consequently, this activation contribute composing new fractures in the rocks, and this may be give the interpretation about that most of the faults and major lineaments are located very close to the locations with high values of density.

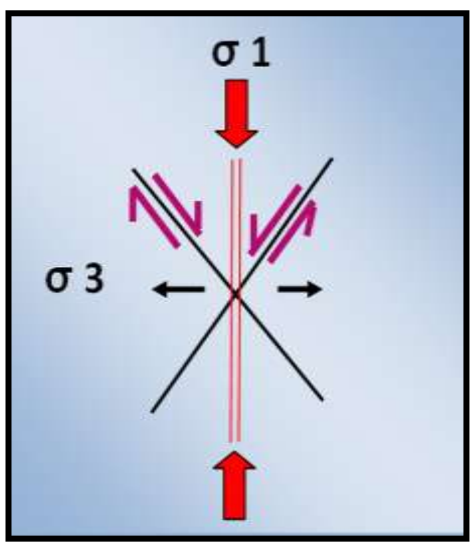

Figure 8: Arrangement of the main tectonic force of the studied area

Conclusions

The flowchart of this study is an efficient way for extracting and analyzing the geological lineaments over large regions with little outcrops (covered area). Combination of auto extracted lineaments with the geospatial data (length, density and trend) can update the tectonic setting and determine the fracture zones.

VOL. 2 ISSUE 2, FEB.-2013 ISSN NO: 2319-7463

References

[1]. Al-Azzawi, N. K. B., 2003. The structural development of folds shape in the foreland belt of Iraq, and its tectonic implications, Unpublished Ph.D thesis, Mosul university, Iraq, 203p.

[2]. Casas, A. M., Cortes, Angel L., Maestro, A., Soriano, M.A.,Riaguas, A. and Bernal, J., 2000. A program for lineament length and density analysis, Computers and Geosciences, Vol. 26, No. 9/10, 1011-1022.

[3]. Geosurv-Iraq, 1995. Geological map of Al- Mosul quadrangle, Sheet Nj-38-13, 1: 250,000. State establishment of survey and mining, Baghdad, Iraq.

[4]. Hung, L.Q., Batelaan ,O. and De Smedt, F., 2005. Lineament extraction and analysis, comparison of Landsat ETM and Aster imagery. Case study: Suoimuoi tropical karst catchment, Vietnam, Proc. of SPIE Vol. 5983, 59830T, 1-12.

[5]. Jensen, J. R., 1996, Introductory Digital Image Processing, Prentice Hall Series in Geographic Information Science, New Jersey, 316 p.

[6]. Lattman, L. H. and Nickelsen, R. P.,1958. Photogeologic fracture-trace mapping in Appalachian plateau, geological notes, 2239-2244.

[7]. Masoud, A. A. and Koike, K., 2011. Auto-detection and integration of tectonically significant lineaments from SRTM DEM and remotely-sensed geophysical data, ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 66, 818–832.

[8]. Neawsuparp, K. and Charusiri, p., 2004. Lineaments Analysis Determined from Landsat Data Implication for Tectonic Features and Mineral Occurrences in Northern Loei Area, NE Thailand, ScienceAsia, vol. 30, 269-278.

[9]. Numan, N. M. S., 1997.A plate tectonic scenario for the Phanerozoic succession in Iraq, Iraqi geological journal .V.30.No.2.PP.85-110.

[10]. O'Leary, D. W., Friedman, J. D. and Pohn, H. A., 1976. Lineament, linear, lineation: Some proposed new standards for old terms", Geological Society America Bulletin, Vol.87, 1463-1469.

[11]. Sarp, G., 2005. Lineament Analysis From Satellite Images, North-West Of Ankara, Msc thesis, Middle East Technical University, 76 p.

[12]. Suzen, M.L. and Toprak, V., 1998. Filtering of Satellite Images in Geological Lineament Analyses: An Application to a Fault Zone in Central Turkey, International Journal of Remote Sensing, 19(19), 1101-1114.