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DEM and GIS-based assessment of structural elements in the collision zone: Çağlayancerit, Kahramanmaraş (Türkiye)

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Abstract

Topographic and linear data are precisely linked to the tectonic structure of the region. This relation can be identified both in the field and in satellite images. As it is recognized, high topographic areas are formed with the effect of the compression regime in the zones where different continents are sutured. There are traces of the suture zone in the northeast of Kahramanmaraş. Because of the closure of the Neotethys Ocean, a collision zone developed in and around Çağlayancerit, located in the northeast of Kahramanmaraş. Units in the Arabian Autochthonous and Taurus Orogenic belts came together in this district. Thrust belts and faults have been observed in this vicinity. In this region, there are different tectonostratigraphic sequences sliced on top of each other by the effect of compression. These slices and their structural features have caused different morphological traces in the region. Structural events have led to the development of linearity and topographic elevations, respectively. According to the in-situ observation and the digital elevation model (DEM) analysis results which were performed in the QGIS environment, the topographic elevations in the collision belt are relatively higher than the areas in the south. As a result of the north-south compression, the thrust lines formed definite linearity. Each fault characterized in the region controls the morphology directly.

1. Introduction

Many geological studies utilize lineament and topographic components as ancillary indicators [1-2]. Depending on the geological development of a region, basins and orogenic belts are observed. In this situation, regional lineaments and morphological data have their ultimate form under tectonic and sedimentation control [3-5].

Remote sensing (RS) and geographic information systems (GIS) are platforms for the map-based evaluation of geological structures. With technological advances and recent developments in spatial analysis techniques, large-scale linearity and morphological analyses have become relatively practicable [6]. These studies use numerical data such as satellite images and Digital Elevation Model (DEM). Such studies interpret morphological and linear structures [7-9].

Structural elements (fault, lineament, fracture, joint, etc.) cause the emergence of geomorphic expressions. These relationships are revealed by using reliefs and slopes on the DEM image. Satellite images are matched with the data obtained in the field and structural features are revealed. Thus, using many factors, the geological boundary relations, tectonics, and structural geology of the regions are revealed [10-11].

In terms of its geological structure, Kahramanmaraş is a complex region where different tectonic units are observed together. Many thrust and fault zones associated with the closure of the southern branch of the Neotethys Ocean are observed in this region [12]. Suture belts were formed by the closure of this ocean and the convergence of the Tauride and Arabian plates as a result [13-14]. With the depletion of the ocean floor, allochthonous units were thrust onto the Arabian platform in the south, and a suture belt was formed between these two continents [15-16].

Gül [17] explained that the Anatolian and Arabian plates collision occurred in the Late Cretaceous and that a compressional regime was active in the region during the Paleocene-Early Eocene period. Yılmaz and Yiğitbaş [18] stated that as a result of the movement of the Arabian continent towards the Anatolian plate between the Late Cretaceous-Miocene, the region gained a nappe character.

Rigo De Righi and Cortesini [19] divided the tectonostratigraphic units in the Southeast Anatolian Region into four primary tectonic belts: the Taurus Orogenic Belt, the Margin Fold Belt, the Folded Belt, and the Foreland, respectively.

On the other hand, Gül [20] described Kahramanmaraş and its vicinity as Orogenic Belts. Yalçın [21] mapped the rocks of different origins in Çağlayancerit and its west and revealed the deformation structures of the region. This region still has an active fault, such as the East Anatolian Fault (EAF). It is recognized that this main fault affects many morphological formations. In this region, distinctive morphological structures have cropped up due to the coexistence of rocks belonging to two different plates and the presence of different tectonic sequences on the thrust zones.

Yalçın and Kop [22] stated that there are different types of rock groups developed in the Paleozoic-Quaternary age range in the region. They stated that Malatya Metamorphics, Suture Belt, and Arabian Autochthonous units are located in this region, which is located in the collision zone, from north to south, and that there are different tectonostratigraphic sequences sliced on each other with the effect of compression. Yalçın [23] stated that the structural elements in this region are effective in shaping the morphology of the region and that these lineaments can be revealed/identified using the remote sensing method.

2. Material and Method

The study area is located in the Çağlayancerit region, approximately 60 km northeast of Kahramanmaraş province (Figure 1a), in the Eastern Taurus Orogenic Belt. This region and its vicinity were named Engizek Askuşağı by Gül [20] (Figure 1b). Just south of this belt is the marginal fold belt of the Arabian plate.

In this region, allochthonous Malatya Metamorphites form the Berit Metaophiolite, Ziyaret Tepe, and Kaleköy Tectonic Slices from bottom to top, respectively, due to nappes. Sedimentary and volcanic units belonging to the Suture Belt were sliced on the thrust front just south of these slices. In the areas south of the Suture Belt, autochthonous rock assemblages representing the Arabian Platform and also called the margin fold belt crop out [21-22]. Structural elements show that the compression regime continues for a long time in this region.

2.1. Geology

Different stratigraphic sequences have emerged due to the coexistence of rock groups of different origins in the study area and allochthonous rocks overlying nappes and younger rocks in large areas. Allochthonous rocks, Suture Belt, and Autochthonous units were defined from north to south [21].

In the study area, the tectonic slices present an imbricated structure, and the units belonging to different plates come together, indicating a very complex structural position in the region (Figure 2). According to the structural elements examined, it can be said that the region has been under the influence of an N-S oriented compression for a long time.

In the NW of Çağlayancerit (Kahramanmaraş), around Kaleköy and Hombur districts, lithostratigraphic units representing different environments and facies from Paleozoic to Quaternary crop out [22]. Because the region is located in the continent-continent collision belt, allochthonous rock groups were dragged over the autochthonous units in the nappe and frontal thrusts. For this reason, the rock assemblages outcropping in the study area were classified into two main groups autochthonous and allochthonous according to their location. Allochthonous rocks, on the other hand, are considered in two main groups the Suture Belt and the Malatya Metamorphites located in the Taurus Orogenic Belt, taking into account their origin.

Allochthonous units, which are widely distributed in Kaleköy, Hombur, and Zorkun regions in the study area, consist of Malatya Metamorphites and Suture Belt units. From north to south, Malatya Metamorphites were emplaced as nappes on each other and on Suture Belt units along the approximately E-W trending lines (Figure 2, Figure 3). As a result of these nappes, different lithological and stratigraphic sequences emerged, and tectonic slices were formed [21-22].

Considering the locations and contact relationships of allochthonous rocks, it was determined that the rocks from north to south were sliced to form an annealed structure. These slices are defined under the names of Berit Metaophiolite, Kaleköy, and Ziyaret Tepe Tectonic Slices respectively [21-29].

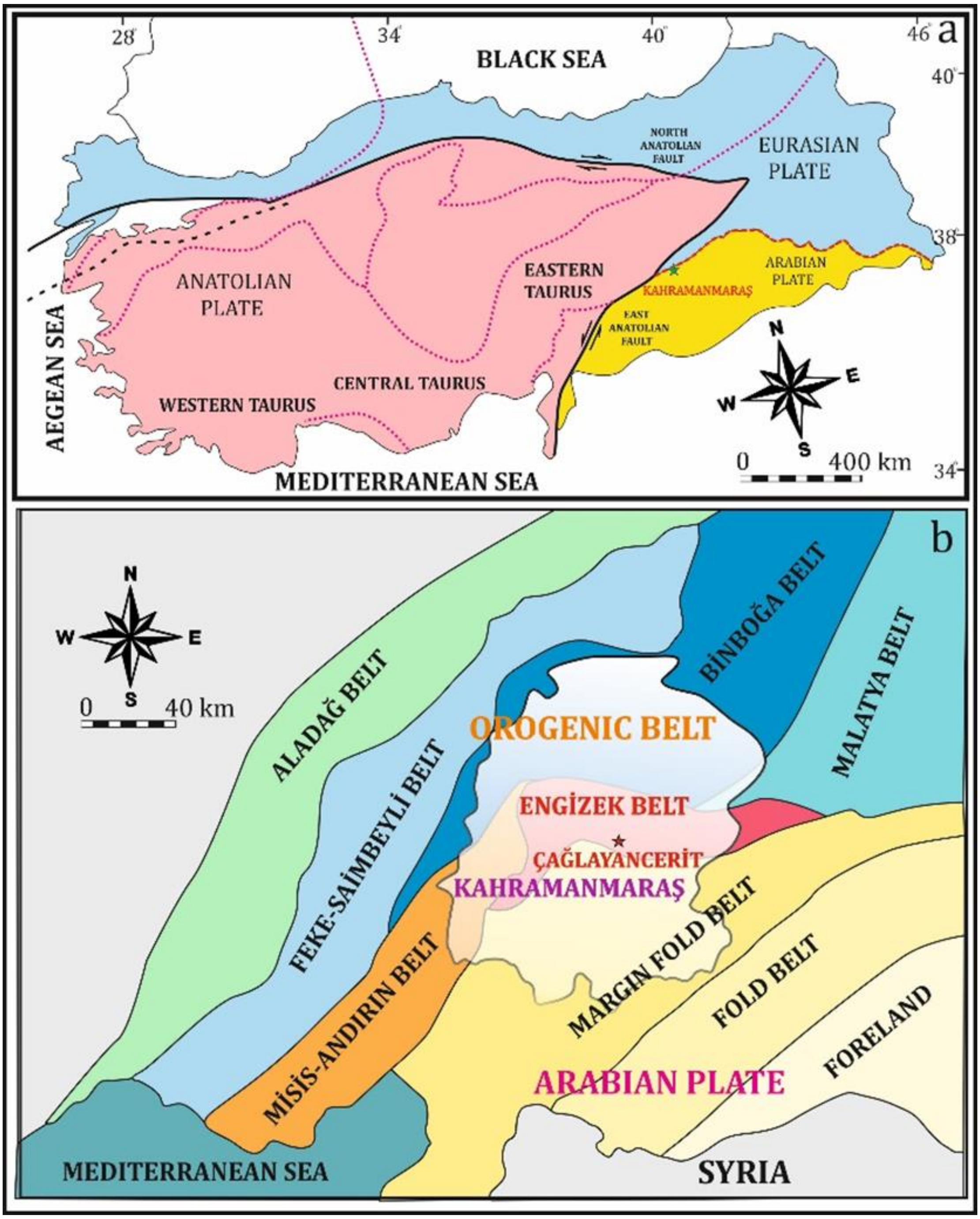

Figure 1. a) Tectonic location of the study area (Modified from [30]) **b)** Location of the study area according to tectonic belts. (Modified from Gül, [20]).

2.2. GIS-based analysis

Topographical approaches were obtained with the DEM of Çağlayancerit and its vicinity, a tectonically active region and an important belt where two different continents collide. ASTER GDEM data provided by JPL (Jet Propulsion Laboratory) was used to derive topographic approximations.

The DEM of this geologically significant region has been downloaded from the United States Geological Survey (USGS) website [31] (Earthexplorer, https://earthexplorer.usgs.gov). GIS-based structural analyses were performed in the QGIS environment, an open-source Geographical Information System. Aspect and slope analyses were performed in order to define the structural elements of the study area. The combination of raster/vector output of this analysis, in-situ measurements, and visual lineaments analysis were used in multi-layer-based decisions. In addition, active faults in the region are placed on these layers. The DEM and the active faults in the region overlapped (Figure 4).

The processing steps of GIS-based structural elements determination used in the QGIS environment, respectively, are as follows;

1.DEM data was classified and colored in the QGIS environment with a single-band pseudocolor application (Figure 5a).
2.The relief image for the slope map of the region and the slope image on it were overlaid, revealing the slope map (Figure 5b). The red-colored areas represent the areas with the highest topographic elevation.
3.A view map of the region was created. According to the field studies, it has also been revealed with DEM that the slopes generally face south because there are thrusts from north to south (Figure 5c).
4.A 3D map of the region was created to obtain a more understandable image. The most important linearity obtained according to this image belongs to EAF. Other important linearities are thrust zones and dip-slip faults that form the boundary of the thrust front and autochthonous units (Figure 5d).

Considering that there are different active and inactive faults in and around Çağlayancerit, the region's morphology is quite rugged, and the topographic elevations are relatively lower in the southern areas. According to these DEM data, some important lineaments have been determined, which are structures generally affected by faults.

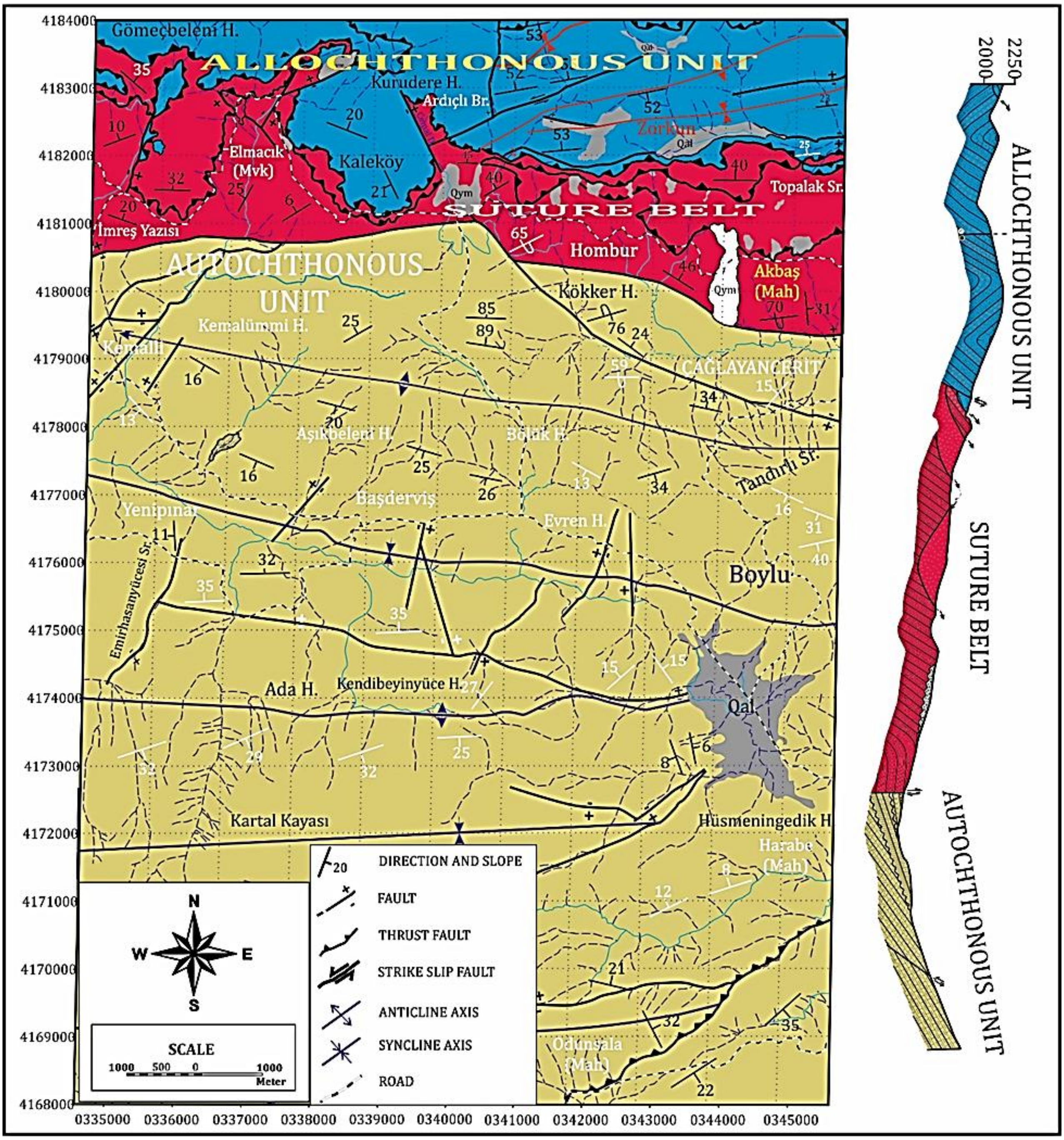

Figure 2. Structural map of the study area (Modified from [21]).

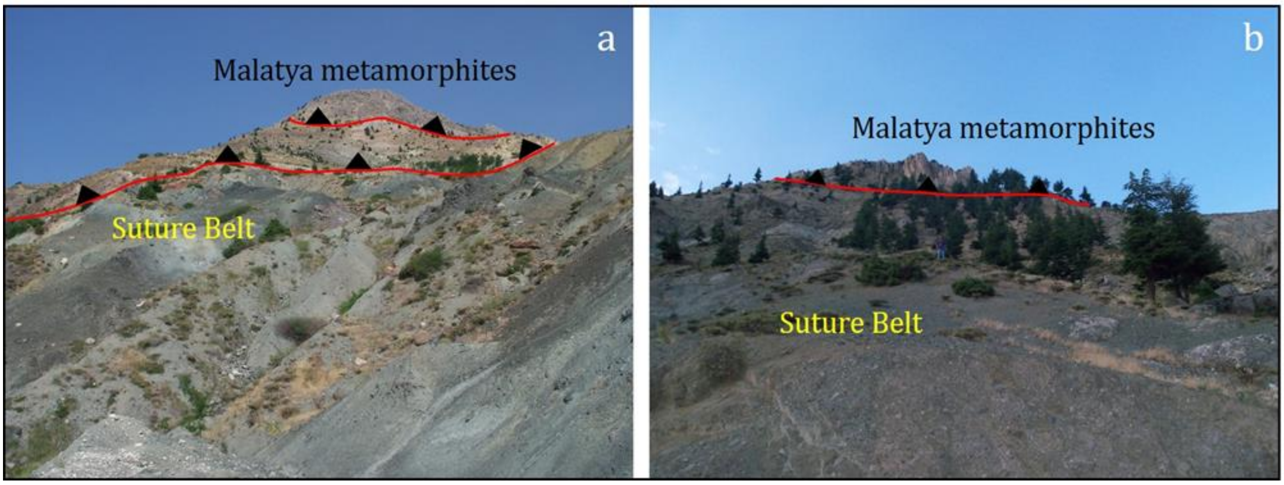

Figure 3. General view of thrust faults and allochthonous units.

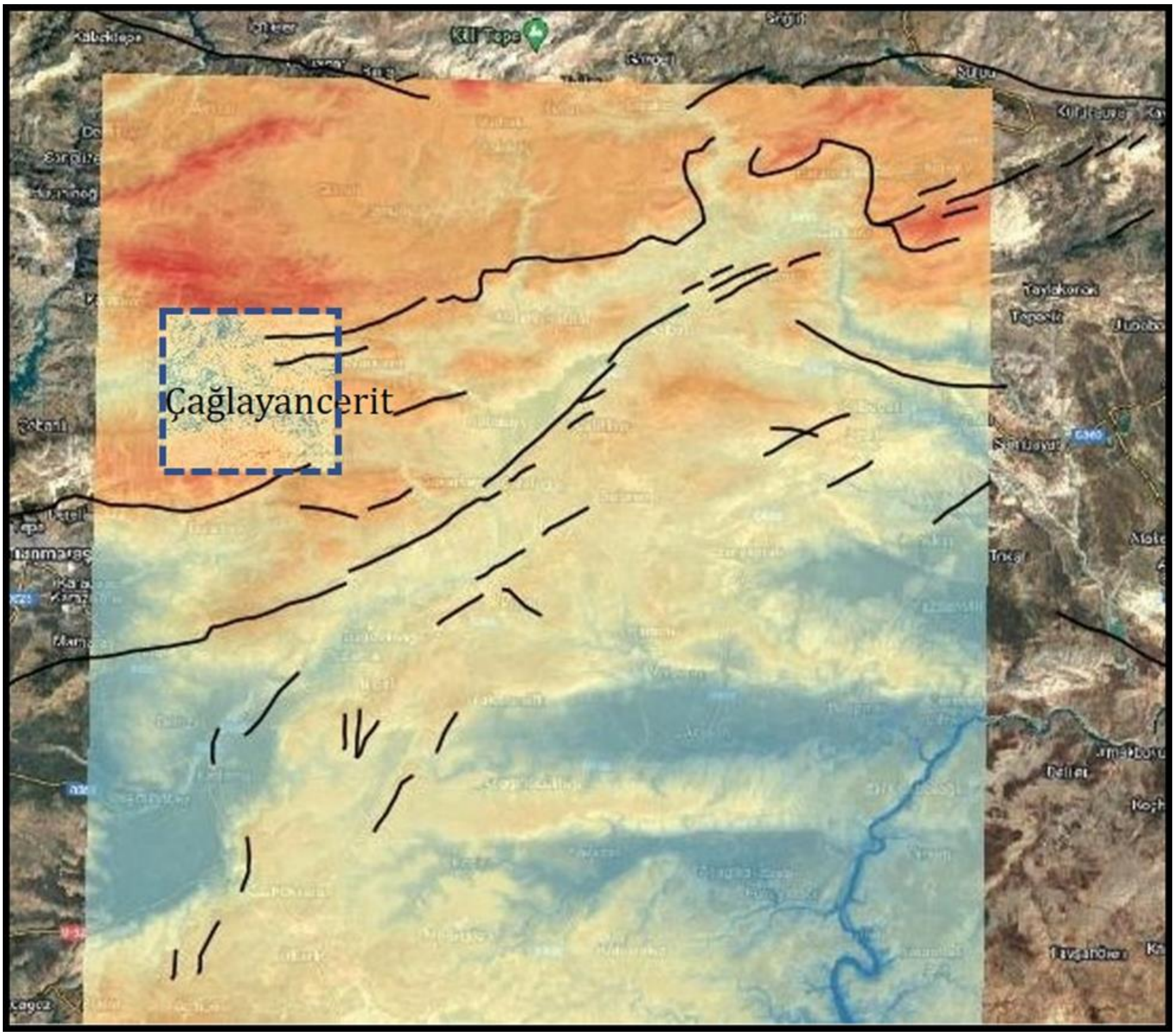

Figure 4. Satellite and DEM image of the study area.

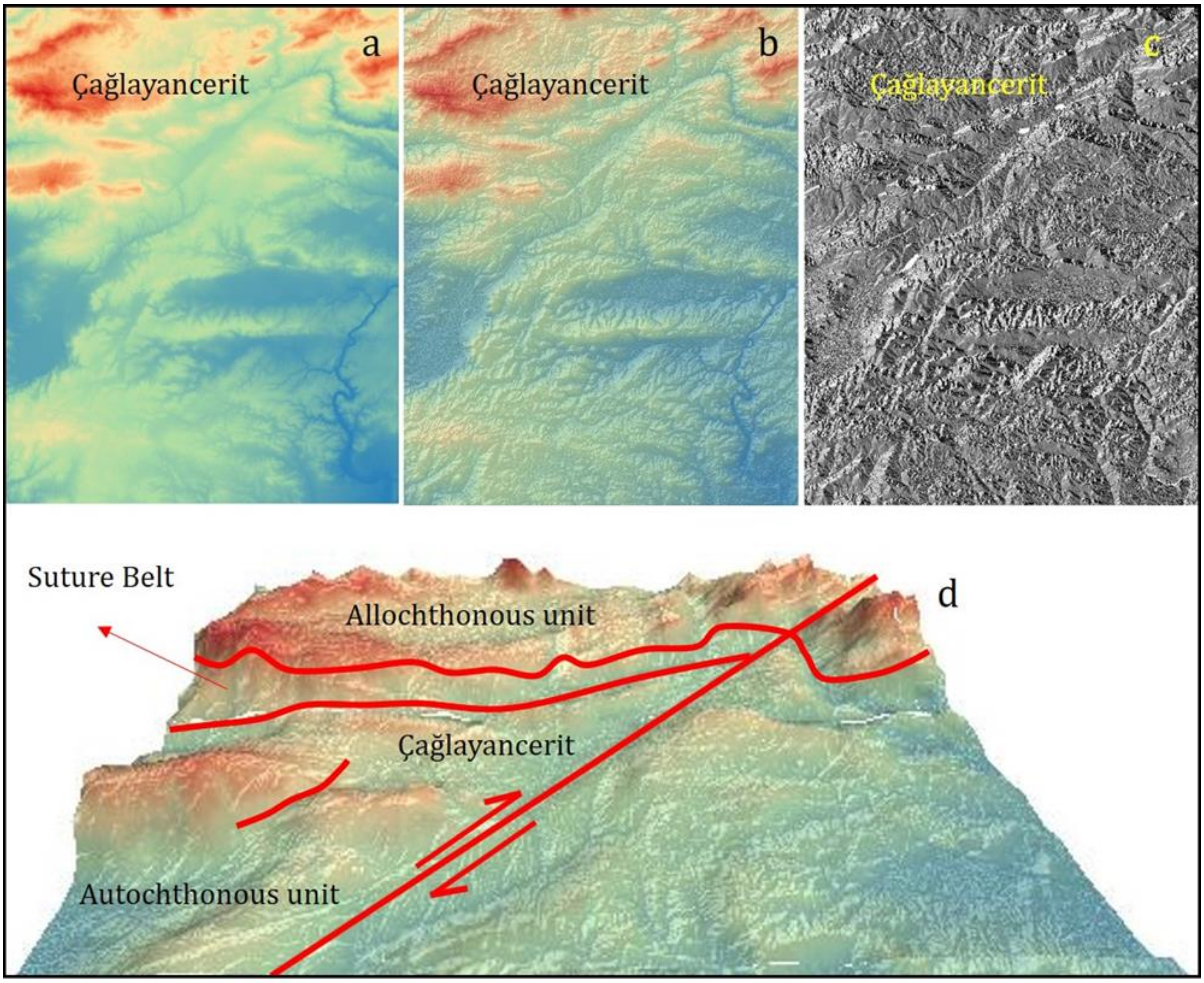

Figure 5. a. DEM **b.** slope, **c.** aspect **d.** 3D image of the study area.

3. Results

Geological lineaments are an important element to reveal the paleo or neo-tectonic features of a region. The use of remote sensing data to describe the lineaments of these tectonic features has been applied in many geological settings [32].

The study area is an important region where Arabian plate and allochthonous units come together. In the study area, there are lithostratigraphic units deposited in the Upper Permian-Quaternary age range. From north to south, Malatya Metamorphics, Suture Belt and Arabian Autochthonous Units are located. Thrust zones were developed by the closure of the southern branch of the Neotethys Ocean [12] and then by the convergence of the Tauride plate and Arabian plate [13, 33].

In these thrust belts, allochthonous units were thrust over the northern margin of the Arabian platform in the south. As a result of this pushing movement, both allochthonous rocks were sliced and frontal charges were formed between the Taurus Orogenic belt and Arabian Autochthonous [15-16]. The Arabian Platform consists of a thick marine sedimentary succession and is a belt compressed between nappes in the thrust zone [34]. In the nappe regions, ophiolitic rocks and Malatya Metamorphites caused the formation of the regional orogeny. Later, as a result of the collision of the nappes with the Arabian plate in the Late Miocene, the present successions were formed [34]. The tectonostratigraphic slices identified from Yalçın and Kop [22] study also support the theory of the development of this orogenic belt.

At the end of the compression system in the region reached a level that could no longer be met by thrusts, the Eastern Anatolian Fault and other strike-slip faults in the region developed in this period, which is called the Neotectonic phase [35]. The region started to undergo deformation under the control of strike-slip faults since the Upper Miocene. Such Miocene-Present units are bounded by left-lateral strike-slip faults known to be active (such as the Sürgü fault) [36].

In the research prepared by Yalçın [21], it was stated that the units belonging to the collision belt in Çağlayancerit and its west came together, and deformation structures belonging to different periods developed in the region. The region's structural elements and surroundings were re-evaluated in this study with remote sensing methods. Topographic data and linear structures reveal that tectonic forces in the region are effective in geomorphology. In supplement, the faults in the structural map obtained in the field study are in harmony with the satellite images.

4. Conclusion

Tectonic lineaments are important parameters of any structural geological study. Linear structures help in mapping and tracing fault structures related to geological hazards. Lineaments in DEM have topographic relief and/or tonal features on the earth.

The maps prepared for tectonic and structural purposes can still be verified with GIS-based techniques. Morphological changes are the most common, especially in tectonically active areas where different continents come together. Very high topographic data is obtained in the thrust belts. In this study, the units of the Arabian Autochthonous and Taurus Orogenic belts collided, and then the position of the EAF was evaluated together. DEM and field data can be compared by evaluating them in the GIS environment. Other parameters/variables such as hydrological factors, lithology, and shading should be used and specified in such research.

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Conflicts of interest

The authors declare no conflicts of interest.

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