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Lineament Mapping of Jabal Arkenu in Southern Libya

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الملخص

تعد تقنية الاستشعار عن بعد تقنية مهمة في دراسة الأماكن المحفوفة بالمخاطر التي يصعب الوصول إليها للتحري عنها ميدانياً. علاوة على ذلك، فإنه يوفر بيانات سريعة ودقيقة لوصف السمات أو الظواهر الطبيعية على الأرض. ويمكن استخدام بيانات الاستشعار عن بعد مع مناهج أخرى لتقديم نظرة عامة أكثر شمولاً عن الظاهرة محل الاهتمام.

وبناءً عليه تم في هذه الدراسة دراسة الخصائص الخطية لجبل أركنو في حوض الكفرة جنوب ليبيا درس عن بعد. مصدر البيانات الرئيس هو صورة الأقمار الصناعية التي أُنْتِجتْ من القمر الصناعي (Alos Palsar)، التي تبلغ دقتها المكانية 12.5 متر. أُنْشِئتْ خريطة ميزات الخط لجبل أركنو من خلال تحليل العديد من صور الظل البارزة الناتجة عن جبل أركنو. تم استخراج الطول والكثافة والاتجاه والتقاطع للخطوط من خريطة الخطية ومقارنتها لتوفير خرائط واضحة لتحديد نوع الصدوع والعلاقات الهيكلية والجيولوجيا في منطقة الدراسة. تهيمن الكثافة الخطية العالية إلى العالية جدًا على الجزء المركزي من جبل أركنو، بينما يتميز الجزء الأكبر من منطقة الدراسة بكثافة خطية متوسطة إلى منخفضة. الاتجاه السائد للخطوط التي حُلِّلت في الاتجاه الشمالي الشرقي، وتتركز في الأجزاء الشمالية والجنوبية من جبل أركنو. تواجد بعض الميزات الخطية حُدُوداً بين النفيلين سيانيت (Nepheline syenite) مع الحجر الرملي الكمبرى (Cambrian Sandstone) والفونوليت (Phonolite) مع سيانيت جرانيت (Syenite granite).

الكلمات المفتاحية: جبل أركنو، الميزات الخطية، نماذج الارتفاعات الرقمية.

Abstract

Remote sensing technology is an important technique in studying perilously and hard-to-reach places for investigating them in the field. Furthermore, it provides fast and accurate data to characterize natural features or physical objects on the ground. Remote sensing data could be used with other approaches to provide a more comprehensive overview of the feature of interest.

Accordingly, in this study, the linear features of Jabal Arkenu, in the Kufrah Basin, south of Libya, were studied remotely. The main source data is a satellite image produced from the Alos Palsar satellite, which has a spatial resolution of 12.5 meters. The lineament features map of Jabal Arkenu was created by analyzing several shadow relief images. The length, density, direction and intersection of the lineaments have been extracted from the lineaments map and compared to provide clear maps for determining the type of faults, structural relationships and the geology in the study area. Additionally, the central part of Jabal Arkenu is dominated by high to very high lineament density, while the greater part of the study area is characterized by medium to low lineament density. The dominant direction of the analyzed lineaments is in the northeast direction, and they are concentrated in the north and south parts. Some linear features exist as a boundary between Nepheline syenite with Cambrian Sandstone and Phonolite with Syenite granite.

Keywords: Jabal Arkenu, Lineament, Digital Elevation Models.

1. INTRODUCTION

Remote sensing technology is an important technology in day-to-day life, especially after the development of sensors and computers to process data. It becomes increasingly important when the area of interest is difficult to access or the study is in the field. Remote sensing technology can be used in many fields of geology, such as structural geology, distinguishing rocks, geomorphology and linear geology. The term "lineament" has recently become more common and has gained popularity in the remote sensing geology literature [1]. The linear features of elements on images are some of the most evident features in high-altitude aerial and space images.

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The term lineament has been applied to refer to the alignment of various geological features, such as shear/rift zones, fault valleys, fracturing or folding, carving outcrops, joints and mineralized veins, shear zones, dikes, linear sinkholes, or springs aligned along a fault., etc [2]. Furthermore, human facilities such as roads, dams, and railways can also appear as linear features.

Identification of lineaments using aerial images or digital elevation models is effective in facilitating and characterizing shear or fracture zones [3]. Linear features that are obviously of structural origin are important for indicating fault zones and faults [4].

This paper is a quantitative study of linear features of Jabal Arkenu by extracting them from the Digital Elevation Model (DEM) and makes a basic statistical analysis to help understand and identify the places most affected by the shear zones areas or

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faults. The study area is uninhabited and has well-exposed rocks, so the linear features can be distinguished very easily.

2. LOCATION STUDY AREA

The study feature is a mountain called Jabal Arkenu (ring complex), which is an integral part of Jabal Al Awaynat area, SE Libya. Generally, the area of Jabal Al Awaynat extends over two countries; the southeastern part of Libya and the southwestern part of Egypt (Fig.1). Jabal Arkenu (ring complex) is situated between Latitudes 22° 14' 00" & 22° 21' 00" N and Longitudes 24° 38' 00"& 24° 48' 30" E. Jabal Arkenu covers an area of about 270 km^2 with a width of about 21km from east to west and a length of about 16 km from north to south. It is surrounded by Jabal Al Bahri and Jabal Babein in the north, Jabal Al Awaynat in the south. It takes an oval shape and seems to be a flaming ring when seen from space (Fig.1).

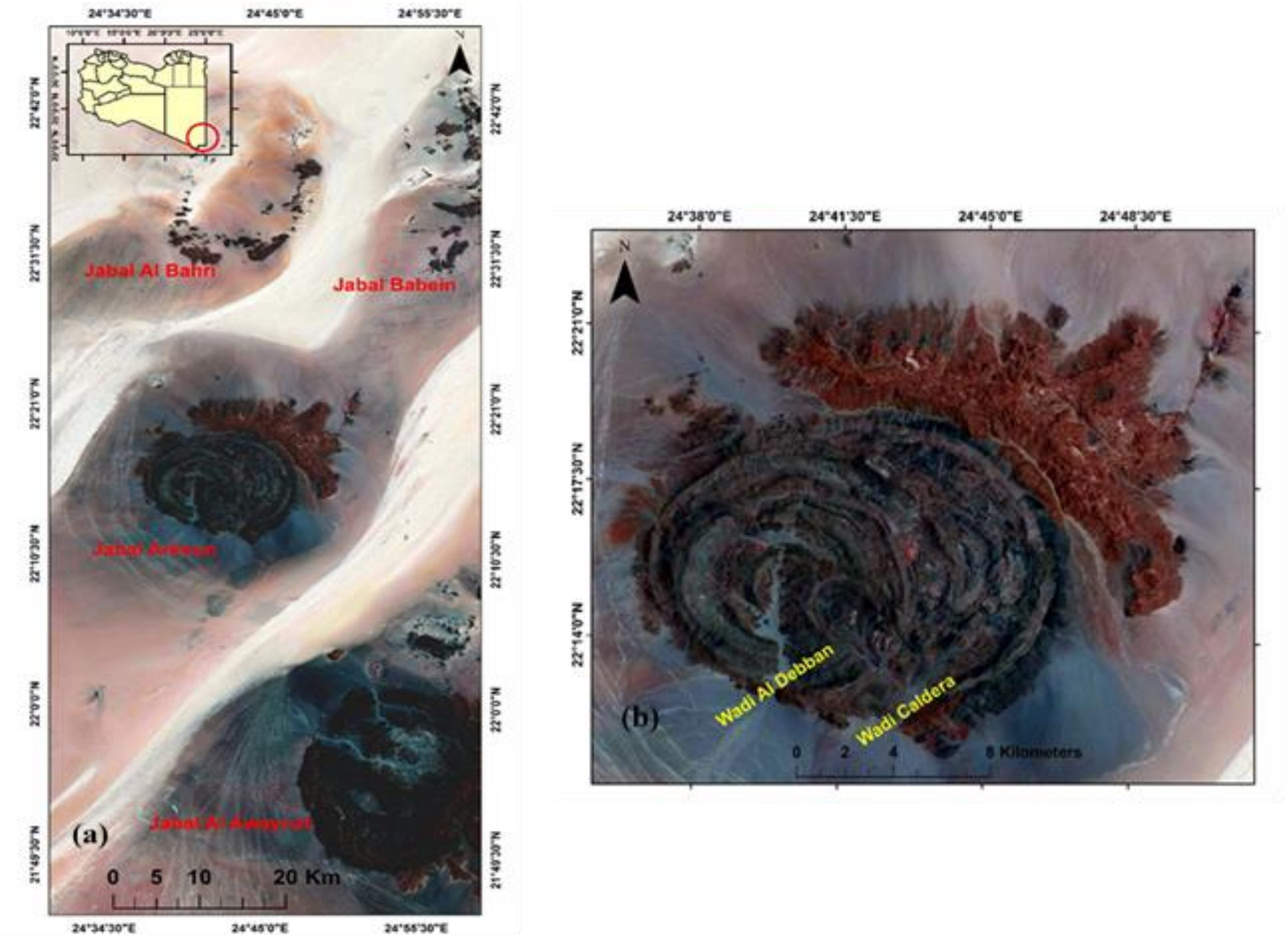

Figure. 1. a) General location of the study area and a satellite image showing Jabal Al Awaynat, Jabal Arkeun, Jabal Al Bahir and Jabal Babein; b) Satellite image of Jabal Arkenu Ring Complex.

3. GEOLOGY AND GEOMORPHOLOGY OF THE STUDY AREA

The mountain under study is composed of undifferentiated Precambrian rocks that are unconformably overlain by the Palaeozoic and Mesozoic sediments and invaded by igneous rocks, ring complexes, tertiary volcanic and quaternary deposits that cover extensive parts of the area [5][6]. These rocks have been subjected to intense deformation, that resulted in folding, faulting and foliation as well as extensive lineations. Foliations and lineations have a northeast direction with a sub-vertical dipping. The trending axes of folds are in NE -SE and NW-SE directions, while most faults are of the strike-slip type and they have NE - SW, NW - SE, E -W and N - S directions [6]. In addition, the most distinguished geological features of Jabal Al Awaynat area are the ring complexes of the Cenozoic age. These ring complexes comprise Jabal Babein, Jabal Bahari, NE of Jabal Al Awaynat, and Jabal Arkenu, which is the area of interest. Jabal Arkenu ring complex is a massif in the south-eastern corner of Libya. It borders the Kufrah Basin at its south-eastern edge. Jabal Arkenu can be classified into two units; the first unit contains the different kinds of Precambrian basement rocks overlain by Palaeozoic sediments; (Cambrian sediments) that are present at the flanks of Jabal Arkenu and separated by an erosional surface. The second unit includes ring complexes, and both units have the same height [6][7]. Jabal Arkenu ring complexes illustrate repeated igneous events that are overlapped with each other with a shift in the centers towards nearly the southwest [6] (Fig.2-a).

According to Flinn, [8] The ring complexes were formed almost at the surface by the emplacement of a highly Feldspathic magma. On the economic level, there are some possibilities that iron-quartz veins in the north and east of Jabal Arkeun contain sources of both gold and silver. [9].

Geomorphologically, Jabal Arkenu is a ring mountainous area that is composed of phonolite, syenite, nepheline syenite and granite. It is characterized by a belt of longitudinal sand dunes (Seif Arkenu, and Seif Al Awaynat) stretching in the northeast-southwest direction. Besides that, the study area is dissected by two wadies (Wadi Al Debban and Wadi Caldera) running in E-W and N-NW directions. The highest elevation of Jabal Arkenu based on the Alos Palsar Satellite produced by the Alaska Satellite Facility [10] is 1384 m (Fig.2-b). Moreover, it is surrounded by flat or gently undulating plains that lay mostly below 600 m. These plains are composed of sand or gravelly sand and they exist beside the Sief dunes or as separate areas distributed all over the area. At the base of Jabal Arkenu and several kilometres away from the mountain margin, the outwash fans occur. They are mainly composed of boulders, gravel and sand whose size becomes smaller far away from the base of the mountains [6].

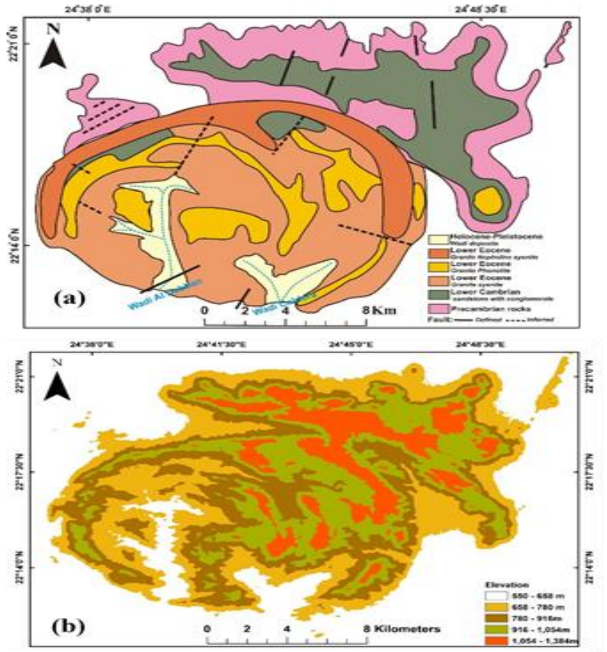

Figure. 2. a) Geological map of Jabal Arkenu, modified by authors. b) Elevation map of the study area.

4. MATERIALS AND METHODS

This work was done by using digital elevation models with a spatial resolution equal to 12.5 meters from open-source satellite data ALOS PALSAR produced by the Alaska Satellite Facility (ASF) on (https://search.asf.alaska.edu/#/)[10]. A virtual simulation of sunlight and shadows was made on Jabal Arkenu via an environment tool in ArcMap 10.5. Considering that Jabal Arkenu is an uninhabited area with a high altitude, well-exposed rocks, and no vegetation cover or natural obstacles, the ideal height angle of light for simulating sunshine in the Arc Map is 45 degrees.

In addition, PCI Geomatica 2016 was used for extracting the linear features using the logarithm, and finally, direction analysis by using RockWorks16.

5. DATA PROCESSING AND LINEAMENT EXTRACTED

The process of extracting the linear features was carried out in three stages by using digital elevation models and the effect of shadow on the area. In the first stage, eight separated images were produced in eight azimuth directions of light, which represents the light within the ArcMap10.5 program. The eight distinct azimuth orientations that were used to create eight images are (0, 45, 90, 135, 180, 225, 270 and 315); (Fig.3, 4 and 5).

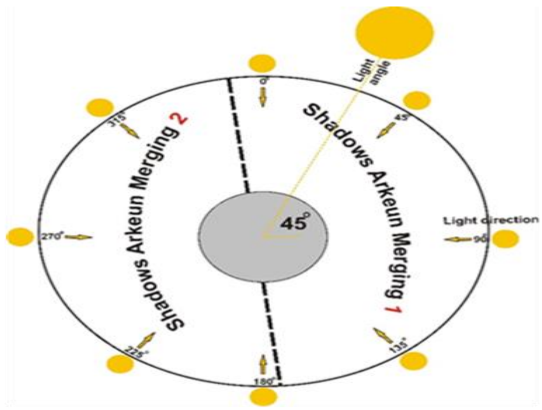

Figure. 3. Illustrates the various illumination directions and the height angle of sunlight for producing shadows on the area.

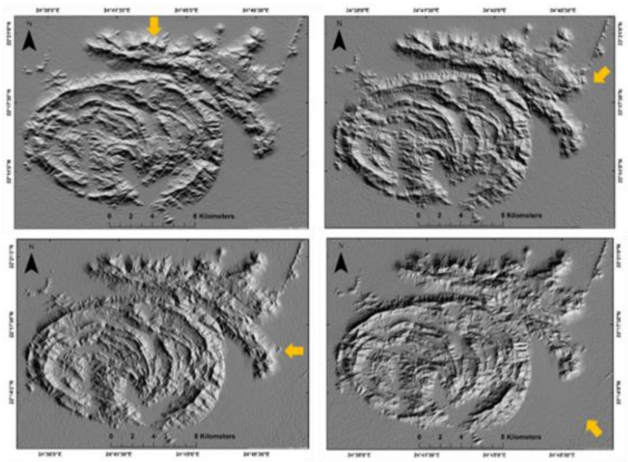

Figure. 4. Shows the first four shaded relief images derived from simulating the sunlight in four azimuth directions (0, 45, 90, & 135); the yellow arrows represent the direction of applied light on the DEM.

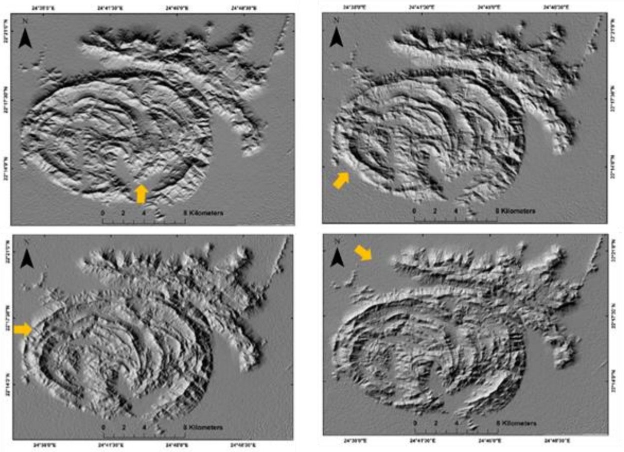

Figure.5. Shows the second four shaded relief images derived from simulating the sunlight in four azimuth directions (180, 225, 270, & 315); the yellow arrows represent the direction of applied light on the DEM.

The second stage is to merge the eight images into two shaded relief images, each with several azimuth orientations. The first merged shaded relief image was named Shadows Arkeun Merging 1 (SAM-1) including (0, 45, 90, 135) as azimuth orientations, and the second merged shaded relief image was named Shadows Arkeun Merging (SAM-2) with (180, 225, 270, & 315) as azimuth orientations (Fig. 6).

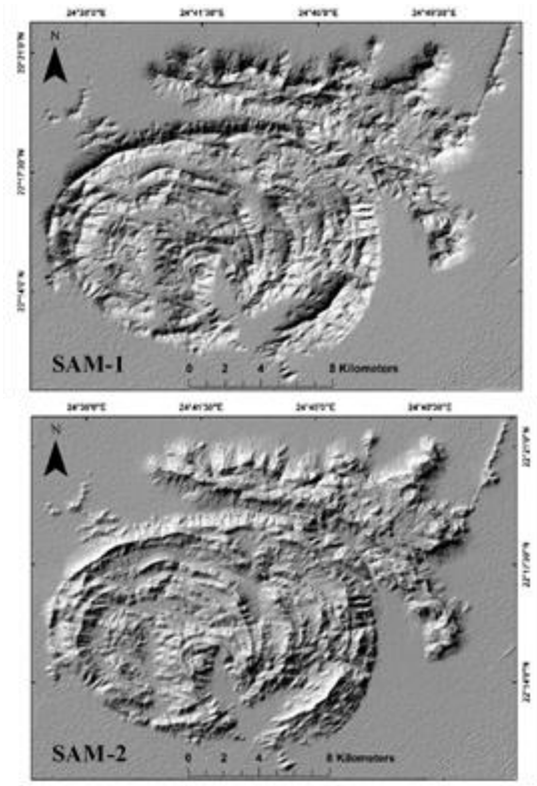

Figure. 6. Represents the two shaded relief images (SAM-1 and SAM-2) that were created by combining the first four shaded relief images for (SAM-1), and the second four shaded relief images for (SAM-2).

In the third stage, when extracting the automatic linear features in both images (SAM-1 & SAM-2) for the purpose of study and comparison, a PCI Geomatica program was used. (Fig.7).

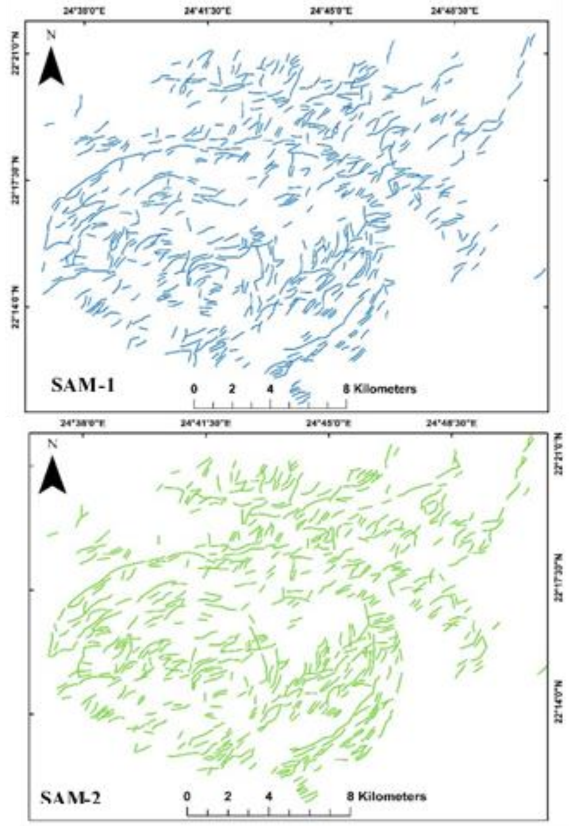

Fig.7 Two lineament maps of shaded relief images by PCI Geomatica.

Figure.7. Shows two generated lineament maps of shaded relief images by PCI Geomatica.

6. GEOSPATIAL ANALYSIS

Length of lineaments

The lengths of lineaments in the generated maps range from 0 to about 6000m long, and they have been classified into three categories: very short (0 to 2000m) short (2000 to 4088m) and extensive (4088 to 6000m). A total of 600 lineaments from the SAM-1 and SAM-2 have been selected to find an agreement between the number of lineaments' frequency and their length in both maps. As a result, in both maps, most of the areas are mainly controlled by lines less than 1100 meters (Fig.8).

However, the most extended length of the lineaments occurs on the flanks of Jabal Arkenu and in the central part (Fig.9). It is possible that, in addition to the variation in the existing rocks which are dominated by distinct granite rocks that have limited faults displacement, the research area has been affected by a displacement motion.

Table 1: Statistics of total automatic extracted lineament.

	SAM-1	SAM-2
Count	603	615
Max	4505m	4544m
Min	375m	375m
Sum	424Km	434Km
Mean	0.703	0.707
Standard Deviation	0.37694	0.37916

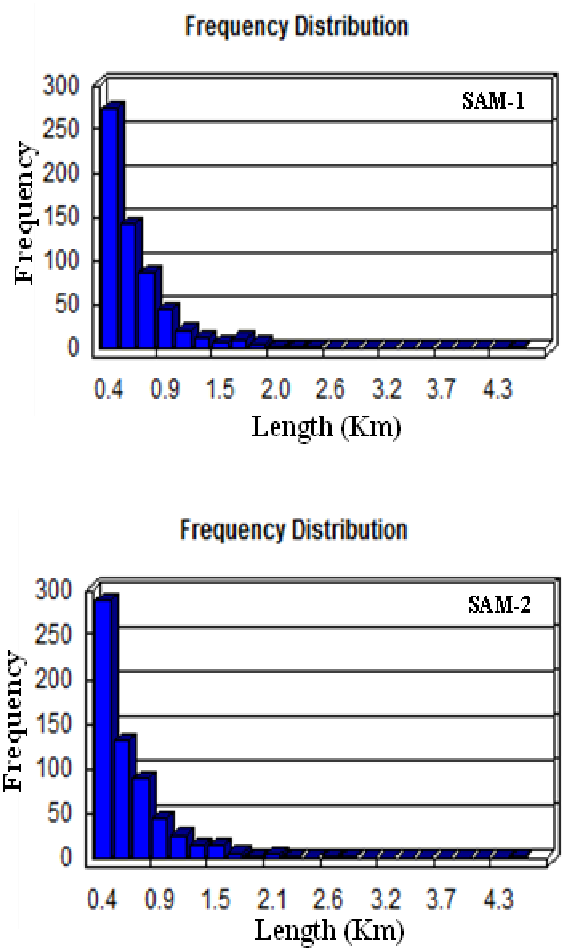

Figure. 8. Two frequency distributions of automatic extraction lineaments.

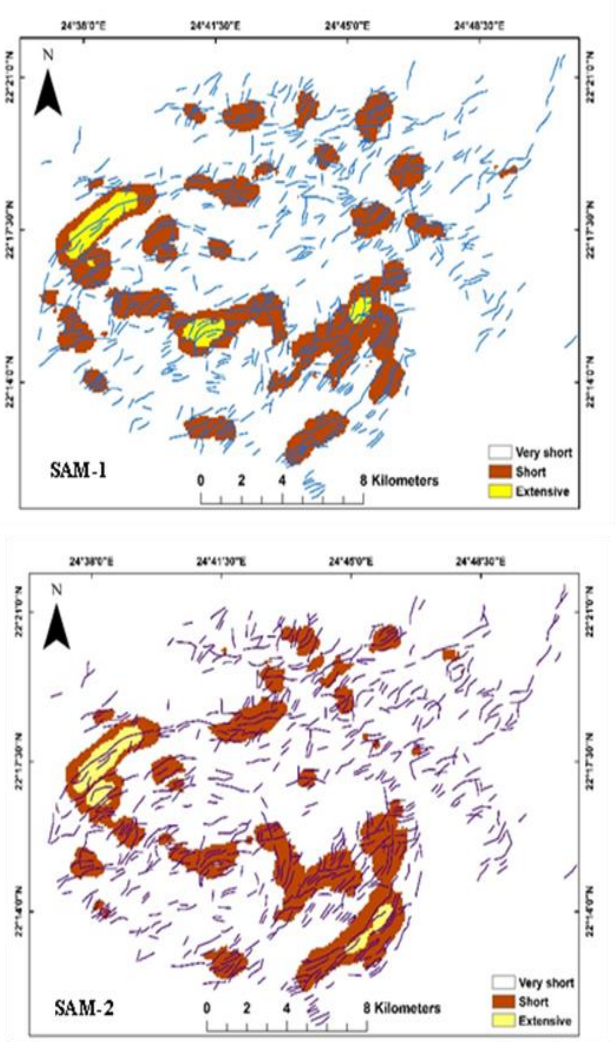

Figure.9. Shows the length maps lineament of SAM-1 and SAM-2.

Lineament Density

The lineament density analysis which is also known as lineament-frequency can be defined as the frequency of the lineaments per unit area [11]. According to [12] and [13], lineaments represent the total length of lineaments in a unit area divided by the total area. The average lineament density in Jabal Arkenu in general is 1.5 in total area. However, the lineament density in the study feature was classified into four categories; low (0 – 0.9), moderate (0.9 – 1.9), high (1.9 – 2.9), and very high (2.9-3.8) (Fig.10).

The central part of Jabal Arkenu is dominated by high to very high lineament density, while the greater part of the study area is characterized by medium to low lineament density. Interestingly, the high-intensity lineament is compatible with higher altitudes (see Fig.2).

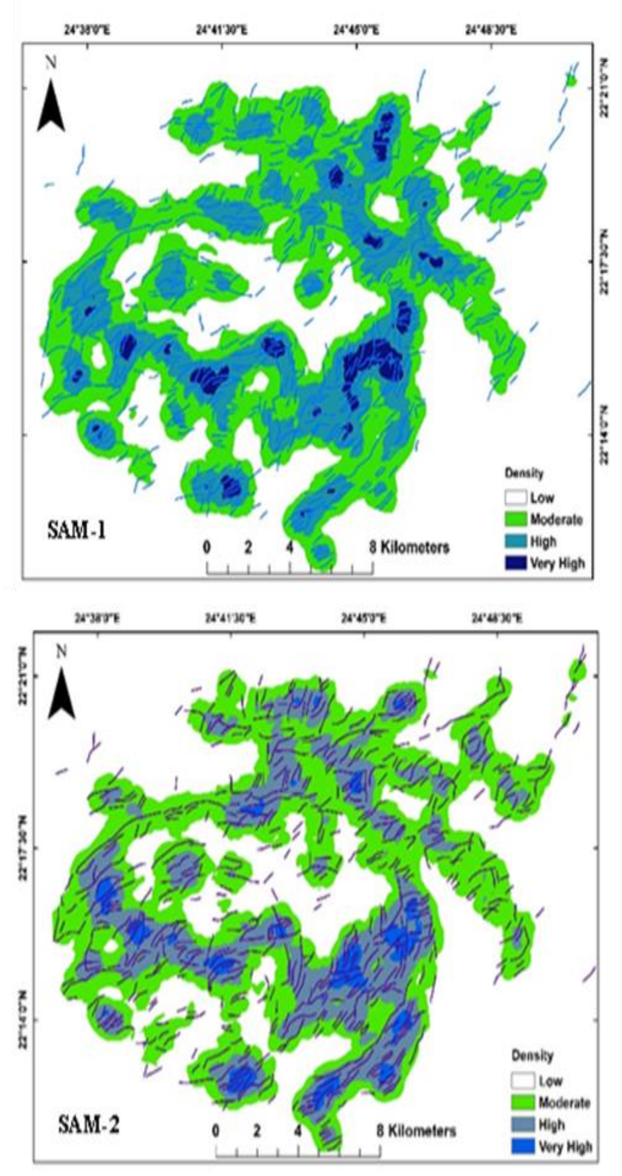

Figure.10. Illustrates the density maps lineaments for SAM-1 and SAM-2.

Lineament intersection

Lineament intersection is a plan value frequency of intersections that occur in a unit cell. The intersection map is used to approximate the regions of different linear directions [14]. The intersection maps of SAM 1 and SAM 2 show that the generated lineaments are generally parallel to each other (Fig. 11-a). The point intersection map was created to locate intersections of lineament that cover the entire study area (Fig.11-b). From overlapping the SAM-1 and SAM-2, it can be seen that most of the lines on both maps are matching with slight differences in directions.

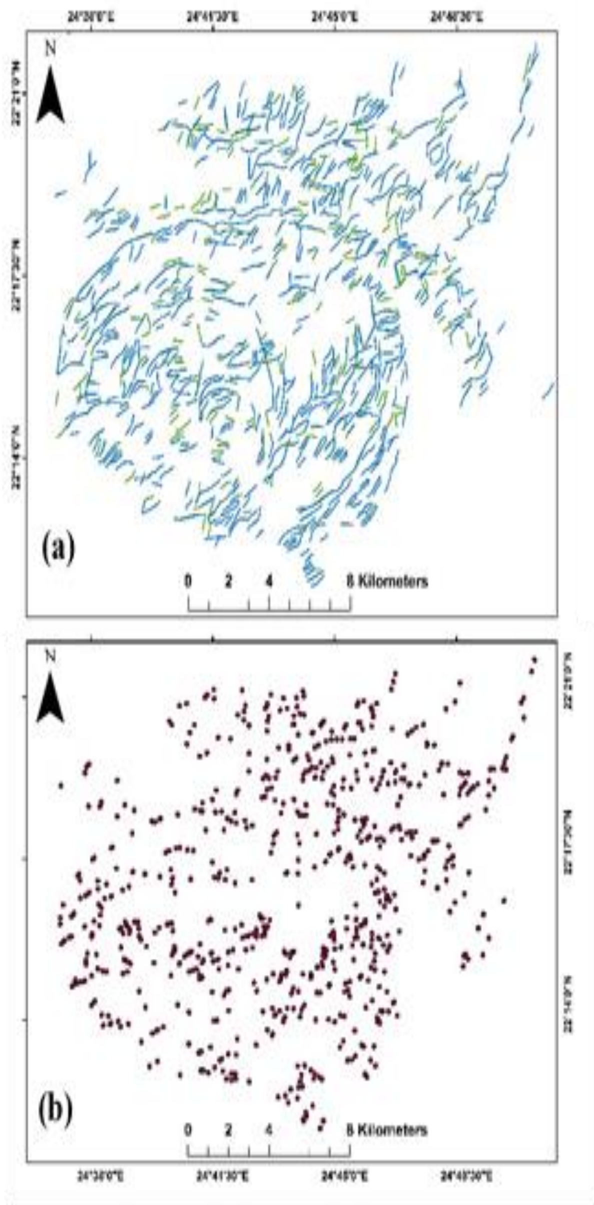

Figure.11 a) Intersection map of SAM-1 and SAM-2

b) Point Intersection map

Orientation of the lineaments

The lineaments direction is one of the methods for studying the linear feature. The dominant direction of the analyzed lineaments on both maps is in a northeast direction, and they are concentrated in the north and south parts of the area. Whereas the least dominant direction is the northwest which is concentrated in the middle Jabal Arkenu (fig. 12).

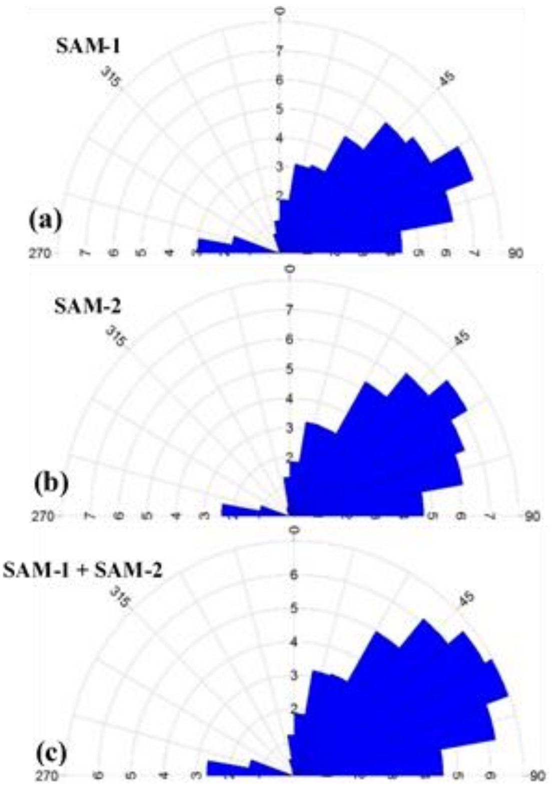

Figure.12 Rose Diagram a,b and c of the lineaments in the study area showing dominant trends of NE-SW direction

Lineament analysis

The concordance is shown in terms of number, length, and density Lineament in two maps (SAM-1 and SAM-2) (fig. 9, and 10). This reflects the compatibility of the terrain on both maps and the absence of large cliffs which could affect the appearance of lineament. Moreover, the lineament features surround parallel to the entire Jabal Arkenu in the form of a ring in a northeast direction.

According to [15] and [16], the high-value of lineament density zone contains the majority of faults and major weak zones, irrespective of the types of faults. Accordingly, in the study area, the entire region is characterized by medium density 1.5km^2, while the flanks, where there are both Cambrian sandstone on the west and lower Eocene granite syenite on the east, is high density. Therefore, the lineament density statistics indicate that there are weak zones with a strong fracturing effect.

From the visual comparison, the intersection lineament map (fig. 11 a and b) shows an absence of clear intersections and the presence of a high density of parallel lineament whereas the density is concentrated in the edges (fig. 10), in the northeast direction of Jabal Arkenu.

According to [6], most faults are strike-slip faults, which explains the lack of visible intersections or significant overlaps. It moreover shows that there is not much compression or reverse fault productivity.

By comparing the structural relationship and the existing lithology, some linear features exist as a boundary between Nepheline syenite with Cambrian Sandstone and Phonolite with Syenite granite. However, some linear features crossed different lithology toward the E-W direction (Fig.13) and they are concentrated in the Precambrian rocks. Therefore, it is possible that these areas of high lineament density are concentrated fault zones.

For validation of the extracted lineaments, the Geological map of Jabal Arkenu that was published by the Industrial Research Centre (IRC) of Libya is visually superimposed with the point density intersection map (Fig. 13). Many faults in the published geological map (Fig.2) have been identified on the flanks and in the surrounding area of study, which are in line with the results of the lineament extraction using (ASF) DEM used in this study.

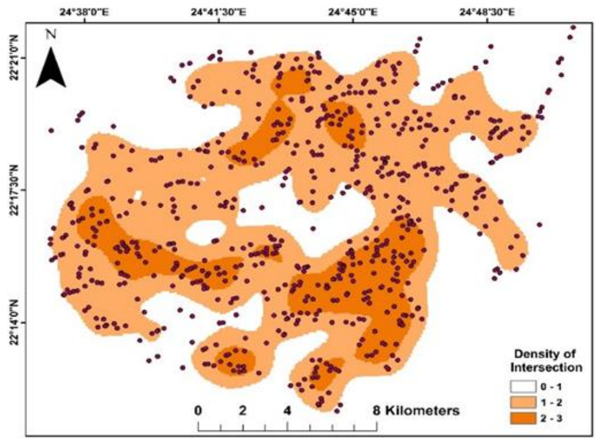

Figure.13 Illustrates the density map of point intersection between SAM-1 and SAM-2.

7. CONCLUSIONS

Jabal Arkenu is an area of widespread fractures that are mostly in parallel directions in the northeast, which makes them difficult to discriminate with local faults. in addition, the area is rich in strike-slip faults with low displacement, which are concentrated in the flanks and some areas in the middle. Finally, the area is less impacted by weathering and erosion, due to the young age of the ring granite intrusions that control the entire structure of the area.

8. RECOMMENDATION

This research is based on automatic extraction of the linear features. It is possible that this topic of study needs a manual extraction to be carried out with another sensor and compared to reclassify all the structure features on Jabal Arkenu.

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