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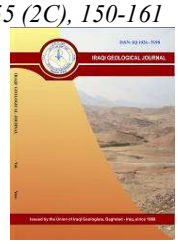

Lineament Analysis by Using Remote Sensing and GIS Technique of Sangaw Area, Kurdistan Region, NE Iraq

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Abstract

Recently, structural lineaments have typically been increasingly emphasized in morphotectonic research because they are thought to be an excellent guide for determining tectonic settings and fracture zones in rocks. ERDAS Software was used to extract and analyze the lineaments within the Sangaw area, which is located in the northeastern part of Iraq. This study employed a Digital Elevation Model from the Shuttle Radar Topography Mission with a resolution of 30 meters. Directional filtering was used to extract the lineaments in four distinct directions (N-S, E-W, NE-SW, NW-SE). The overall trend's direction of the lineaments is determined to be NW-SE, indicating that the area was succeeding the main tendency of Zagros folds. According to the density map of the lineaments, the low and medium-density lineaments occupy the main portion of the study area. The direction of the maximum tectonic stress and the rotation of the Arabian Plate counterclockwise led to the formation of joints in multiple directions, which were clarified by the system of lineaments' relationships in harmony with the directions of the tectonic stresses and their contrast and effects. The field study showed high density and distinct activity in the study area of erosion and weathering processes as well as tectonic.

Keywords: Structural lineaments; Tectonics; Sangaw Area; Lineament density

1. Introduction

For many years, geologists have been researching structural lineaments. The term lineament was coined in the twentieth century and established by Hobbs (1912). Cliffs, significant structural ridges, valley terraces, valleys, and stream and river courses are typical landform representations of lineaments, which may have morphotectonic implications. In general, lineaments are the result of structural displacement or zones of weakness in the crust of the earth. Most tonal contrast utilized to determine lineaments is accounted for variations in moisture content, vegetation, and rock or soil composition (O'leary et al., 1976). The science and art obtained data by a remote device and analyzing it is known as remote sensing. In geomorphological and geological studies, remote sensing has become an essential tool for geological applications. Within the field of geology, one of the applications of remote sensing is the extraction and analysis of lineaments. The adoption of remote sensing techniques with radar data has proven highly efficient in determining many structural discontinuities, especially the derivation of linearity and determining their density or direction. Recently, the application of images processing has

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taken an important place in the geological aspect, especially in the detection and investigation of minerals, rocks, and hydrothermal alteration zones, as well as in the study of linearity in form of extraction, mapping, analysis, or found its general direction (Rowan and Bowers, 1995; Thannoun, 2013; Othman and Gloaguen, 2014). Lineaments derived from multispectral remote sensing satellite images create confusion since they include anthropogenic structures, whereas lineaments extracted from a Digital Elevation Model (DEM) depend exclusively on elevation data, rather than the tonal variation of features; as in satellite images. The study of lineaments is related to several fields and is a good indicator of the structural condition, morphology, groundwater and mineral accumulations (Hubbard and Thompson, 2012; Aziz et al., 2021; Thannoun et al., 2021).

The goal of this study is to apply remote sensing techniques in terms of lineaments extraction, analysis, density mapping, or detecting general direction to indicate geological structures (Singh et al., 2021), water and hydrocarbon seepages (Palamakumbura et al., 2020; Enoh et al., 2021), as well as slope stability (Choanji, 2016; Choanji et al., 2018), and drainage pattern (Singh et al., 2021). The selected area is sited in the NE of Iraq, on the border between the governorates of Sulaimaniyah and Kirkuk, it is about 1480 km^2 and stretches from Latitudes 44°55' to 45°26' N and from longitude 35°07' to 35°27' E, (Fig.1).

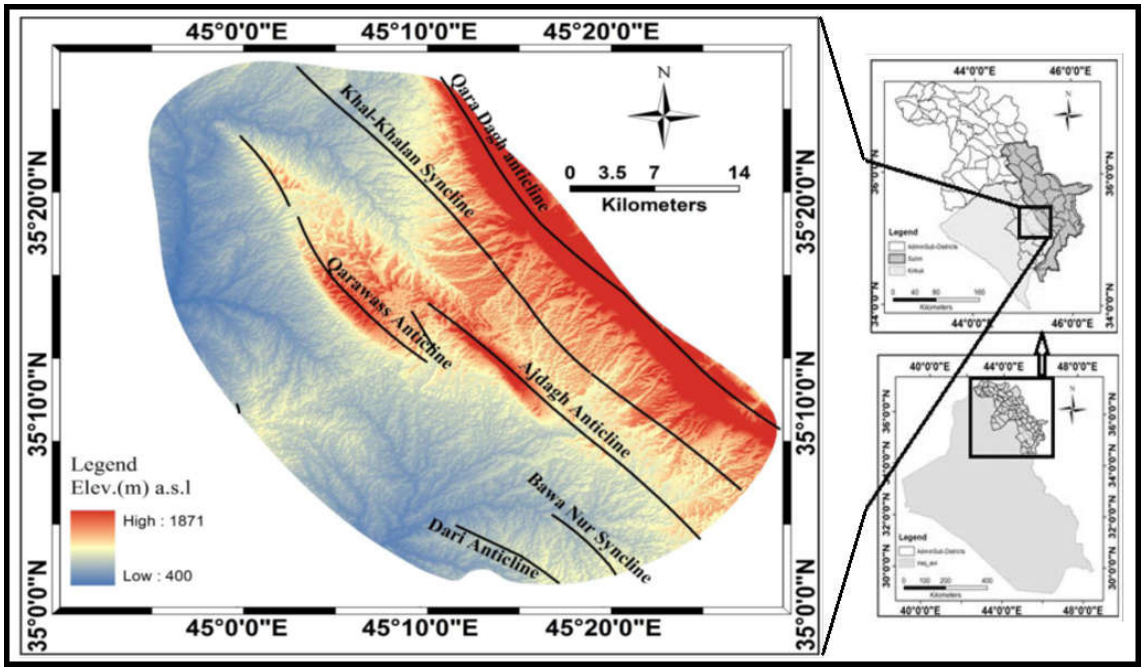

Fig. 1. The geographic location of the Sangaw area shows the DEM with the main structures.

2. Geology

The study area is ranging in heights from 400 m to 1871m a.s.l., the highest area mostly covers the northeastern part within Qara Dagh Mountain and within Ajdagh anticline (Chamchamal south anticline) and in the middle parts within Qarawass anticline, (Fig. 1). Tectonically, the study area is situated within the Low Folded Zone and High Folded Zone in the western part of the Zagros Fold–Thrust Belt according to the tectonic subdivision of NE Iraq (Al-Qayim et al., 2012; Sissakian and Fouad, 2015). In general, the folding and faulting of the main structures in northeast Iraq have formed from several phases of deformations for the period of the Alpine Orogeny. The trend of the folds and the strike of the beds are generally in the NW-SE direction following the main trend of Zagros folds.

Structurally, many folds are distributed through the study area as anticlines and synclines; the main folds are Qara Dagh anticline, Khal – Khalan syncline, Ajdagh anticline (southern part of Chamchamal

anticline), and Qarawass anticline. All the fold axes are oriented NW-SE direction coinciding with the main trend of Zagros folds.

Stratigraphically, many stratigraphic units are exposed in the study area, ranging from Lower Cretaceous to Quaternary deposits, those formations are presented in the geological map of Iraq (Sissakian and Fouad, 2015), (Fig. 2 and Table 1). Many geological formations from Pliocene to Paleocene are distributed within the study area; they are the Kolosh, Sinjar, Gercus, Pila Spi, Fatha, Injana, Mukdadiya, and Bai Hassan formations. The main Quaternary deposits in the area are: Slope sediments, which are represented by rock fragments with fine clastics, and depression fill sediments, which are represented by silt and mud.

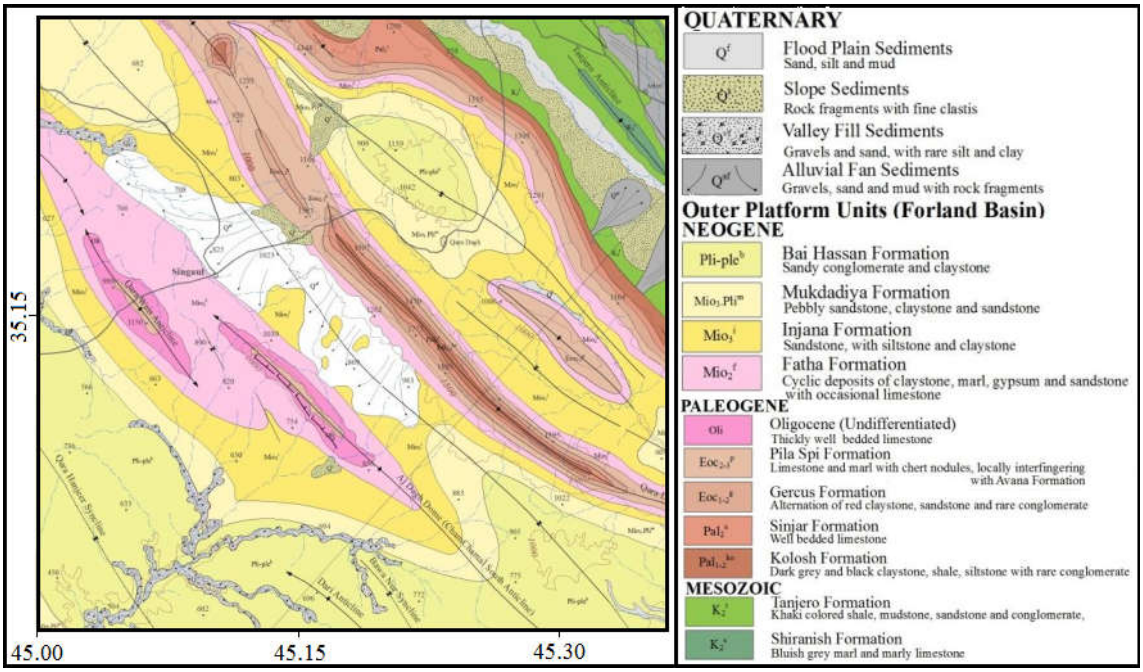

Fig. 2. Geological map of the study area, (After Sissakian and Fouad, 2015).

Table 1. The rock description of the formations within the study area.

Formation	Age	Description
Bai Hassan	Pliocene – Pleistocene	Thick and coarse conglomerates, alternated with thick reddish-brown claystones, and thin sandstones
Mukdadiya	Late Miocene – Pliocene	Claystone, grey and coarse sandstone, and rare thin layers of conglomerate, some of the sandstone beds are pebbly
Injana	Late Miocene	Reddish-brown sandstone and claystone
Fatha	Middle Miocene	Limestone and green marls with red claystone and rare gypsum
Pila Spi	Middle-Late Eocene	Well bedded limestone, dolomitic, clayey, or chalky with limestone and rare yellow marl
Gercus	Middle Eocene	Red clastics, mainly claystone, siltstones, and sandstones
Sinjar	Early Paleocene – Early Eocene	Limestone, massive and thickly bedded, crystalline, and fossiliferous
Kolosh	Paleocene – Lower Eocene	Black shale, claystone, sandstone, siltstone with rare conglomerate

3. Materials and Methods

3.1. Fieldwork

Field study shows successions of hard and soft rock formations (Fig. 3). This phenomenon may fit in correlation with the lineament's distribution and density. Hard rock formations imply the appearance of good lineaments, whereas soft rock formations indicate uncertainty and disappearance. The majority of the traced lineaments within the brittle rocks are caused by the discontinuity surfaces, while the soft rocks show weak lineaments, which are difficult to be traced (DesRoches et al., 2018).

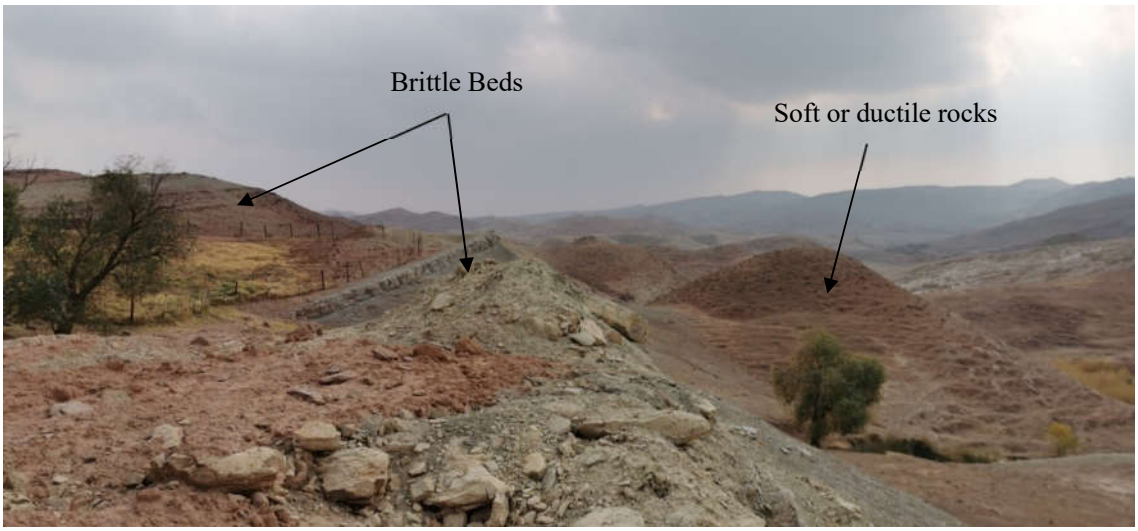

Fig. 3. Hard beds in the Gercus Formation on the left indicate the good appearance of lineaments in this area and soft rocks on the right

3.2. Desk Study

The desk study includes the processing of remote sensing data.

3.2.1. Digital elevation model

Digital elevation models are essential for geological and geomorphological studies using satellite images, especially in mountainous regions. Topographic information benefits from DEM, which may better describe the distribution of terrain components that contribute to spectral response (Giles and Franklin, 1996). Digital image processing processes and digital elevation analysis by an active method were used to extract lineaments from a DEM with a resolution of 30 m.

3.2.2. ERDAS Software

Throughout this study, a subset of the digital elevation model was analyzed by the user processing within the LINE tool of ERDAS Software for automatic lineaments extraction. All potential linear features that can be represented in fracture zones are included in the extracted lineaments. The ERDAS Software was used to extract lineaments in four directions (N-S, E-W, NE-SW, and NW-SE), which was found to be the most appropriate method. The four maps were then combined to create a single map depicting the distribution of the lineaments within the research area. The resulting map of the digital processing within ERDAS Softwares was used as a base map to find the general trend direction of the lineaments within the study area by drawing a rose diagram.

3.2.3. Rose diagram

The rose diagram is employed to determine the length, orientations, and directional frequency of the lineaments that represent the discontinuities arising from tectonic movements and geological processes, which influence the circulation of groundwater and oil migration.

3.2.4. Lineament density

In contrast to azimuth histograms, lineaments are usually studied using frequency or length (Mostafa and Zakir, 1996) (Zakir et al., 1999), and rose diagrams (Karnieli et al., 1996), and/or the maps of lineament density (Zakir et al., 1999). The most typical method for determining lineament density is to utilize the total length of lineaments per unit area (km/km^2), the total number of lineaments per unit area (number/km^2), or a combination of both, as it was done in this study.

4. Results and Discussion

Remote sensing and GIS technology were applied and provided ability in the analysis and interpretation of special linear data relationships. The general trend direction of the lineaments within the study area is found to be NW-SE, which means that the area follows the main trend of the Zagros folds. The lineaments are distributed within all directions in the study area, but their abundance in the NW-SE direction is more than the other directions. The lineaments are distributed within all geological formations within the study area, and it is higher in the Pila Spi, Fatha, Injana, and Mukdadiya formations. The condition would be due to the succession of these geological formations and their differentiation from hard rocks that are interbedded with soft rocks. The study area is classified according to the lineament's density from low to high density. The medium and high densities cover most parts of the area. The classification depends on the most common elements of generalization in use, and it is a thought process for assembling phenomena with similar characteristics to gain relative simplicity (Robinson, et al., 1995). The direction of shear fractures is Sigma 1, while the direction of extension fractures is Sigma 2. In the study area, the zones of the medium and high lineament densities may be feasible zones for groundwater exploration. Most of the study area is affected by soil erosion in the zones of the medium and high lineament densities.

The rose diagram of the study area (Fig. 6) shows that the general trend direction NW-SE represents the direction of the folds, faults, and lineaments direction. The main trend of the lineaments as a bearing is NW-SE, and can be given as azimuth (135°-315°), which means the area is affected by NW-SE orientation folding, and the deposits were uplifted within the Arabian-Eurasian collision event, especially within Zagros Fold – Thrust Belt. As part of the Alpine-Himalaya mountain system, the Zagros orogeny is a distinct active doubly-divergent and asymmetric orogeny band (Alavi, 2004). As a result (Figs. 4, 5, and 6), paleo stress trends were tentatively brought out, where the maximum stress component (σ1) is normal for the axial folding surface in the direction NE-SW, and the intermediate stress components (σ2) coincide with the fold axis, as well as the minimum stress component (σ3) normal to the plane comprising the orientation of both components (σ1) and (σ2). According to Hung, et al. (2005), the most common method for determining lineament density is based on the number of lineaments per unit area (number/km2), the total length of the lineaments per unit area (km/km2), or a combination of both. The zones of medium and high lineaments densities cover mostly middle parts of the area which could probably be feasible zones for groundwater prospecting, with regards to lineaments and rock types. Water development is regarded to be better in areas where there are a lot of lineaments.

The various lineaments detected are distinguished by their trend and length variations have formed in certain parts of the study area as a result of two factors. The one by constructing regional structural units that characterize the recent phase of folding in the Iraqi Foreland Zone (Al-Azzawi, 2003). Second, faults in this area are associated with the lineaments.

The output of the ERDAS software revealed that the main directions of the lineaments in the study area were in four directions (N-S, E-W, NE-SW, and NW-SE) (Fig. 4). The most concentration of the main linear direction was towards NW-SE, and this completely coincides with the direction of the strike of the bedding and tension joints (Fig. 5A), as well as the valleys were carved in the same directions (Fig. 6). The direction of the valleys can change in the direction of the dip joints (Plate 2), and thus it can be concluded that the valleys were carved as a result of the structural control.

The rose diagram (Fig. 7) confirmed the focus of this trend as well, which indicates the congruence of the results, through which it is possible to determine the direction of the main tectonic force that affected the area regionally and led to the formation of folds in this direction (Fig. 8). As shown in Fig. 8, the dominant trends in the lineamsntes' directions include (N-S, E-W, NE-SW, NW-SE). In this context, about 45% of the extracted lineaments length falls in NW-SE trend. The relationship between the extracted lineaments in each one of the produced maps in lengths and number (frequency) is shown in Fig. 9 and the distribution of each trend is shown in Fig. 10. The total number of the lineaments generated in different directions is 245. The number of the lineaments in N-S, NE-SW, E-W, and NW-SE, directions is 54, 55, 45, and 91, while the total length is 119, 142, 130, and 319 km, respectively.

The density of lineaments' map within the study area was created by using GIS and the density was divided into five classes as shown in Fig. 10. The density map of the average lengths of the lineaments can be used to define the fracture zone in the study area. The lineamnts' density map shows that most parts of the study area are classified as medium to high density, and this mostly covers the middle part of the study area (Fig. 11).

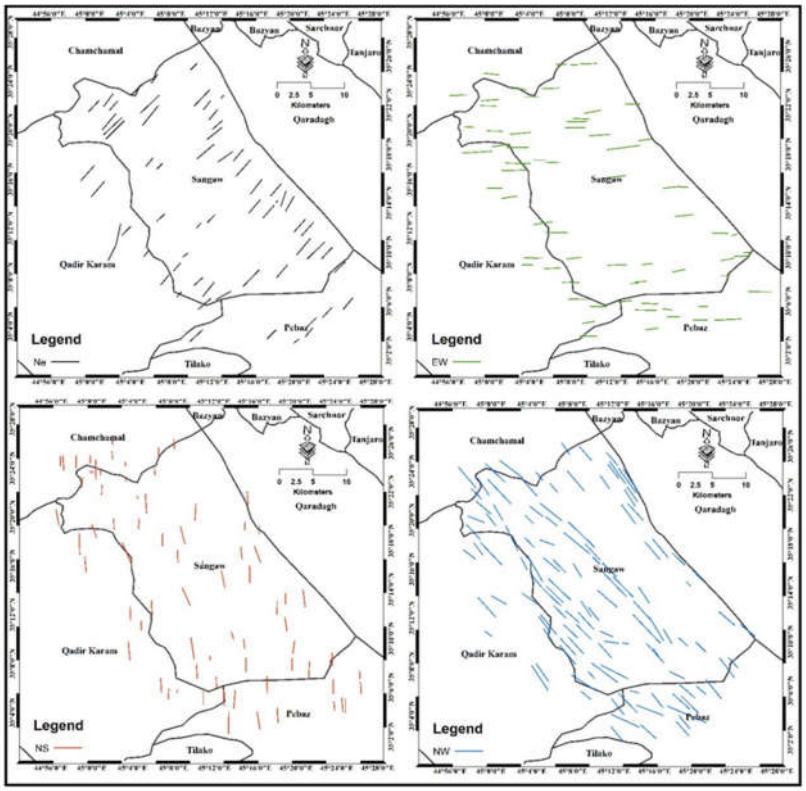

Fig. 4. Lineaments' maps within four principal directions (N-S, E-W, NE-SW, NW-SE)

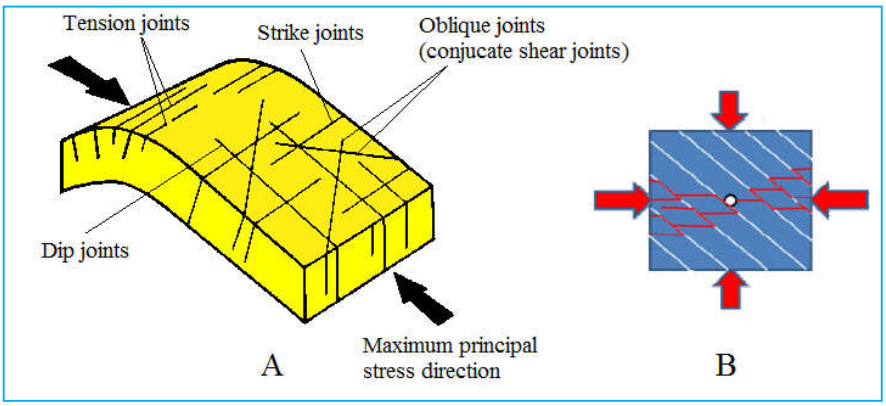

Fig. 5. The relationship between geologic structures, tectonic force, and lineaments. A: the tension joints close to the hinge of fold and strike joints on the limbs refer to the same direction of lineaments, while the dip joints refer to perpendicular to the previous, as well as the shear (oblique or conjugate) joints represent the acute and obtuse lineaments. B: explanation of the relationship between the principal and secondary directions and the angular relation between them.

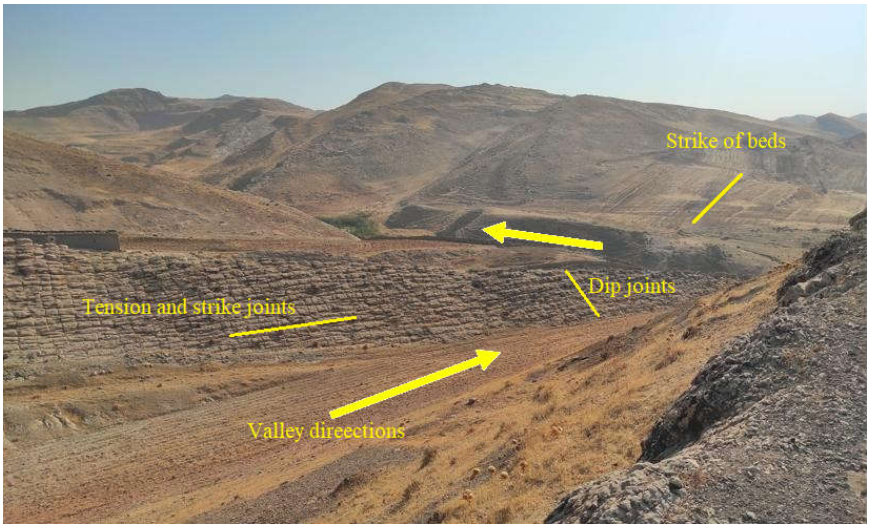

Fig.6. The structural control of extending the tension, strike, and dip joints, as well as the strike of beds on the directions of the valley.

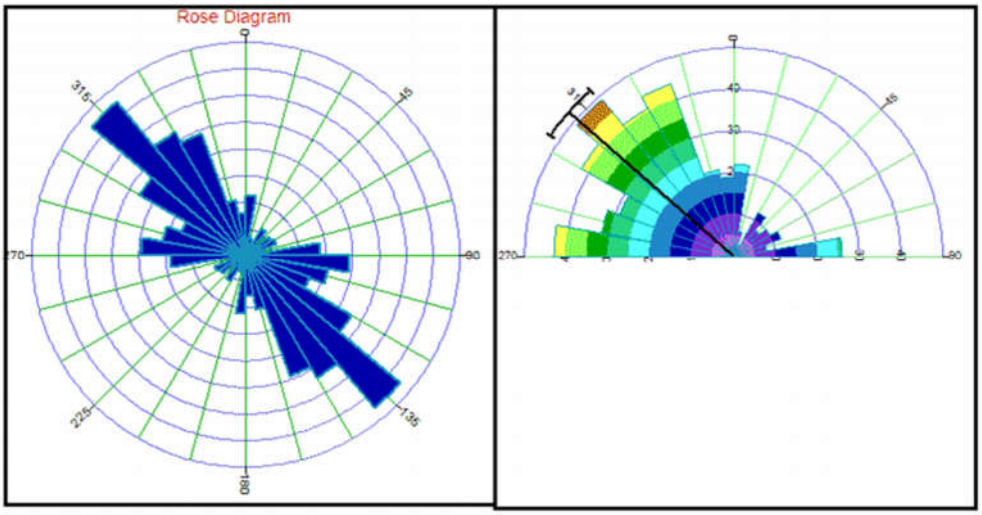

Fig. 7. Rose diagram of the studied lineaments, Left: shows the main directions and Right: the density according to the direction

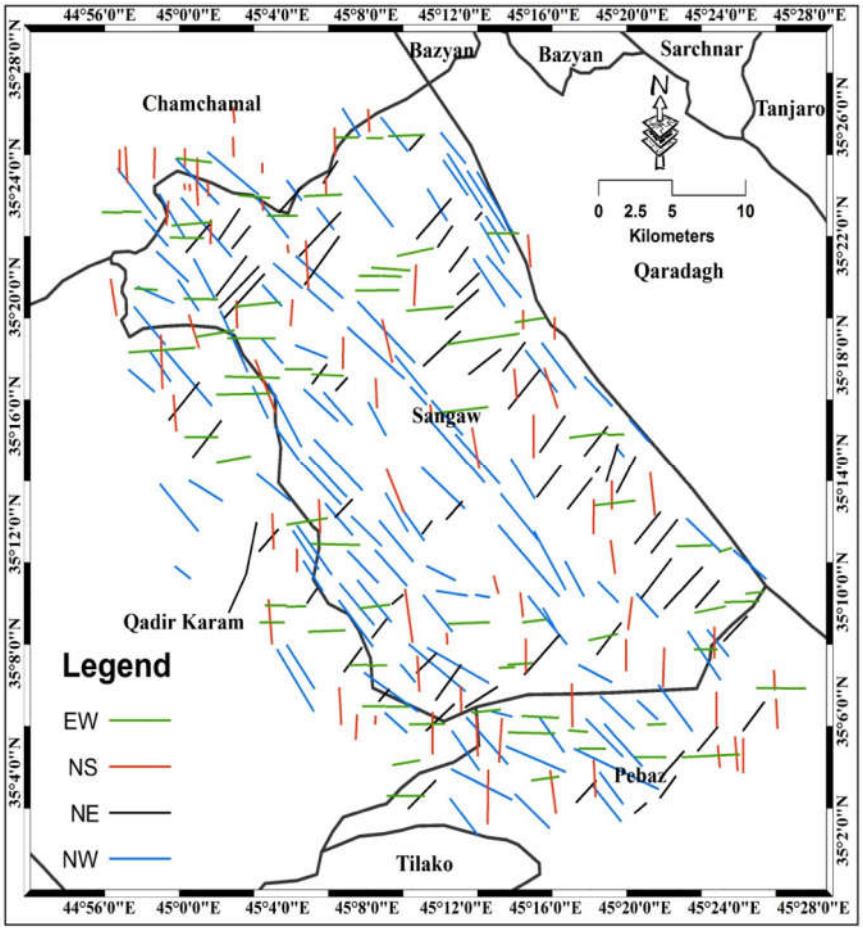

Fig. 8. Digital map of the dominant trends of the lineaments within the Sangaw area.

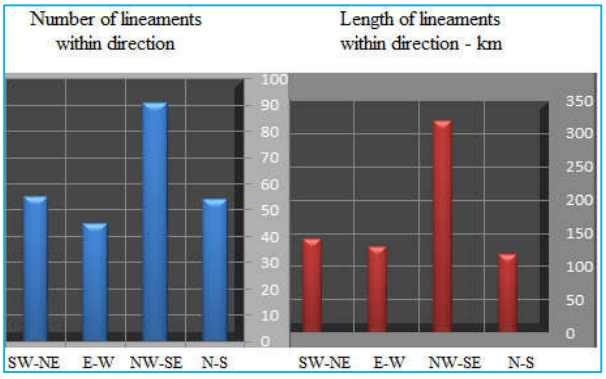

Fig. 9. Length and number of extracted lineaments

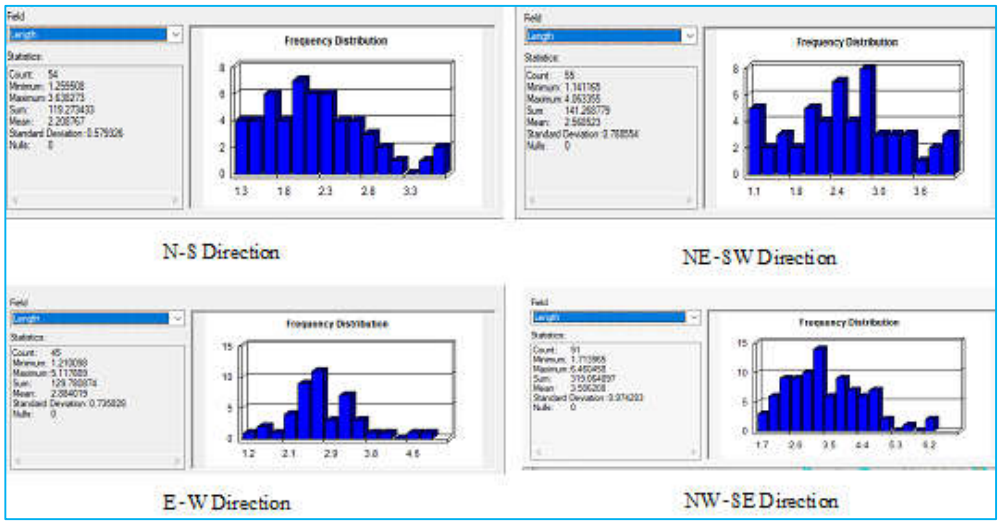

Fig. 10. Frequency information and statics data of the lineaments.

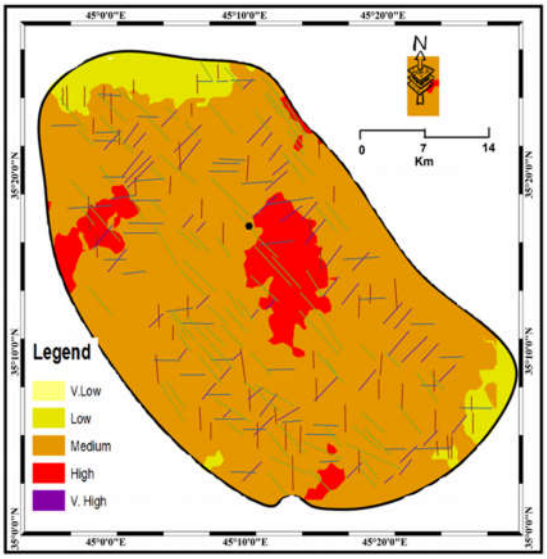

Fig. 11. Lineaments density classification map of the study area.

The NW-SE direction is the dominant direction in the lineaments in terms of length and number Fig. 9 because it represents the direction perpendicular to the direction of the great force of tectonic stresses, which is represented in the direction of the strike of the beds, strike joints, and tension joints close to the axes of anticlines or synclines with the same (Fig. 5A). The orientation of the geological structures of any area, including strike, dip, and fault orientations, is indicated by the trend of the lineament's orientations (Fig.12) (Arifin and Adnan, 2021). The great tectonic force led to an extension of the geological structures in the perpendicular direction and stretching it, so a high density in that direction represented the prevalence of dip joints Fig. 5. The acute angle between the direction of the common lineaments NW-SE with other E-W lineaments is the result of the formation of the shear joints so that the acute angle is in the direction of NW-SE, which resulted from the direction of the force as a result of the rotation of the Arabian Plate (Thannoun, et al., 2022). The Arabian-Eurasian plates collision results in the acute angular relationship between the NE-SW lineaments direction and the N-S direction lineaments, as these two directions of lineaments, are almost identical in terms of length and number (Fig. 8). The general pattern of the lineaments is evidently related to folding and is characterized primarily as longitudinal, transverse, and oblique lineaments (Zahmatkesh et al., 2015). It is evident from the aforementioned angular relationships that there is a great contrast between the intensity of the principal stresses generated by the Arabian-Eurasian plates collision (Fig. 5B). Actually, this contrast in the stresses, and the density of lineaments from medium to high refer that study area has been subjected to various stresses due to subduction and collision (Martin, et al., 2020).



Fig. 12. General view of bedding and joints in the study area.

5. Conclusions

The current study concluded that by analyzing the direction and density of the lineaments were developed at least in two stages and at successive times. The lines resulting from the processing of the DEM data are the representation of the trends of the joints and the strike of the beds that suffered from the weathering processes and which led to their appearance. It became clear by matching the direction and density of the lineaments that their concentration is in the areas of the hinge of the folds, that is, they are caused by the tensile joints, as well as the strike joints and the strike of the bedding. In addition, to the appearance of a high density in the northwestern part of the study area, which resulted from a large activity of weathering processes. The highest density of the joints was in the hinge of the Qara

Dagh and Ajdagh anticlines. This explanation is closely related to linear density, tectonic activity impact, and valleys distribution together.

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