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The interpretation of the Arabian-Taurus plates collision zone by satellite images: Western Çağlayancerit (Kahramanmaraş, Türkiye)

Cihan Yalçın*[1]

[1]*Ministry of Industry and Technology, General Directorate of Industrial Zones, World Bank Project Implementation Unit, Ankara, Türkiye; cihan.yalcin@sanayi.gov.tr*

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Abstract

Kahramanmaraş region has been of interest to many researchers for its complex geologic structure. Especially the coexistence of lithologies belonging to different plates has led to the formation of different tectonic units. West of Çağlayancerit is an important area where both the Taurus and Arabian plates collide and is very close to the Gölbaşı-Türkoğlu Segment (left-lateral strike-slip fault). In addition, the Ahırdağı Thrust Zone, defined as an active fault, is also in this region. Tectonic slices were formed in the region due to the Arabian-Taurus collision. These tectonic slices comprise Malatya metamorphics, the Kenet Belt, and units belonging to the Autochthonous Arabian Plate. In this area where North-South compression is dominant, different structural elements have developed with the effect of the East Anatolian Fault that developed after the collision. Verifying these data obtained in the field with satellite images and revealing possible structural elements is important. In this study, ASTER L1T-Band3, Sentinel2A-Band11, and Landsat 8 OLI-PanBand8 bands were utilized to reveal the lineaments of the west of Çağlayancerit. High-resolution images were obtained from these satellites. First of all, the geologic elements of the area were determined with Sentinel2A data. Then, ALOS DEM (12m), SRTM DEM (30m), and NASA DEM (30m) data were used to determine the lineaments to identify potential faults and fold axes. Then, the data obtained from the three satellites were evaluated together. According to the evaluations, four different lineaments were identified in the region. These lineaments are Engizek Thrust Zone, Suture Zone, Arabian Plate Marginal Fold Belt, and Ahırdağı Thrust from north to south. The direction of these important lineations is generally East-West. The west of Çağlayancerit, which is very important in tectonics, has gained its present structural state with the effect of both collision and post-collision stresses.

1. Introduction

Satellite images with different geospatial resolutions are convenient for defining structural elements (e.g., fault traces, fold axis, structural patterns) in the field and provide a great advantage in interpreting the geological structure [1-2]. Satellite images are essential for rapid and fundamental research and help facilitate decision-making. Satellite images are now available in various resolutions and can be acquired from many different satellite bands.

Many geological studies have utilized lineament and topographic components as ancillary indicators [3-4]. Basins and orogenic belts are observed depending on the geological development of a region. Regional lineaments and morphological data have their ultimate form under tectonic and sedimentation control in this situation [5-7].

Remote sensing (RS) and geographic information systems (GIS) are platforms for assessing geological structures using maps. Large-scale linearity and morphological analyses have become more feasible due to technological advances and recent developments in spatial analysis techniques [8].

Regarding the geological structure, Kahramanmaraş is a complex region with several tectonic units coexisting. This region contains numerous thrust and fault zones associated with the closure of the Neo-Tethys Ocean's southern branch [9]. Suture belts were formed due to the closure of this ocean and the subsequent convergence of the Tauride and Arabian plates [10-11]. As the ocean floor depleted, allochthonous units were thrusted onto the Arabian platform in the south, forming a suture belt between these two continents [12-13].

According to Gül [14], the Anatolian and Arabian plates collided in the Late Cretaceous, and a compressional regime was active in the region during the Paleocene-Eocene period. According to Yılmaz and Yiğitbaş [15], the region acquired a nappe character due to the movement of the Arabian continent towards the Anatolian plate between the Late Cretaceous and Miocene.

Rigo De Righi and Cortesini [16] classified the Southeast Anatolian Region's tectonostratigraphic units into four primary tectonic belts: the Taurus Orogenic Belt, the Margin Fold Belt, the Folded Belt, and the Foreland.

Gül [17], on the other hand, described Kahramanmaraş and its surroundings as Orogenic Belts. Yalçın [18] mapped the rocks of various origins in Çağlayancerit and its west, revealing the region's deformation structures. The East Anatolian Fault (EAF) is still active in this area. This main fault is known to affect many morphological formations. Because of the coexistence of rocks from two different plates and different tectonic sequences on the thrust zones, distinct morphological structures have emerged in this region.

According to Yalçın and Kop [19], different rock groups formed in the region during the Paleozoic-Quaternary period. They claimed that the Malatya Metamorphics, Suture Belt, and Arabian Autochthonous units are situated in that area, which exists in the collision zone from north to south, and that different tectonostratigraphic sequences are sliced on top of each other as a consequence of compression. According to Yalçın [20-21], this region's structural elements effectively shape the region's morphology and are formed using the remote sensing method.

The main cause of major earthquakes in Turkey is the collision between the Arabian and Taurus Plates. Since this collision continues today, major earthquakes have occurred in the segments of the Eastern Anatolian Fault and the Dead Sea Fault, respectively. Moreover, the February 6-7, 2023, earthquakes occurred in this region. For this reason, geological studies in these collision belts should be reinterpreted with modern technologies.

The subject of the research area is in the Eastern Taurus Orogenic Belt, approximately 60 km northeast of Kahramanmaraş province (Figure 1a). Gül [17] named this region and its surroundings the Engizek belt (Figure 1b). The Arabian plate's marginal fold belt is located just south of this belt.

The presence of nappes and allochthonous Malatya Metamorphics form the Berit Metaophiolite, Ziyaret Tepe, and Kaleköy Tectonic Slices from bottom to top in this region. The Suture Belt's sedimentary and volcanic units were sliced on the thrust front just south of these slices. Autochthonous rock assemblages representing the Arabian Platform, also known as the margin fold belt, crop out in areas south of the Suture Belt [18-19]. The structural elements exhibit that the compression regime has been present in this region for a period of time.

2. Material and Method

Remote sensing techniques with multispectral (Landsat-8, ASTER, Sentinel-2, etc.) and hyperspectral (EO-1 Hyperion, AVIRIS, AVIRIS) methods are used in geological studies for mapping, morphological features, lithological discrimination, mineral exploration, mineralogy, or hydrogeology [22-27].

Initially, Sentinel2A data was used to figure out the geologic elements of the area. The lineaments were subsequently assessed using ALOS DEM (12m), SRTM DEM (30m), and NASA DEM (30m) data in order to recognize potential faults and fold axes. The data from the three satellites were then analyzed together.

The data obtained from satellite images were then plotted as polylines with the ArcGIS Pro program to interpret structural elements visually.

3. Geological Background

Different stratigraphic sequences have formed because of the coexistence of rock groups of different origins in the study area, as well as allochthonous rocks overlying nappes and younger rocks in large areas. From north to south, allochthonous rocks, the Suture Belt, and autochthonous units were defined [18].

The tectonic slices in the study area have an imbricated structure, and units from different plates come together, implying a very complex structural position in the region (Figure 2). Based on the structural elements investigated, the region has been forced to an N-S-oriented compression for many years.

Lithostratigraphic units representing different environments and facies from Paleozoic to Quaternary crop out in the NW of Çağlayancerit (Kahramanmaraş), around Kaleköy and Hombur districts [19]. Allochthonous rock groups were dragged over autochthonous units in the nappe and frontal thrusts due to the region's location in the continent-continent collision belt. As a result, the rock assemblages outcropping in the study area were divided into two major groups based on their location: autochthonous and allochthonous. On the other hand, allochthonous rocks are divided into two major groups based on their origin: The Suture Belt and the Malatya Metamorphics of the Taurus Orogenic Belt.

Malatya Metamorphics and Suture Belt units are allochthonous units found in the study area's Kaleköy, Hombur, and Zorkun areas. Malatya Metamorphics were set up as nappes on each other and on Suture Belt units along roughly E-W trending lines from north to south (Figure 2). As a result of these nappes, various lithological and stratigraphic sequences formed, as well as tectonic slices [18-19].

Based on the positions and contact associations of allochthonous rocks, it concluded that the rocks were sliced to form an annealed structure from north to south. These slices are known as the Berit Metaophiolite, Kaleköy, and Ziyaret Tepe Tectonic Slices [18-19].

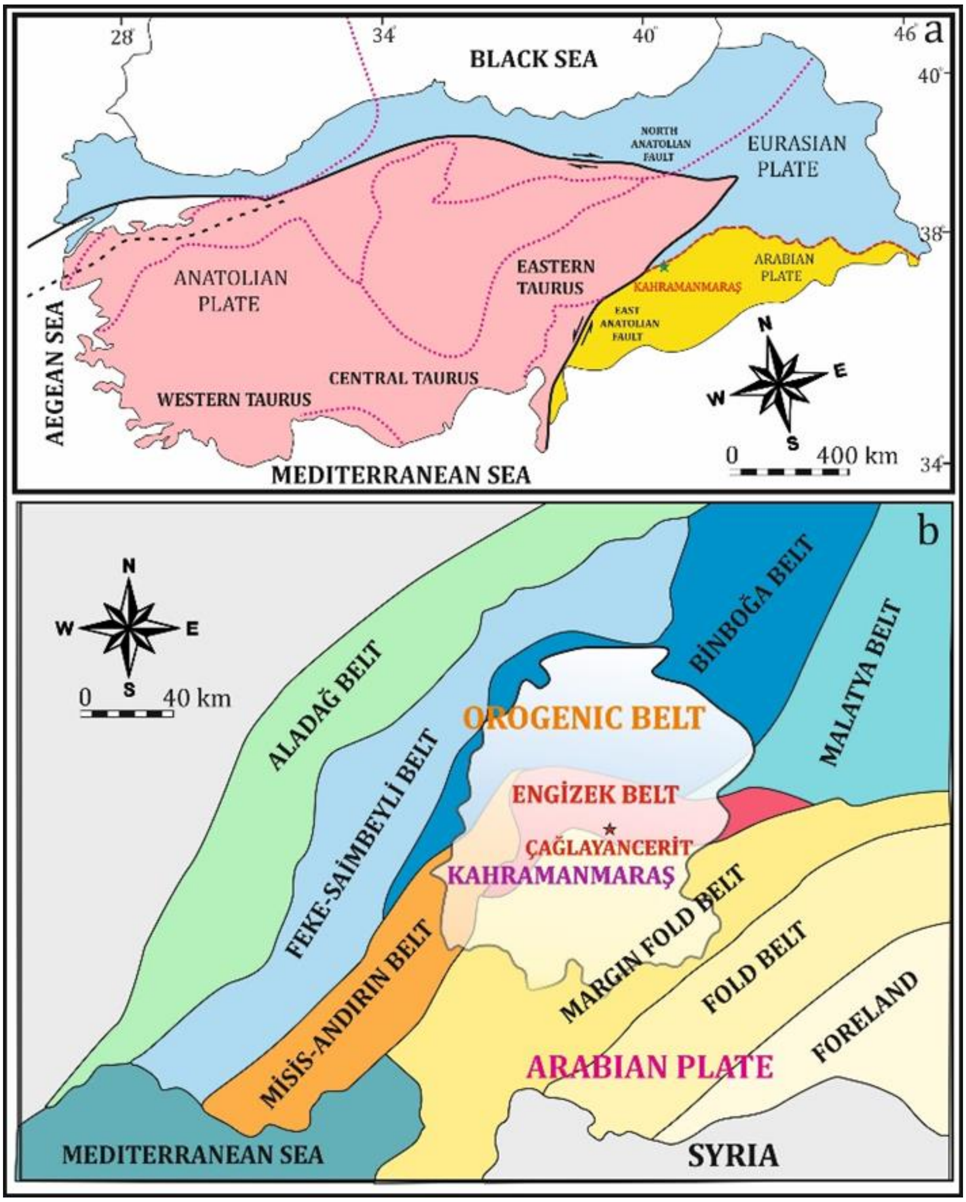

Figure 1. a) Tectonic location of the study area (Modified from Işık, [28]) b) Location of the study area according to tectonic belts. (modified from Gül, [17]).

4. Satellite Images

Based on Sentinel2A data, the geological elements of the site were first identified. In order to attain this result, the following methodology was implemented.

Radiometric calibration and atmospheric correction were not required because Sentinel2A data was already atmospherically corrected (reflectance data). Structural elements and general geology were made visible by applying decorrelation stretching to the selected bands after resampling the 20m and 60m bands to 10m on ENVI 5.6 (Figure 3). The structural elements were drawn as a polyline with visual interpretation in ArcGIS Pro (Figure 4). The obtained map shows the allochthonous unit boundary in the north and the suture boundary in the south. These two boundaries are also the collision boundaries of two continents. Linear structures from the Arabian plate's marginal fold belt can be seen just south of the collision (Figure 4). These divisions are also consistent with the findings of the field studies.

Lineaments in remote sensing are structural lineaments such as potential fault locations, fold axes, etc. They need to be verified in the field. In the structural element map prepared by Yalçın [18], important linearities were identified in the field. These features are thrust zones, dip-slip and strike-slip faults, and fold axes. One of the fold axes, the one near Kemalli, dips towards the west. Thrust zones are dense and complex in the collision zone in the north. In places, this thrust boundary is cut by dip-slip faults (Figure 2).

These lineaments provide important information about the geodynamics of the region. As a result of the collision between the continent and the Arabian plate, a north-south compressional regime was in effect. This compression continued after that, causing the northern limb of the Arabian Plate to fold. According to the data obtained in the field, it can be seen that the axes of the folds after the collision are oriented approximately in an east-west direction. These axes are commonly observed in post-Eocene units. One of the most important indicators is that the Eocene-aged Ahırdağı Formation thrust into the Miocene-aged clastics with a lap joint. This overlap also indicates that the autochthonous units are sliced while there is an active fault. This joint can be considered a consequence of the influence of the East Anatolian Fault in the region. The fact that this deformation is observed especially in Miocene-aged units, indicates that the N-S compression continued after the collision or the effect of the strike-slip fault system may cause it. Therefore, the history and location of structural elements in this region are important in interpreting regional stress.

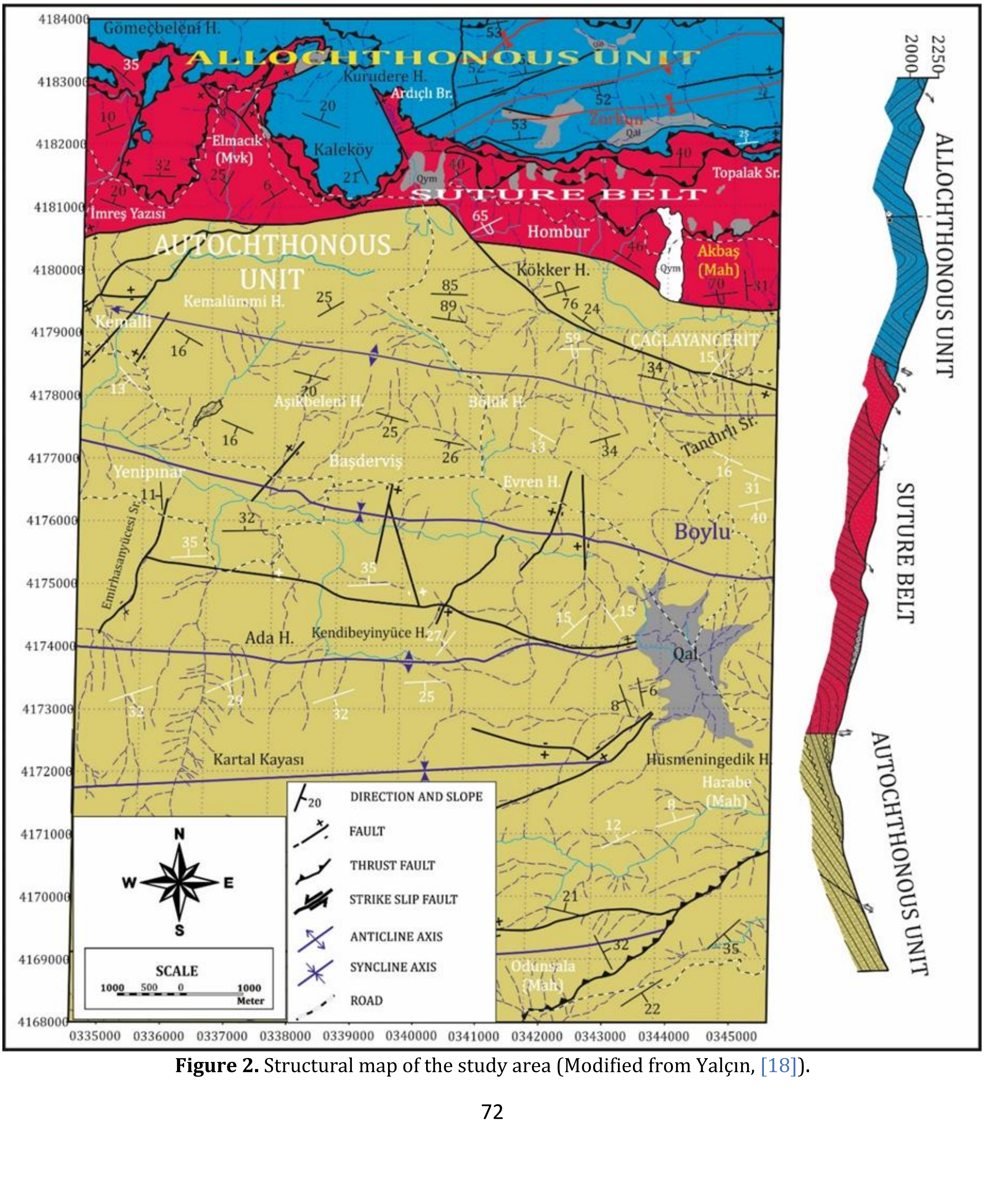

Figure 2. Structural map of the study area (Modified from Yalçın, [18]).

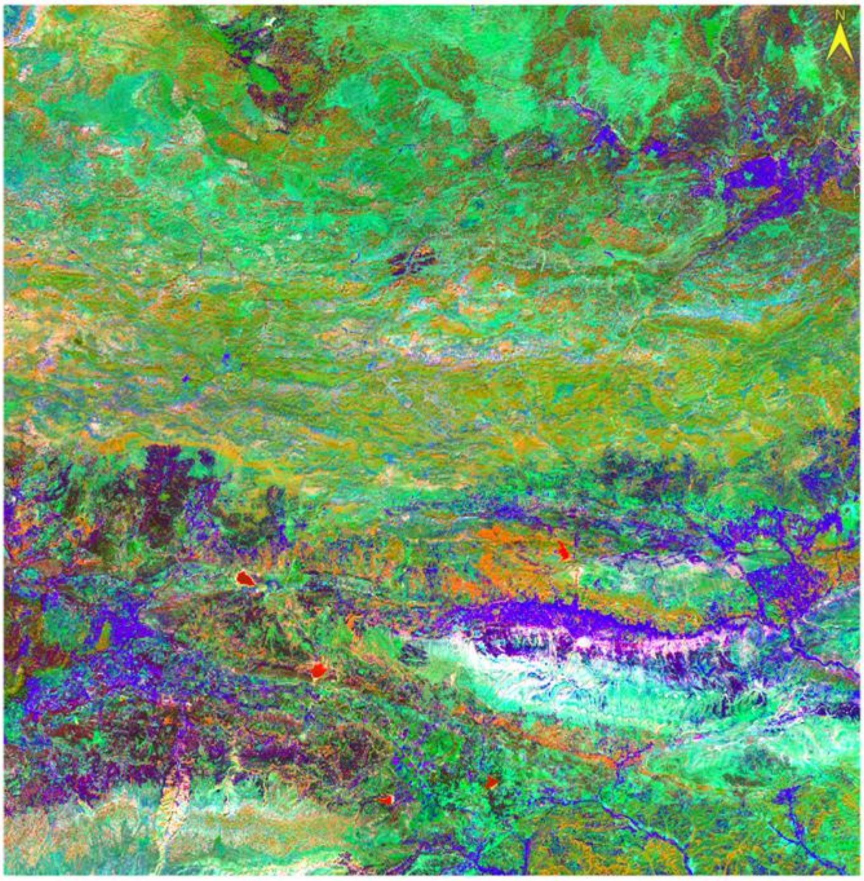

Figure 3. Decoration Stretching d148 result.

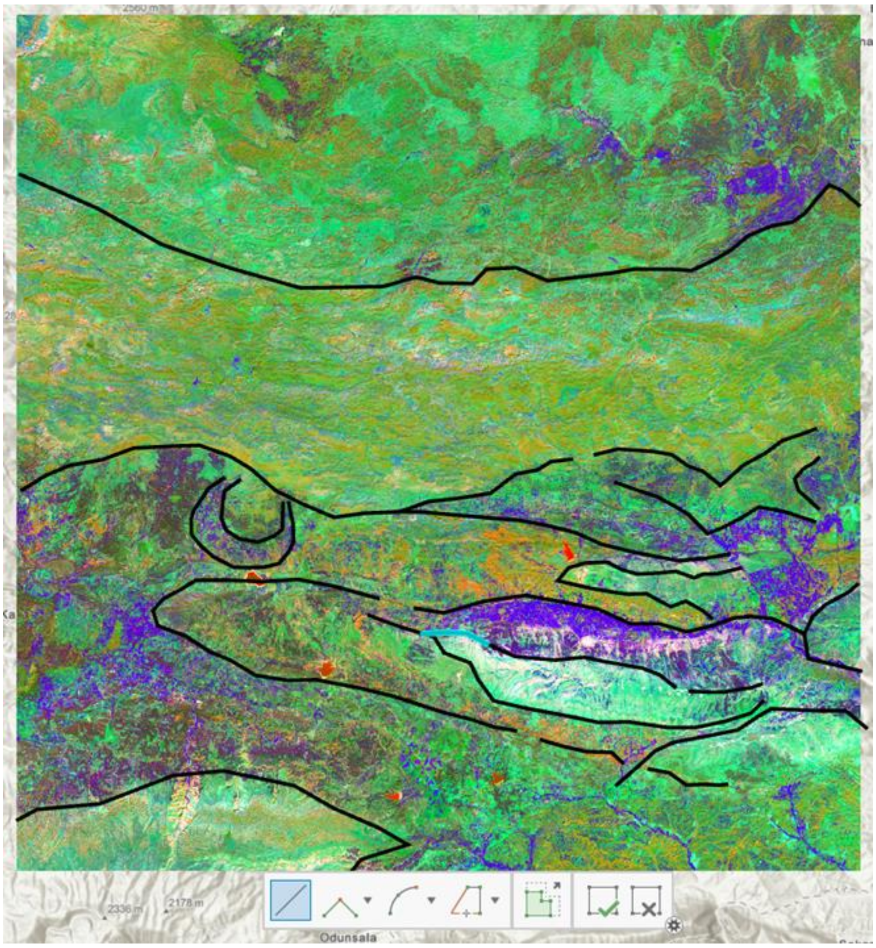

Figure 4. Decoration Stretching d148 result.

In the next stage, ASTER L1T-Band3 (Figure 5), Sentinel2A-Band11 (Figure 6), and Landsat 8 OLI-PanBand8 (Figure 7) data were used to find possible faults and anticlinal-synclinal axes.

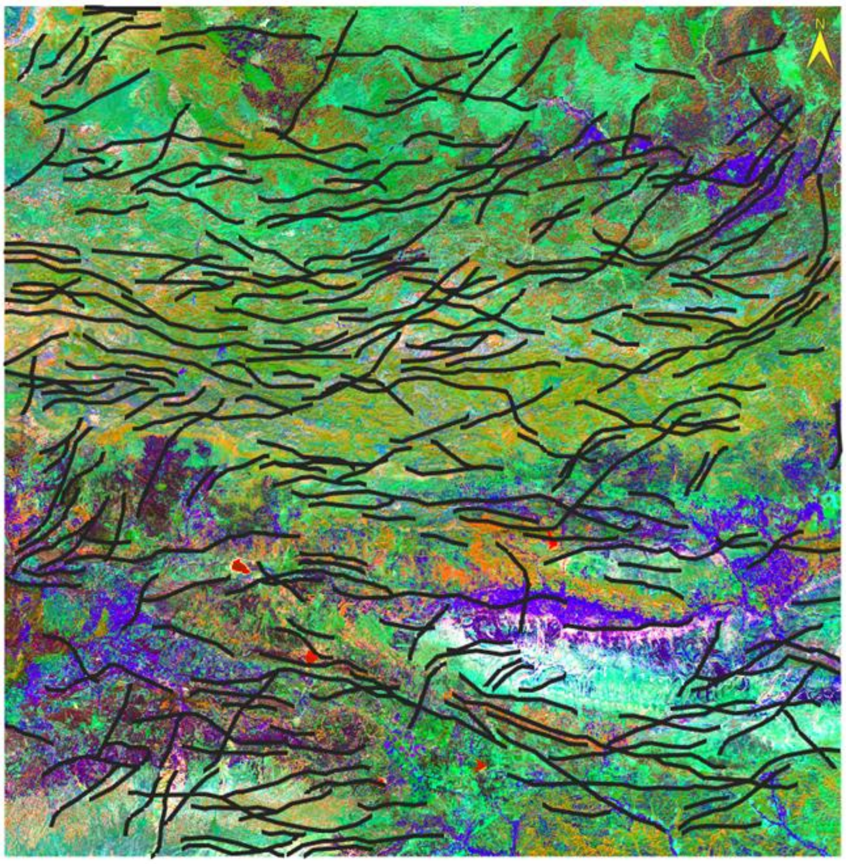

Figure 5. Linearities obtained from ASTER L1T data.

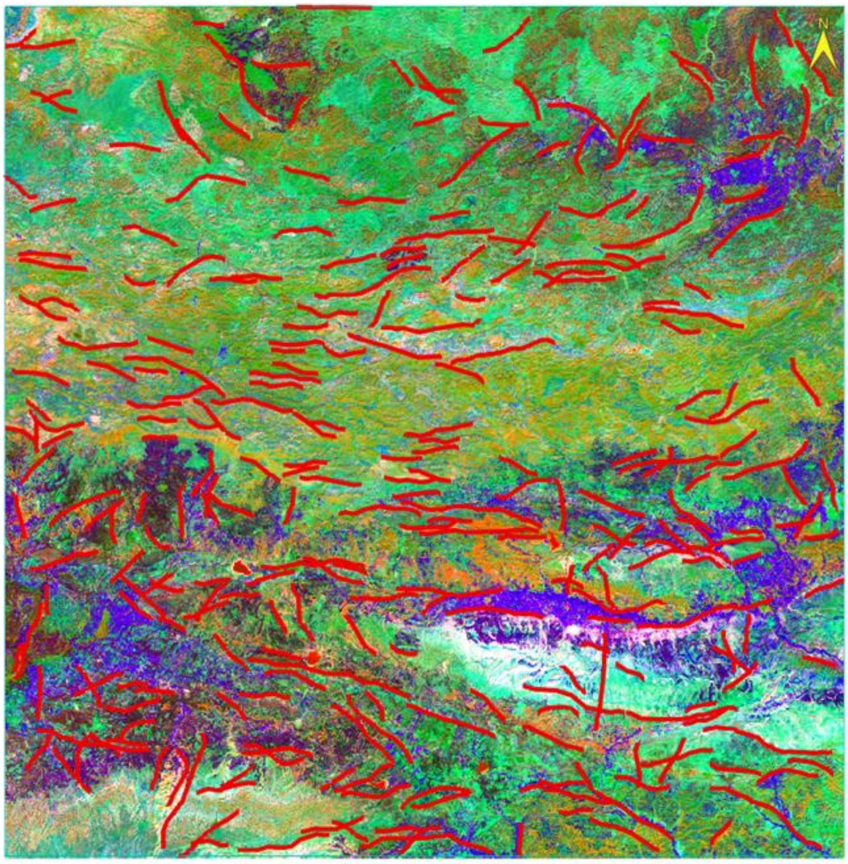

Figure 6. Linearities derived from Sentinel 2A data.

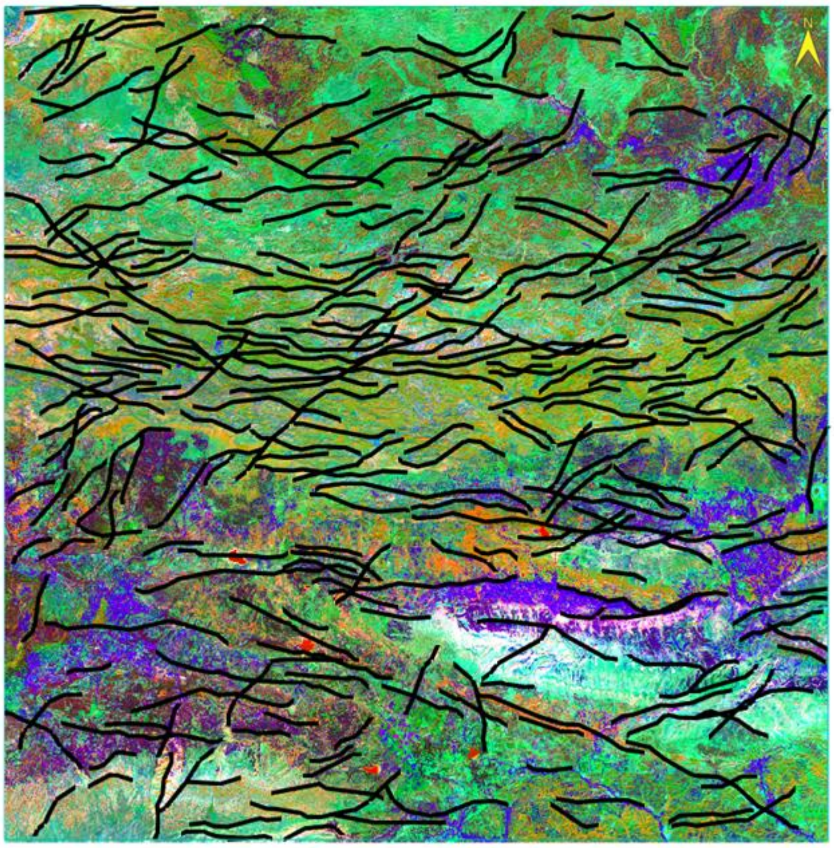

Figure 7. Linearities obtained from Landsat 8 OLI data.

When the three images obtained above are compared, it is clear that the possible lineations exhibit density patterns (Figure 8). Of course, these linearities should be evaluated alongside field study data.

Figure 8. ASTER=white, Landsat8=black, Sentinel2A=red.

5. Results and Discussion

Geological lineaments play a role in revealing a region's paleo- or neo-tectonic features. Many geological settings have used remote sensing data to clarify the lineaments of these tectonic characteristics [29].

The study area is a significant junction of the Arabian plate and allochthonous units. Lithostratigraphic units deposited in the Upper Permian-Quaternary age range can be found in the study area. Malatya Metamorphics, Suture Belt, and Arabian Autochthonous Units are located from north to south. Thrust zones formed as a result of the closure of the Neo-Tethys Ocean's southern branch [9], followed by the convergence of the Tauride plate and the Arabian plate [9, 30].

Allochthonous units were thrust over the northern margin of the Arabian platform in the south in these thrust belts. Both allochthonous rocks were sliced due to this pushing movement, and frontal charges formed between the Taurus Orogenic belt and the Arabian Autochthonous [12-13]. The Arabian Platform is a belt that is compressed between nappes in the thrust zone and comprises a thick marine sedimentary succession [31]. The regional orogeny was formed in the nappe regions by ophiolitic rocks and Malatya Metamorphics. The current successions were formed later due to the collision of the nappes with the Arabian plate in the Late Miocene [31]. The identified tectono-stratigraphic slices from Yalçın and Kop's [19] study also support the theory of developing this orogenic belt.

According to Yalçın's [18, 20] research, the units of the collision belt in Çağlayancerit and its west lithostratigraphic units came together, and deformation structures from different periods developed in the region. The structural elements and surroundings of the region were re-evaluated using remote sensing methods in this study. Topographic data and linear structures show that the region's tectonic forces are active in geomorphology. Furthermore, the faults in the structural map obtained from the field study are consistent with the satellite images [20].

Four distinct linear zones were identified when three different satellite images were evaluated together in this study (Figure 9). Zone 1 contains allochthonous Malatya Metamorphics. Zone 2 is the suture belt, while zones 3 and 4 are the autochthonous margin fold belt. These linear belts correspond to the field studies as well.

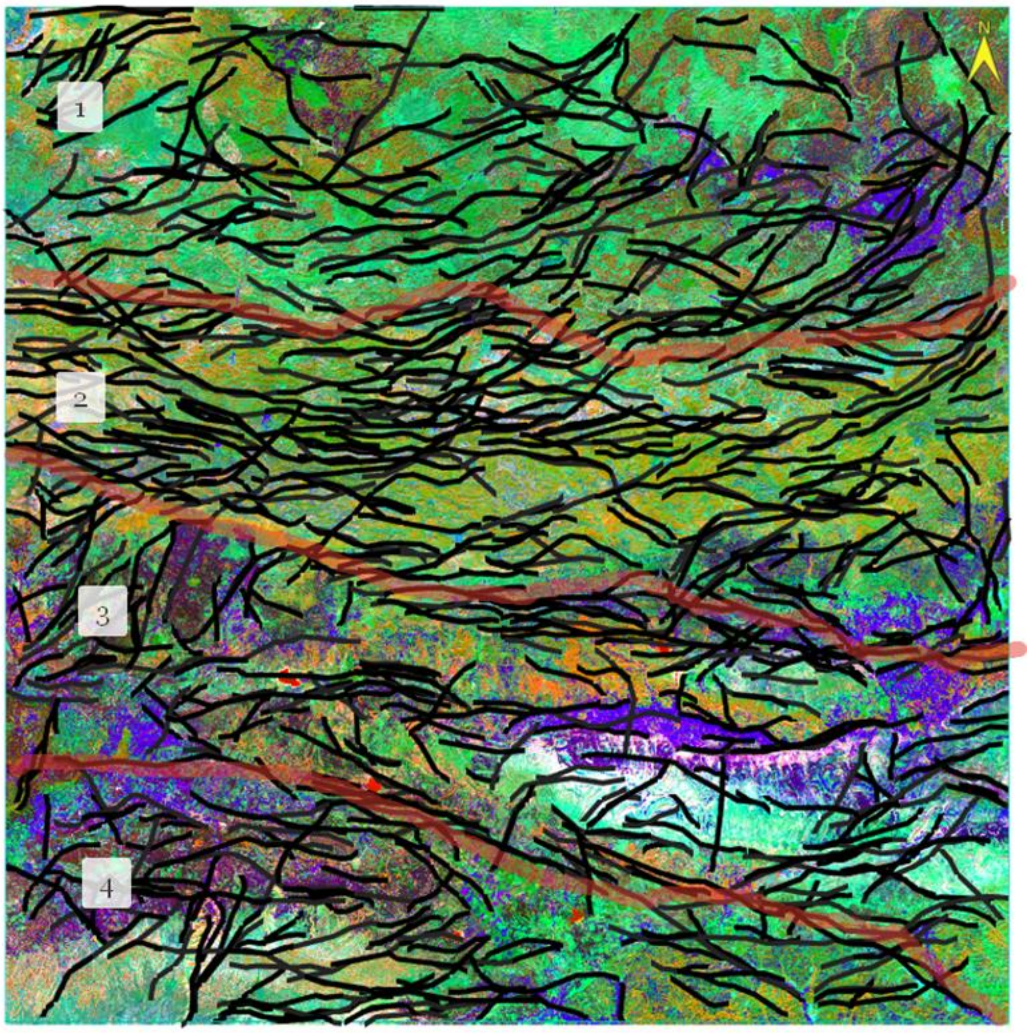

Figure 9. View of 4 separate linear zones defined.

It is well known that satellite images are used to create and interpret maps. Tawfeeq and Atasever [32] used Sentinel-2 images to assess the land cover change of Işıklı Lake and its surroundings. Altun and Türker [33], on the other hand, integrated Sentinel-1 and Landsat-8 images for crop detection. Many researchers have interpreted satellite images according to their subject and obtained results.

6. Conclusion

Tectonic linearities are important parameters in structural geological studies. Lineaments assist in the mapping and monitoring of fault structures associated with geological risks. Topographic relief and/or tonal features on the earth's surface are represented by lines in satellite remote sensing images.

In today's technology, remote sensing methods can still validate maps prepared for tectonic and structural purposes. Morphological changes are the most common, particularly in tectonically active regions where continents collide. In overlap belts, very high topographic data are obtained. ASTER L1T-Band3, Sentinel2A-Band11, and Landsat 8 OLI-PanBand8 bands were used in this study and correlated with field studies.

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Author contributions

Conflicts of interest

The authors declare no conflicts of interest.

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