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Comparison of Geological Structures and Satellite-based Tectonic Lineaments in Gülağaç (Aksaray) and its Surroundings

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Abstract

The study area covers the Gülagaç district of Aksaray and its surroundings in the Central Anatolia region of Turkey. The basement of the study area consists of metamorphic rocks belonging to the Paleozoic–Mesozoic-aged Kaman Group. Mesozoic-aged ophiolites overlie these rocks, and both are cut by Late Cretaceous-aged igneous rocks. These units were then overlain by Palaeocene-Quaternary-aged volcanic and sedimentary units. The region has important geological structures that have undergone polyphase deformation, especially in the Eocene units. As a result of these deformations, faults, fractures, folds and linearities were formed. . These structures were compared with satellite-based tectonic lineaments, and it was observed that the general orientations of the lines determined in the field and the satellite-based lineaments were largely compatible. The results of this study can make an important contribution to the exploration of mineral and geothermal resources in the region.

Keywords: Türkiye, Central Anatolia, Aksaray, Gülağaç, tectonic lineaments.

INTRODUCTION

The research focuses on Gülagaç and its surrounding regions located in the Aksaray province of the Central Anatolia region in Türkiye (Figure 1).

The study area is located within the Cappadocia Volcanic Province, where young volcanism is particularly intense. The region is particularly rich in geothermal resources. Currently, geothermal resource exploration continues in different parts of the region. This study will be a data source for the determination of geothermal areas. There are many studies on geothermal areas and tectonic lineaments in different parts of the world.

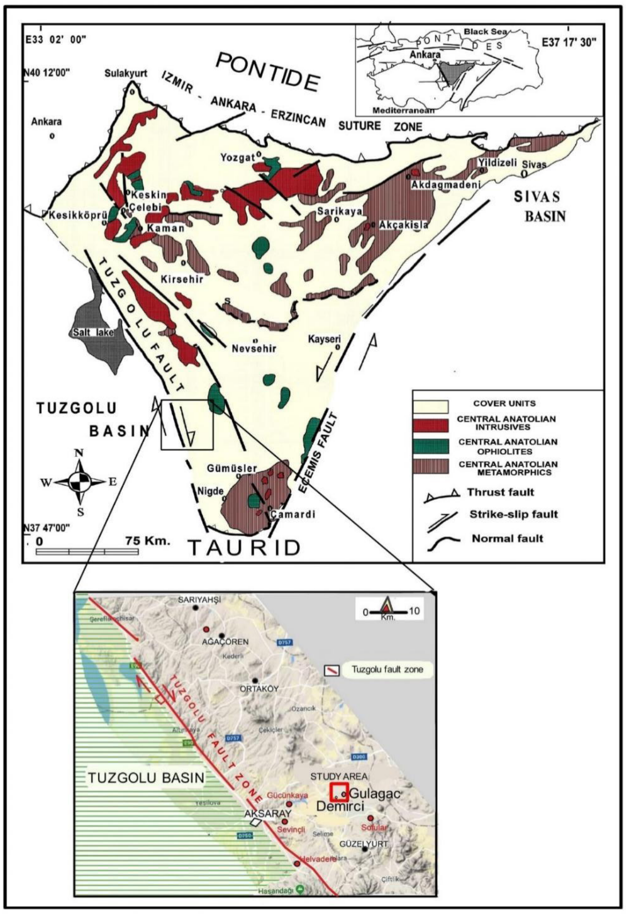

Figure 1 Central Anatolian Crystalline complex and study area (Modified from, [1]).

Previous investigations conducted in and around the study area have included sedimentological, petrographic, and structural geological studies.

Some of the sedimentological studies were carried out by [2-13]. Some of the petrographic studies in the study area were carried out by [14-21].

[22-27] conducted studies on the tectonic-neotectonic features of the study area. Similarly, [28-31] conducted studies on the Tuzgölü fault zone within this tectonic area. The study area is of great importance in terms of natural disasters, especially earthquakes, due to its proximity to the Tuzgölü fault zone. In addition, the geological structure of the rocks in the region increases the possibility of landslides and poses a potential danger. Geophysical and geological studies are very important in engineering studies in order to deepen the emergence of geological structures [32-35].

In recent years, lineament studies obtained by remote sensing have been frequently used in different fields of geology. Some of the studies on mineral deposits and their relationship with linearity are [36-39]. Linearity studies are available for the determination of geothermal areas. Some of them are [40-41]. There are also studies on the relationship between tectonics and linearity. Some of them are [42-45].

This study aims to compare the structures showing tectonic lineaments (fault, fracture, fold axis) observed in the Eocene-aged units in Demirci and its vicinity with the satellite-based lineaments.

MATERIAL AND METHODS

A geological map of the study area was completed during the fieldwork. The planes of the faults and fractures, which exhibited linearity, were measured and assessed.

The study area underwent a thorough evaluation by analysing the prior research and comparing it with the findings of this study. A meticulous review and assessment of both field observations and computer analyses were conducted to arrive at a comprehensive conclusion. For the computer analysis, a flowchart was created (Figure 2). The image is first analysed in Envi, Geomatica, and ArcGIS before being turned into a lineament map (Figure 5b). The generated maps do not contain any artificially constructed structures-only naturally occurring lines. During the field studies, structures such as field boundaries, roads, etc. that create lineaments in satellite images were identified, and these lineaments were excluded.

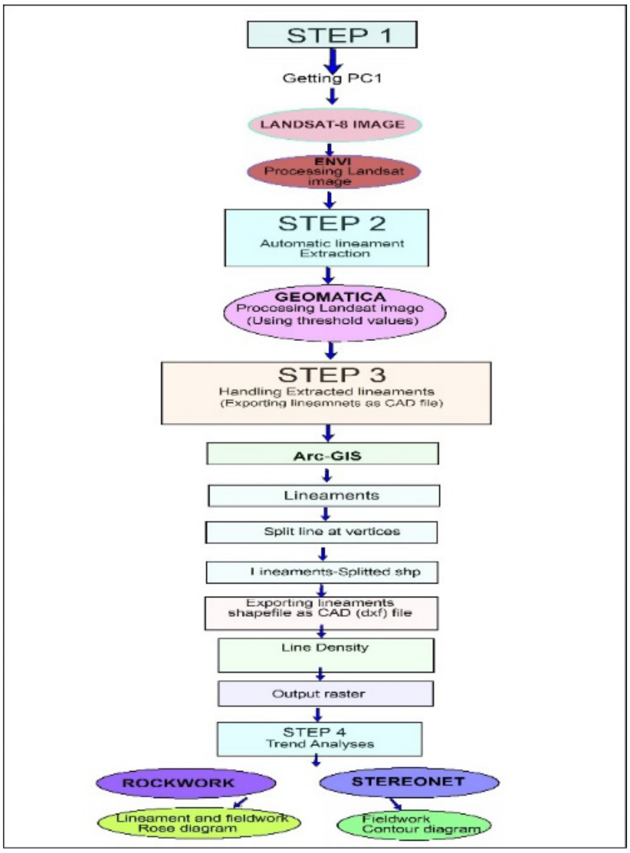

Figure 2 Flowchart of lineament maps and diagram preparation.

A thorough assessment was carried out by combining on-site observations with computerised analysis of satellite imagery. Figure 2 illustrates the lineaments obtained through computer programs. These results facilitated a comparison between the geological structures such as faults, fractures, and fold hinge lines in the Gülağaç area and the lineaments extracted from the satellite images.

GEOLOGY

Stratigraphy

This study is focused on the Gülağaç district and Gülağaç town in the Aksaray province, along with its surrounding areas. The Tamadağ and Bozçaldağ metamorphics, which belong to the Kaman Group of the Kırşehir Massif, are crucial in the basement rocks of the study area. The Tamadag metamorphites are mainly composed of gneisses and quartzites (Figure 3).

Bozçaldağ metamorphites are composed of marbles and amphibolites in interbeds with them. Central Anatolian ophiolites are thrust on these units. These units were cut by Late Cretaceous aged Central Anatolian igneous rocks such as granite, granodiorite and syenite (Figure 4). [46].

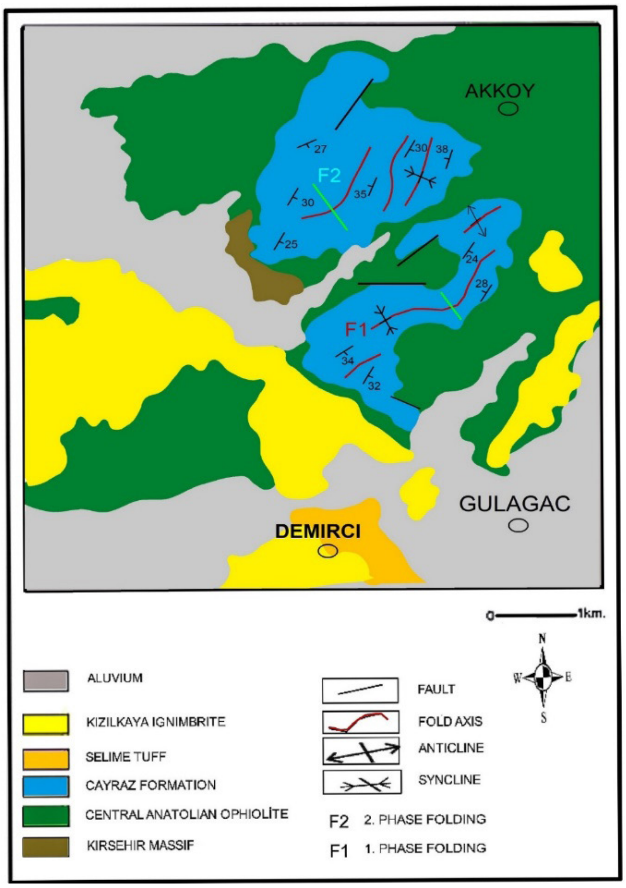

Figure 3 Geological map of the study area and its surroundings.

The Kızıltepe Formation, which consists of loosely consolidated, purple-coloured conglomerate, sandstone, claystone, and mudstone, is a Late Cretaceous-Paleocene-aged terrestrial formation.

Overlying these units is the Cayraz Formation, which consists of marine sandstone, marl, and limestone and is of the Lower Eocene age. These units are unconformably overlain by the Oligo-Miocene-aged Mezgit Formation, consisting of shales, sandstones, mudstones, and evaporites.

The Gostuk Ignimbrite, Uzunkaya Formation, Melendiz Volcanite, Selime Tuff, Kızılkaya Ignimbrite, and Gosterlı Volcanite are all units composed mainly of Pliocene-Pleistocene volcanic material. These units are unconformably overlain by recent slope debris, travertine, and alluvium (Figure 4).

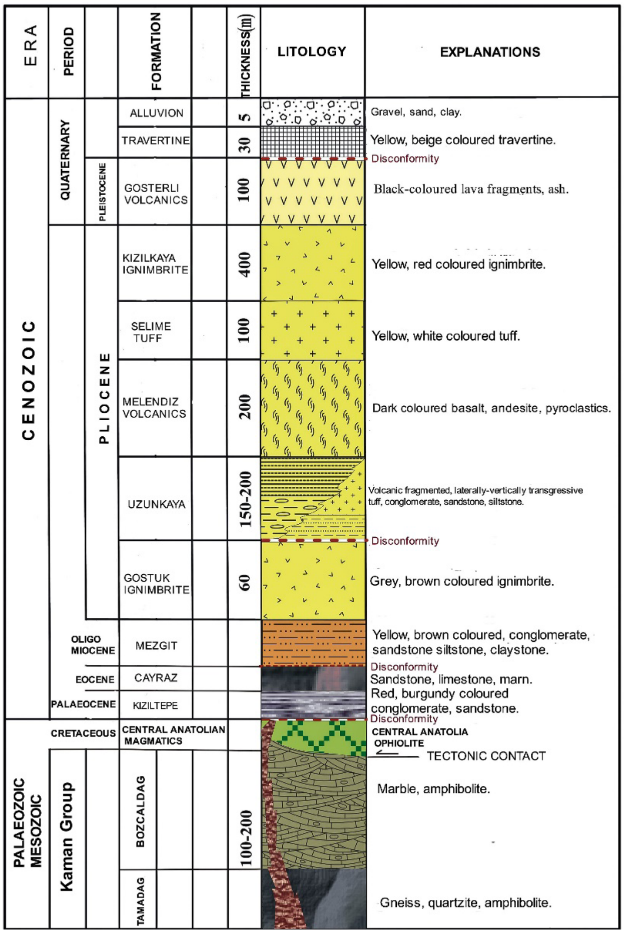

Figure 4 Stratigraphic columnar section of the study area and its surroundings (modified from [47]).

Structural Geology

In the area we studied, the metamorphic rocks of the Kaman Group, which are of the Palaeozoic-Mesozoic age, went through polyphase deformation and created folded and fractured structures. Additionally, the Lower Eocene-aged units of the Cayraz formation in the same area underwent at least two stages of folding. These changes are believed to be connected to the closure of the Inner Taurus Ocean. In the study area, the Palaeozoic-Mesozoic-aged metamorphic rocks belonging to the Kaman Group underwent polyphase deformation and formed folded-fractured structures. In the study area, the Eocene-aged units belonging to the Cayraz formation also underwent at least two stages of folding. These deformations are thought to be related to the closure of the Inner Taurus Ocean.

RESULTS AND DISCUSSION

Lineament Maps

Satellite imagery and software tools such as Envi, Geomatica, and ArcGIS were utilized to create automatic lineament maps in the Gülağaç area [48-52].

These maps were generated by using Landsat-8 images obtained from a website (earthexplorer.usgs.gov) (Figure 5a). Landsat-8 pictures of Gülağaç and its surroundings were obtained and an automatic lineament map was produced using suitable filters and threshold values as described in [53] (Figure 5b).

To create a lineament map, the image is first processed in Envi, Geomatica, and ArcGIS (Figure 5b). The resulting maps include only natural lines and exclude artificially created structures.

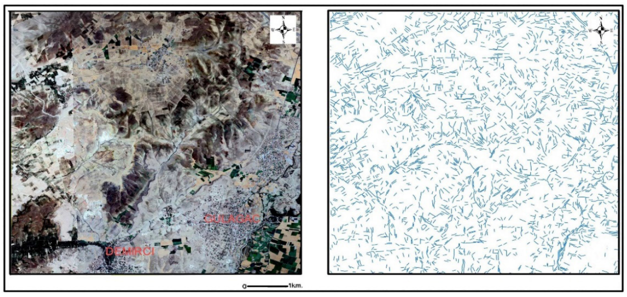

Figure 5 a- Satellite image of the Gülağaç and it's surroundings b- Lineament map of the study area.

The lineament map was determined by superimposing the satellite image and the obtained lineament images (Figure 6).

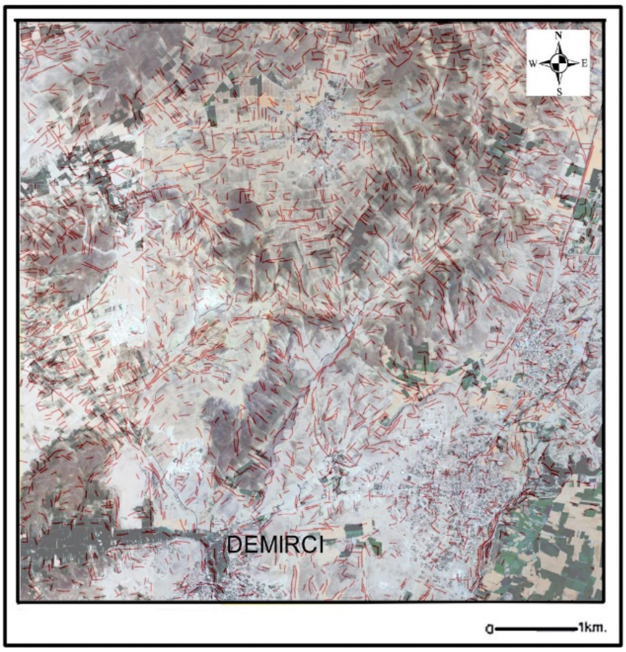

Figure 6 Landsat-8 image and lineaments of the area.

The generated lineament map was converted into a density map (Figure 7a). A density map and automatic lineaments map were also made (Figure 7b).

Tectonic lineaments are represented in the terrain by fault, fracture, and fold hinge line trends (Figure 7). In the terrain, morphological structures are sometimes in the form of lines formed by erosion surfaces. Although such lines are seen as tectonic lineaments, they are not related to tectonism but to erosion. Such morphological lines are kept separate from tectonic lineaments.

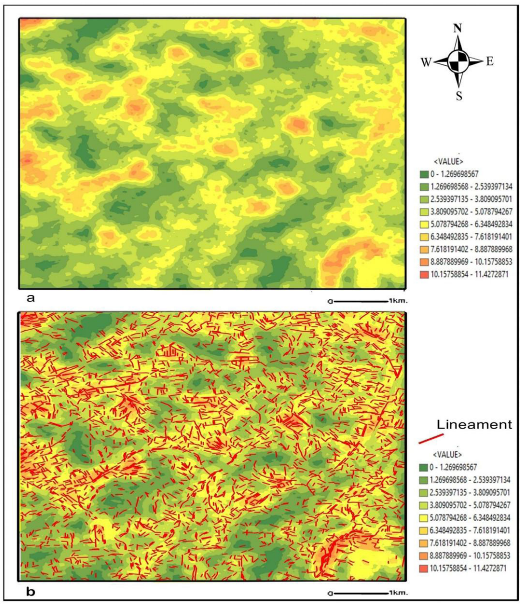

Figure 7 (a) Density map of study area (b) lineament and lineament density map.

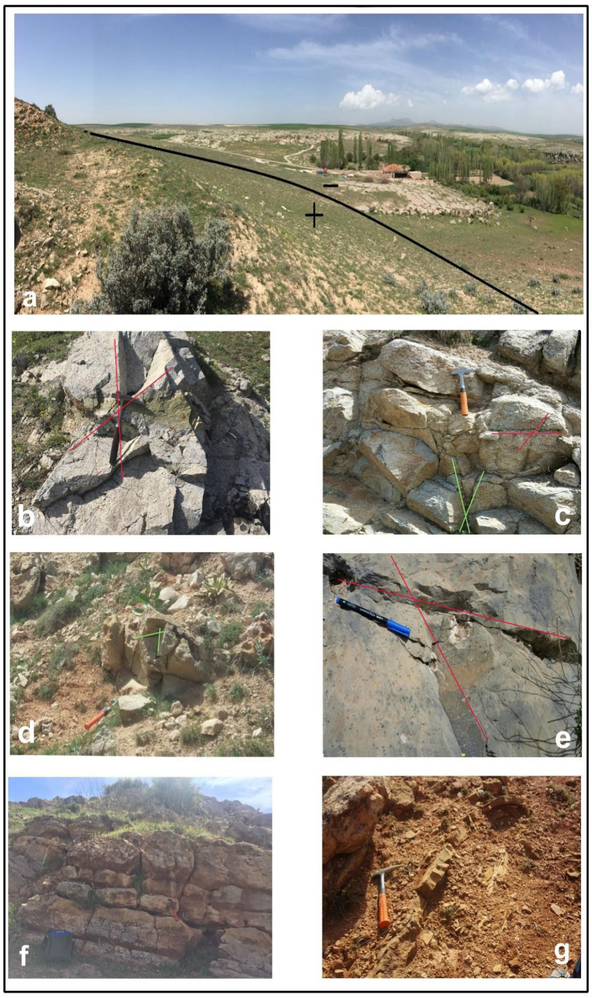

Figure 8 (a) Normal fault in the study area (b-c) Fractures in the ophiolites (d-e) Fractures in the Cayraz formation (f, g) Inclined, folded strata in the Cayraz formation.

Evaluation of Satellite and Fieldwork Lineaments

Rose diagrams were created to analyse the distribution of lineations in the study area based on automatic lineaments. In the study area, fault, fracture, and fold axis measurements, which constitute the lineaments, were evaluated in the Stereonet software (Fig. 9).

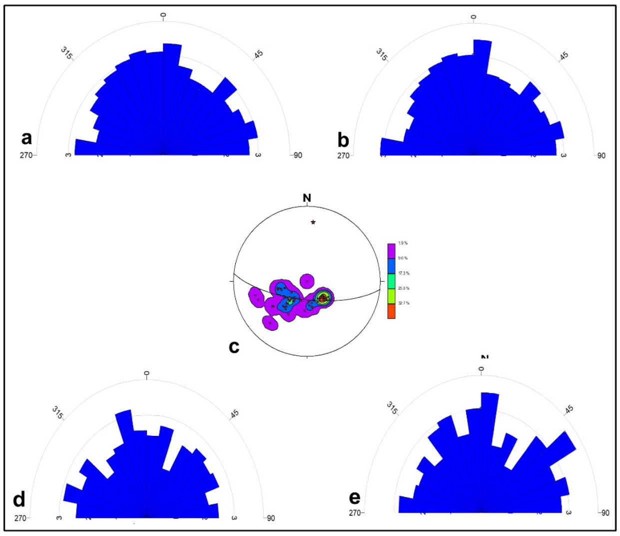

Figure 9 a- Rose diagram of %L: Length as a percentage of the total linear length. b- Rose diagram of %N: Length as a percentage of total lineation population. c- Point-contour diagram of Cayraz formation (65 bedding measurements) d- Contour diagram of 1st phase shear fracture in ophiolites (41 fracture measurements) e- Contour diagram of 2nd phase shear fracture in ophiolites (44 fracture measurements).

Results showed that lineaments were present in all orientations, with the most intense orientations being, N0-10°E, N40-50°E, N70-80°E, and N80-90°W, N20-30°W, and N30-40°W (Figure 9a,b). Additionally, fracture systems were studied and mapped, with diagrams prepared specifically for sedimentary rocks (Figures 9c, d, and e). The results were generally compatible when comparing strike-rose and automatic lineament diagrams based on field measurements. Based on measurements of the layers of the Cayraz Formation (65 bedding measurements), the general fold hinge line orientation was determined to be N8°E/14°NE (Figure 9c). This orientation aligns well with the dominant orientation found in the rose diagrams of satellite-based lineaments. Additionally, phase 1 shear fracture (41 measurements) in ophiolites showed shear fracture planes of N10-20°W and N70-80°W, while phase 2 shear fracture (44 measurements) in ophiolites revealed shear fracture planes of N0-10°W and N50-60°E (Figure 9d,e).

CONCLUSIONS

The region being studied has undergone significant structural changes due to the effects of the tectonic regime that emerged, particularly between the Middle-Late Eocene-Upper Miocene period, which was characterized by compressive forces. These deformations have resulted in the formation of various types of faults and fractures with different orientations. By using automatic lineament analysis to examine the lineations in the study area, rose diagrams were produced that indicated the presence of lineations in all directions. The most intense orientations were N0-10^{0}E, N40-50^{0}E, N70-80^{0}E, N80-90^{0}W, N20-30^{0}W, and N30-40^{0}W. When the Cayraz Formation beds were measured, the general orientation of the fold hinge line was found to be N8^{0}E/14^{0}NE. The ophiolites have undergone phase 1 and phase 2 shear fractures, with N10-20^{0}W, N70-80^{0}W, N0-10^{0}W, and N50-60^{0}E being the identified shear fracture planes. This observation is consistent with the lineaments detected by satellite imagery.

The study compared data collected from field studies with that obtained from satellite-based studies. The findings reveal that the data from both sources are compatible. This study has generated valuable data that can be helpful for future exploration of minerals and geothermal resources. Geophysical and geological parameters can additionally support this study to obtain more realistic supporting results The study area, situated within the Cappadocia Volcanic Province, possesses significant geothermal energy potential. The identified lineations in this study and their concentrated areas may indicate potential geothermal sites

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