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Akkaya-Feke (Adana-Turkey) Assessment Of The Relatıonship Between Fluorite And Rare Earth Elements (REE) IDW And Satellite-Based Tectonic Lineaments

Sinan Altuncua[1] and Ramazan Demircioğlu[2]

Abstract

The study area is in the Central Tauride section of the Taurides, a tectonic unit in Turkey. This region encompasses the village of Akkaya (Feke-Adana) along with the surrounding areas of Adana province. The region has experienced polyphase deformation, resulting in faults and fractures that provide suitable locations for mineralization. Additionally, magmatism has contributed to the formation of various mineral deposits. Among these minerals is fluorite, which is extensively utilised in the metal, chemical, and glass industries. This study aims to investigate fluorite mineralization and the distribution of rare earth elements (REE) using the Inverse Distance Weighting (IDW) method, as well as assess the relationship between satellite-based tectonic lines and mineralization. The findings suggest that vein-type fluorite mineralization and the distribution of rare earth elements are generally aligned with the identified tectonic lineaments.

Key words: Turkey, Feke, Fluorite mineralization, REE, IDW, Tectonic lineament.

Resumen

El área de estudio se encuentra en la sección central de Tauride, una unidad tectónica de Turquía. Esta región abarca el pueblo de Akkaya (Feke-Adana) junto con las zonas circundantes de la provincia de Adana. La región ha experimentado una deformación polifásica, lo que ha dado lugar a fallas y fracturas que proporcionan los lugares adecuados para la mineralización. Además, el magmatismo ha contribuido a la formación de diversos yacimientos minerales. Entre estos minerales se encuentra la fluorita, que se utiliza ampliamente en las industrias metalúrgica, química y del vidrio. El objetivo de este estudio es investigar la mineralización de fluorita y la distribución de elementos de tierras raras (REE) utilizando el método de ponderación inversa de la distancia (IDW), así como evaluar la relación entre las líneas tectónicas basadas en satélites y la mineralización. Los resultados sugieren que la mineralización de fluorita de tipo veta y la distribución de los elementos de tierras raras están generalmente alineados con los lineamientos tectónicos identificados.

Palabras clave: Turquía, Feke, mineralización de fluorita, REE, IDW, alineamiento tectónico.

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1. Introduction

The Akkaya fluorite deposit is situated roughly 110 km away from the Adana province and 8 km from the Feke district. The fluorite mineralization area can be found north of Akkaya Village, as shown in Figure 1. Accessing Akkaya Village is fairly easy and is mostly done through asphalt roads. The area is located on the Anatolide-Tauride block, which is one of the tectonic units of Turkey, as classified by Ketin (1966) and Okay and Tüysüz (1999).

The study area is a part of the Southeastern Taurus Mountains, a region containing highly folded and faulted zones. The rocks in this area have undergone multiple stages of deformation, resulting in extensive folding and faulting. The region has both autochthonous and allochthonous units. Numerous stratigraphic studies have been carried out, including those by Blumenthal (1947), Abdüsselamoğlu (1958), Dean and Monod (1970), and Özgül *et al.* (1991). Tectonic and structural geological studies have also been conducted, including those by Demirkol (1977, 1982, 1986) and Demirkol and Yetiş (1985). The Palaeozoic-Cenozoic Geyikdağı Unit (Dean and Özgül, 1994) and the allochthonous Çay and Doğanhisar tectonic units (Özgül *et al.*, 1991; Güngör, 2013) are considered relatively autochthonous. In the study area, the Geyik Mountain Unit is overlain by the allochthonous Doganhisar tectonic unit (Özgül, 1991) (Figure 1).

Our study aims to investigate the relationship between fluorite mineralization identified through field studies and satellite-based tectonic lineaments in the area. Similar studies have been conducted in different parts of the world, including those by Maude (1987), Arian and Reza (2015), Chen *et al.* (2020), Barhoumi *et*

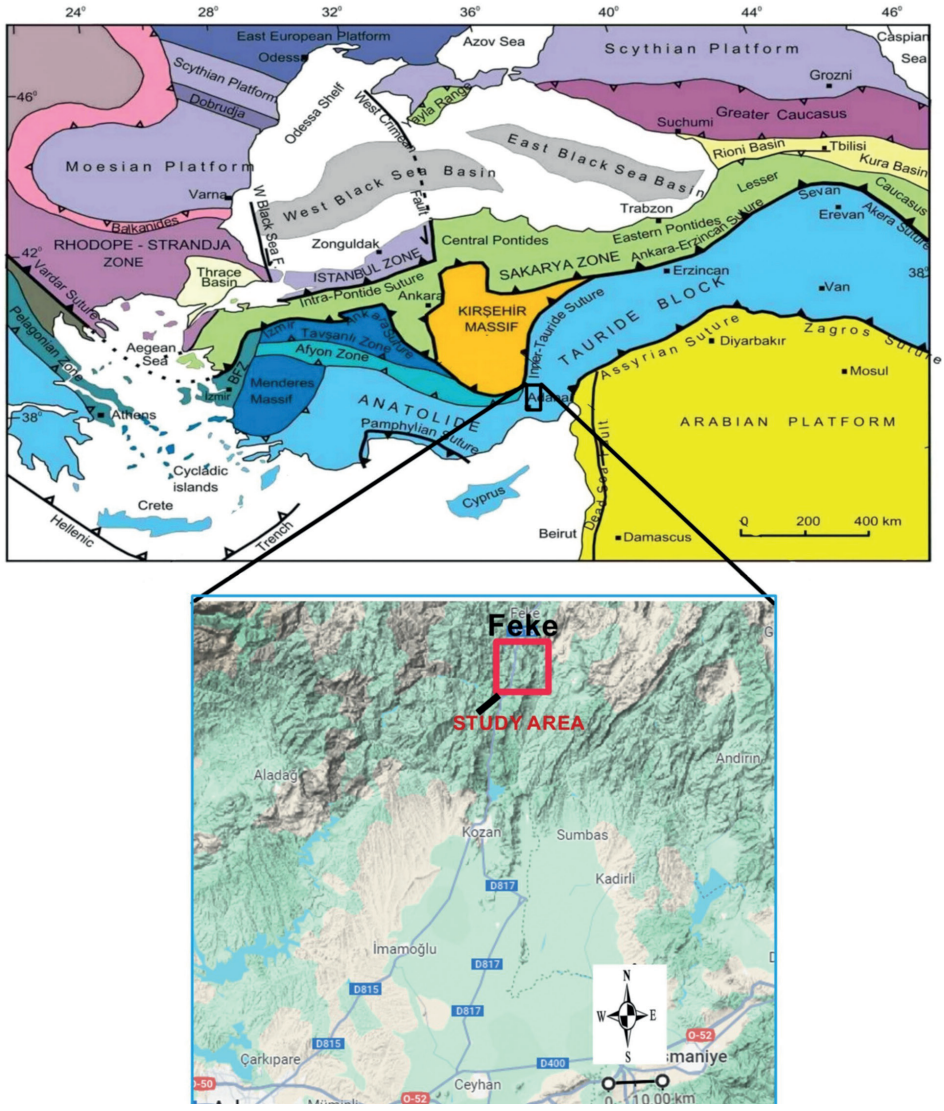


Figure 1. Tectonic settings and location map of the study area. (Modified from Okay and Tüysüz, 1999).

al. (2021), Maleki *et al.* (2021), Shirazi *et al.* (2022), El Galladi *et al.* (2022), Mahdi *et al.* (2022), and Fan and Ni (2023).

Fluorite is a mineral of great versatility, proven invaluable in many essential applications. It is widely used in metallurgy to aid in the flotation of metal ores. Moreover, it is frequently added to glass to reduce its melting temperature and improve its optical qualities, and particularly in iron and steel production. Additionally, fluorite is employed in the treatment of industrial waste for environmental pollution control, and it has an array of uses in optical devices, glass processing equipment, chemical processes, and steel production (Anthony *et al.*, 1990, Ray, 1990, Capper, 2005).

2. Geological Setting

2.1. Structural geology

Haude initially examined the study area's tectonic characteristics in 1968. Later on, further studies were conducted by Demirkol and Yetiş in 1985, as well as Demirkol in 1977, 1982, and 1986. The Paleozoic rocks that create the foundation of the study area underwent numerous deformation events, resulting in the formation of polyphase folds, faults, and fractures (shear and tension) of various types and strikes. The discontinuities created by the faults and fractures became crucial locations for mineralization.

2.2. Stratigraphy

The oldest unit in the region is the Emirgazi Formation, which is considered Lower Cambrian (Figure 2 and 3).

The Değirmentaş limestone unit is covered by the Armutdere Formation. This formation has been assigned the Ordovician age and consists of thin-bedded, laminated shale that contains graptolite and trilobite fossils. The succession containing the Ayıtepe Formation, which is Lower Devonian in age, is observed as a succession of sandstone, limestone, and shale. At the top, the Ayıtepe Formation gradually transitions to the Middle Devonian Şafaktepe Formation. The Şafaktepe Limestone, which is Middle Devonian in age and unconformably overlying it, has dolomitic and karstic voids in places.

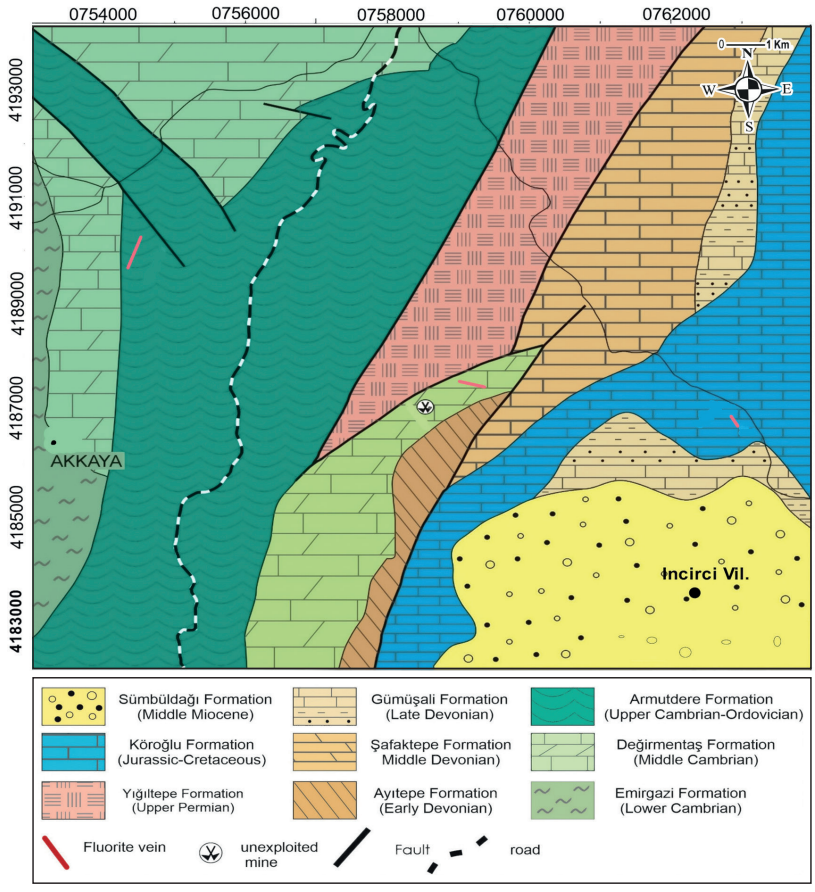


Figure 2. Geological map of Akkaya (Feke-Adana) fluorite deposit (Modified from Altuncu, 2006).

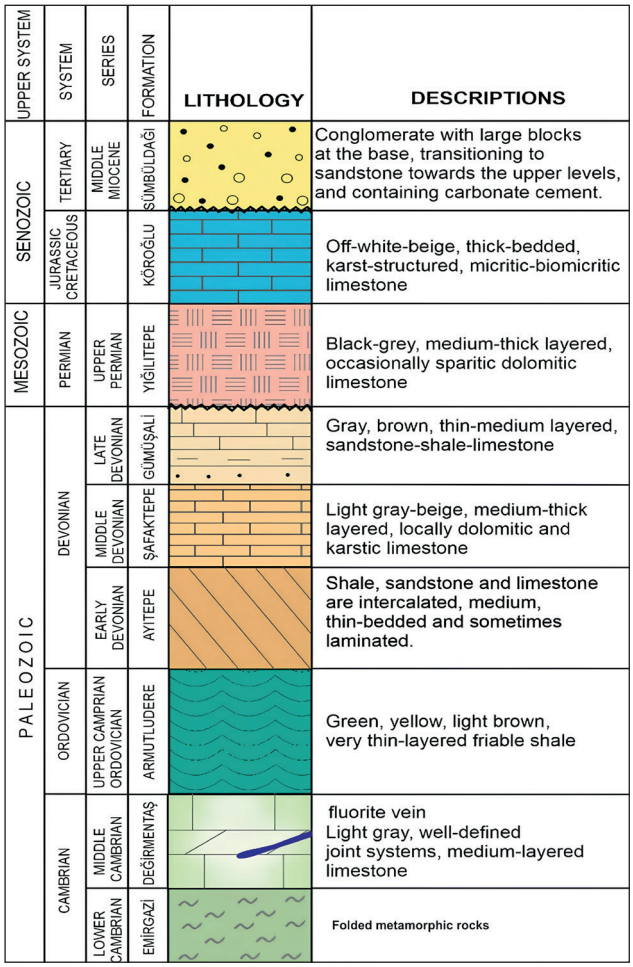


Figure 3. Stratigraphic column of the Akkaya (Feke-Adana) area (without scale and modified from Altuncu, 2009).

The Upper Devonian Gümüşali Formation, which is irregularly observed as sandstone-shale-limestone succession, is unconformably overlying the Şafaktepe Limestone. The Upper Permian Yığılıtepe Limestone unconformably overlies it. The Cretaceous Yanktepe Limestone consists of thick-bedded, abundant rudist clasts, beige-coloured micrite-biomicrite type limestone. Sümbüldağı Formation represents the Miocene. This unit has a conglomerate at its base, and thin-bedded sandstone towards the top, and cover unconformably the older units.

The Değirmentaş Formation is the oldest unit found in the study area and was discovered in Değirmentaş Village by Özgül *et al.* in 1973. This unit is made up of a thick stack of dolomite, conglomeratic limestone, nodular limestone, and limestone, from bottom to top. The dolomite is medium-bedded, jointed, and fractured, with calcite-filled fractures. The conglomeratic limestone is medium-stratified and contains angular and semi-angular pebbles of different sizes. The pebbles are fragments of dolomite, limestone, and quartzite. The limestone in the upper levels is medium-stratified. The age of the unit is given as Cambrian based on comparison with similar rock-type stratigraphy units that surfaced in the Amanos Mountains and Central Tauride Mountains, and it does not contain fossils, according to Özgül *et al.* (1973) and Metin *et al.* (1983). The Armutludere Formation, first named by Demirtasli in 1967, lies conformably on top of the Değirmentaş Formation. The formation consists of nodular limestone, a nodular limestone-shale succession, and a shale-siltstone succession, from bottom to top. The shales are mostly laminated and sometimes foliated, and are very dispersible and unestable. These rocks are found on wide plains in the region. The presence of fossils with macro-cavities and traces of worms in them proves the shallowness of the environment. According to its constituent rock types, it can be said that the formation was formed in a relatively deepening, shallow marine sedimentary environment. This formation is highly affected by tectonism. The Armutludere Formation, which is compatible with the formations above and below it, is easily distinguished in the field with its dark brown and soft morphology. The age of the unit is given as Ordovician according to Özgül *et al.* (1973) and Metin *et al.* (1983). The Lower Devonian Ayıtepe

Formation was named by Özgül *et al.* (1972). This formation is observed as sandstone, limestone, and shale successions. The lower levels of the sandstone are thick, and the upper levels are medium-thick bedded. Limestone and shale are thin- to medium-layered. With a gradual transition, the Ayıtepe Formation transitions to the Middle Devonian Safaktepe Formation at the top. Şafaktepe Formation: The unit named Şafaktepe Formation is unconformable on Ordovician-aged shales. The name of the formation was first used by Demirtasli (1967). This limestone unit is widely observed in Abdiuşağı Mahallesi and the Kizharman area. The fresh surface is black-dark grey, the weathered surface is grey-light grey, and the dominant rock type is medium-thickly bedded limestone-dolomitized limestone with karstic cavities in places. Poorly developed joint systems are mostly calcite-filled. The intersection of the Şafaktepe Formation and the Yığılıtepe Limestone Formation is tectonic contact. Their ages are given as Middle Devonian by Özgül *et al.*, 1973; Metin *et al.*, 1983. The Gümüşali Formation with sandstone-shale-limestone succession is conformable over the Şafaktepe Formation. This formation surfaces east of the Abdiuşağı neighbourhood and north of the Pinargozu area. The limestones surfaced in the region are dark ash-coloured, thin- to medium-layered, and poorly developed. The rock types and fossils of the formation suggest that the unit was deposited in a shallow, hot, and turbulent environment. Its age is given as Upper Devonian by Özgül *et al.*, 1973; Metin *et al.*, 1983; and Tutkun, 1984. Yığılıtepe Limestone was first named Yığılıtepe Formation by Demirtaşlı (1967). The dominant rock type consists of limestone and quartzite. It has abundant fossils, a grey, dark grey-black weathered surface, fresh fracture surfaces, medium-thick layers, karstic voids in places, and abundant joints and fractures. The fractures are filled with calcite and have a resistant structure. Its age is given as Upper Permian by Özgül *et al.*, 1973; Metin *et al.*, 1983; and Tutkun, 1984. Yanıktepe Limestone is observed unconformably on Palaeozoic units in the study area and was first named by Özgül *et al.* (1973) and Metin and Bingöl (1982). It is the only lithostratigraphic unit representing the Mesozoic Upper System in the study area, and it surfaced in the southeast of the Katlar Ridge, forming a high topography. This unit, which is generally composed of white and beige-coloured micritic limestones with abundant fossils, is not named as a formation since its distribution in the region is very small. It is the limestone with the highest melting property in the region. Therefore, it formed a karstic morphology where it is located (Metin and Bingöl, 1982). The Yanıktepe limestone formation is unconformable with the underlying Palaeozoic units and the overlying Sümbüldağ Formation. Its age is given as Upper Cretaceous (Maestrihtian) by Özgül *et al.*, 1973, Metin *et al.*, 1983, Tutkun, 1984. The Sümbülda Formation is the unit representing the Cenozoic upper system in the study area. The base level of the Sümbüldağ Formation contains coarse sedimentary and metamorphic rock fragments. Thin-layered sandstones are observed towards the upper levels. These medium-fine-layered, yellow-brown, medium-fine-grained sandstones containing foreign rock fragments transition back to pebbles are at the uppermost levels of the formation. The age of the unit is given as Lower Miocene by Metin *et al.*, 1983; Tutkun, 1984.

3. Material and Method

This research was conducted in the villages of Akkaya and Incirci in the Feke district of Adana province, where fluorite mineralization was identified, as shown on the M35b3 map of Turkey. Geological mapping was performed in the field, and fluorite deposits were located. Satellite images were obtained from an online source, allowing for the creation of boundary maps for the study area. Landsat-8 images were processed to generate lineament maps, and field measurements were analyzed using the Stereonet program. A flow chart illustrating these processes in detail is shown in Figure 4. In this study, both field and remote sensing studies were carried out together.

Fracture and fault strike was measured in the field and plotted on stereonets using the Stereonet 3.02 program (Allmendinger *et al.*, 2013). Fluorite vein measurements taken during field experiments were also assessed using Stereonet 3.02, and contour diagrams were created for these veins. Tectonic lineaments obtained from satellite images were plotted on rose diagrams using the Rockwork program (Rockwork. 2019).

A comparison was made between the data obtained from satellite images and the data determined at the mine site to establish a relationship between lineaments and mineralization. For example, chalcopyrite, sphalerite, siderite, and other sulphide minerals. Hydrothermal and pegmatitic fluorite veins are located along discontinuity planes in fractures and faults, forming fluorite veins. Therefore, there is a close relationship between the formation of fluorite veins and tectonism.

3.1. Preparation of an automatic lineament map of the study area

Automatic lineament maps were created by processing the satellite image in computer programs (Envi, Rockwork, Arc-Gıs). The Landsat-8 satellite image was obtained from the web site (**earthexplorer.usgs.gov/**) (Figure 5a).

The satellite image was processed to automatically extract lineaments using threshold values and filters with Envi, Geomatica, and ArcGIS. This led to the creation of a lineament map (Figure 5b) and density map (Figure 6) in ArcGIS.

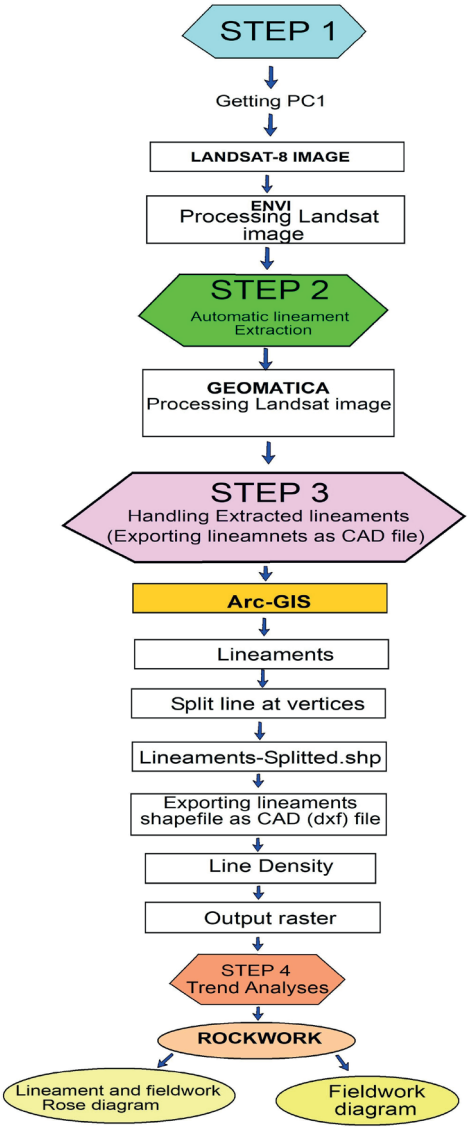


Figure 4. Flowchart for the creation of lineament maps and fieldwork diagrams (Modified from Demircioğlu *et al.*, 2024).

The lineament map was then overlaid with the satellite image of the study area using Envi, Geomatica, and ArcGIS, revealing tectonic lineaments in and around Akkaya area (Figure 6). The tectonic lineaments identified were correlated with known fault systems in the region, we were able to deduce potential tectonic activity and stress distribution patterns. The analysis suggested a predominance of NE-SW and NW-SE trending lineaments, which align with regional tectonic trends.

A density map was prepared for the satellite-based lineaments. Then, the density and lineament maps were superimposed.

3.2. Fluorite mineralization and its identification in the field.

The geochemistry of fluorite formations in the study area was investigated. During the field studies, it was determined that the fluorite veins were located along the fault planes, with fractures and discontinuities at the layer boundaries, which also form the lineaments. Accordingly, the relationship between lineament and fluorite mineralization was tried to be determined.

4. Results

Fluorite formations in the study area occur in the form of veins. Samples were collected and geochemical analyses were performed. Field studies determined that fluorite veins are located along fault and fracture planes and that they also form lineaments. Accordingly, the relationship between lineaments

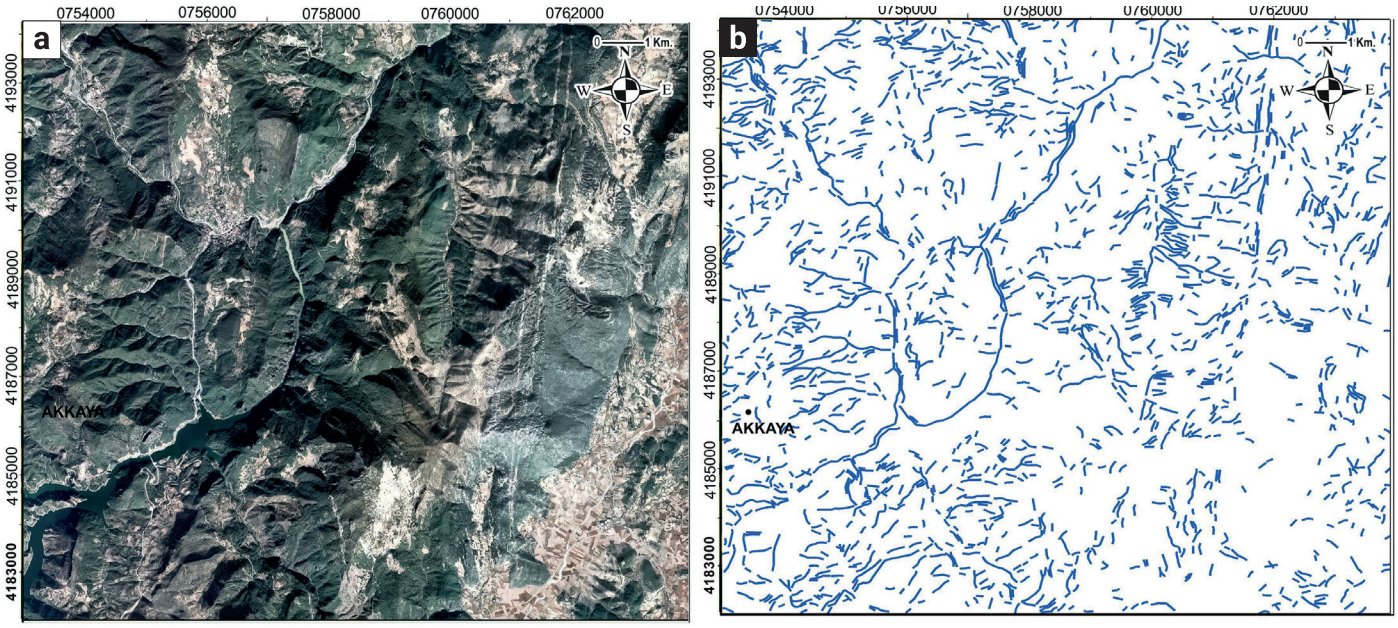


Figure 5. (a) Image of the research region from the Landsat-8 satellite. (b) Lineament map derived from a satellite picture.

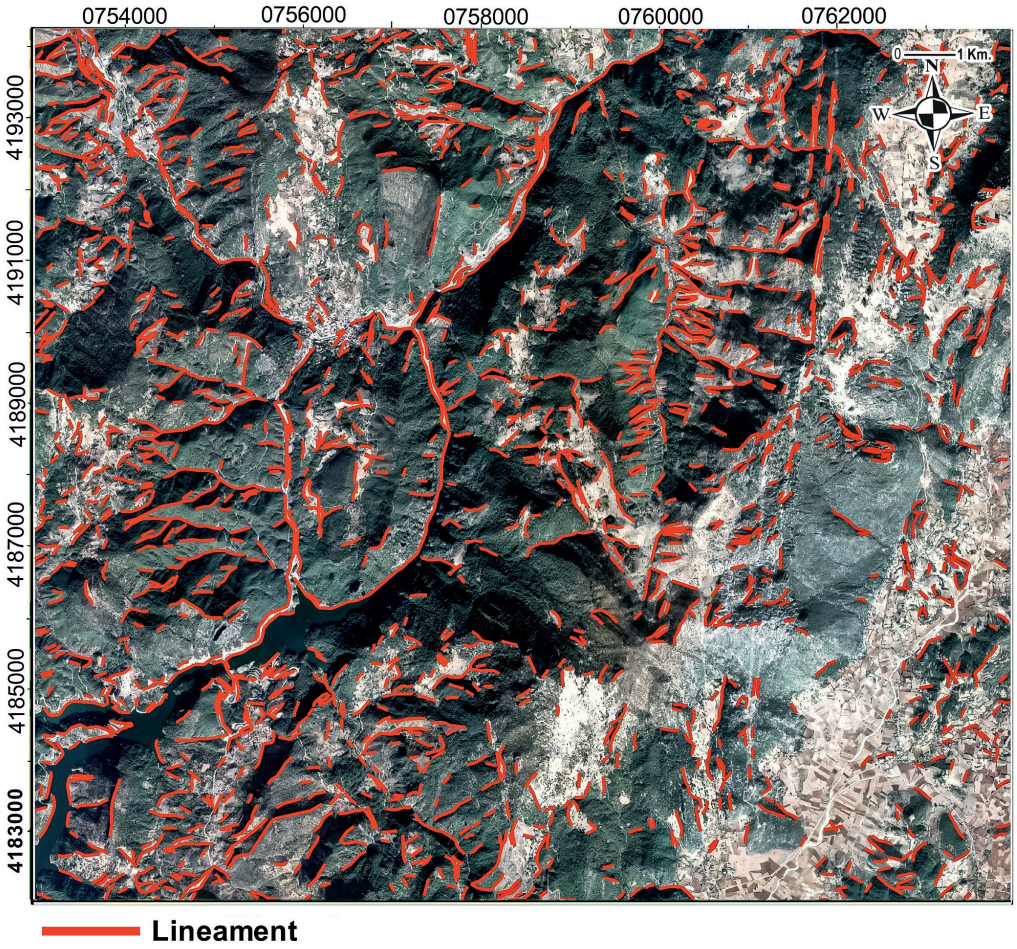


Figure 6. Satellite-based lineament map view of Akkaya area and its surroundings.

and fluorite mineralization was investigated and found to be closely related.

4.1. Rare Earth Element (REE) Geochemistry of Feke-Akkaya Fluorite Deposit

Akkaya (Feke-Adana) fluorite deposit has very low rare earth element (REE) contents (Table 1).

In the diagrams prepared according to REE contents, it is seen that light rare earth element (LREE) ratios are considerably higher than heavy rare earth element (HREE) ratios (Figure 7a, b).This observation suggests a preferential enrichment of LREE within the fluorite matrix, which may be attributed to the geochemical processes involved in the formation of the deposit. A detailed examination of the mineralogical characteristics reveals that the presence of LREE-bearing minerals could facilitate the concentration of these elements during hydrothermal alterations. Further comparative analysis with other fluorite deposits may elucidate the underlying mechanisms that influence the distribution of REEs.

Additionally, the geochemical behavior of fluorite in its host rocks can shed light on the potential for resource exploration in similar geological terrains. The relative scarcity of HREE implies limited economic viability for rare earth extraction; However, understanding the geological context and the processes that control REE distribution might open ways for enhancing recovery techniques or identifying complementary REE sources in adjacent or related formations (Altuncu, 2009). Future studies focusing on isotopic compositions and trace element distributions could provide deeper insights into the genetic characteristics of the Akkaya deposit and its comparative REE profile (Figure 7).

The fluorite ratios of Tb/La and Tb/Ca are useful in determining the degree of fractionation of ore fluids. These diagrams help categorize fluorites based on how they formed (Möller *et al.*, 1976; Möller and Morteani, 1983). According to Özüş and Yaman (1986), Feke fluorites can be found in the sedimentary area based on the Tb/La and Tb/Ca diagrams. This study found that one sample was sedimentary, while the other samples were formed through hydrothermal processes (Figure 8). The diagram suggests that primary crystallization played a significant role in the mineralization process.

Table 1. REE analysis results of Akkaya (Feke-Adana) fluorites by ICP-MS (Altuncu, 2009).

	SMP1	SMP2	SMP3	SMP4	SMP5	AK32
La	4,5	0,1	2,1	1,5	2,4	2,3
Ce	7	1	4,8	1,7	3	3,3
Pr	0,99	0,02	0,41	0,29	0,49	0,39
Nd	3,5	0,3	1	2	1,7	1,4
Sm	0,71	0,1	0,24	0,27	0,35	0,23
Eu	0,02	0,05	0,05	0,02	0,02	0,05
Gd	0,68	0,16	0,24	0,35	0,41	0,23
Tb	0,09	0,03	0,02	0,07	0,03	0,05
Dy	0,61	0,2	0,17	0,43	0,29	0,19
Y	4,8	3,8	5	7,9	7	6
Ho	0,09	0,04	0,03	0,09	0,08	0,05
Er	0,25	0,11	0,06	0,21	0,17	0,14
Tm	0,04	0,01	0,01	0,03	0,02	0,01
Yb	0,27	0,05	0,05	0,1	0,08	0,07
Lu	0,03	0,01	0,01	0,02	0,02	0,01
Total REE	23,58	5,98	14,19	14,38	16,38	14,7
Tb/La	0,02	0,30	0,01	0,05	0,02	0,01
Tb/Ca	2,16	5,88	3,86	1,45	1,01	6,04
Eu/Eu*	0,09	1,21	0,64	0,20	0,16	0,66
Ce/Ce*	0,80	5,38	1,25	0,62	0,67	0,84

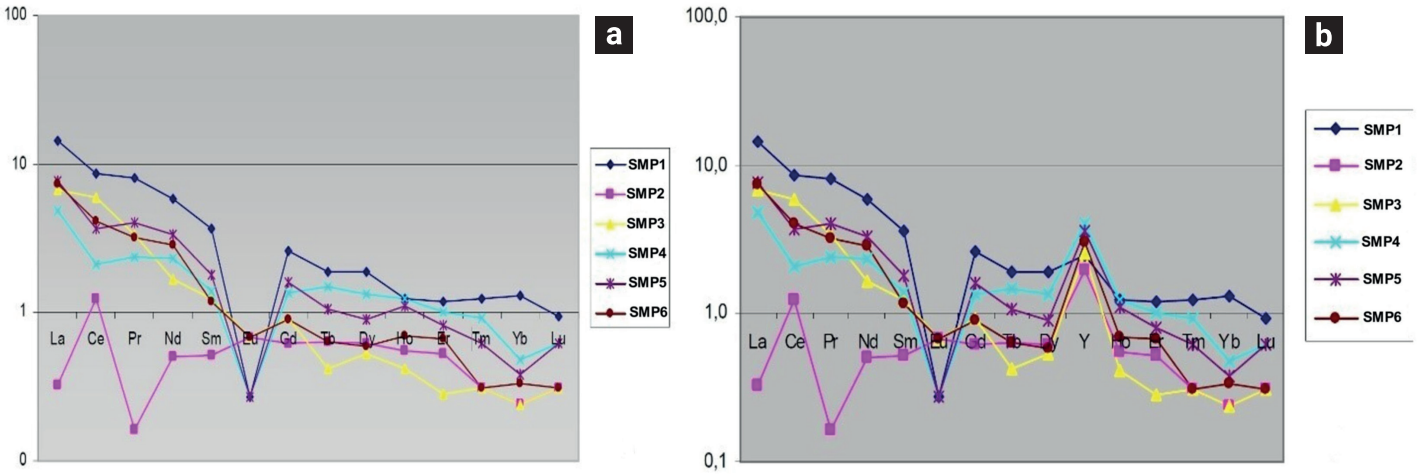


Figure 7. a) REE distribution of Akkaya fluorites normalised by chondrite (SMP: Sample). b) REE distribution of Akkaya fluorites normalised by chondrite with Y included.

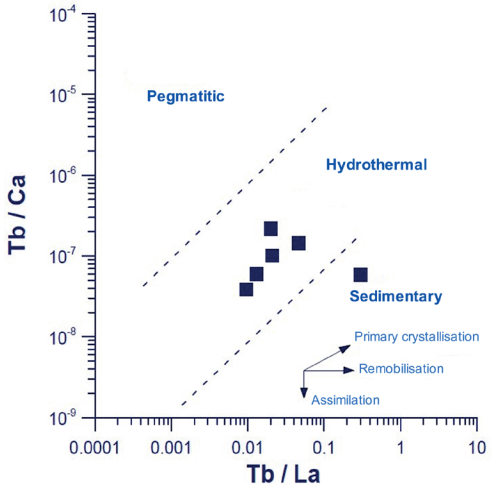


Figure 8. Tb/Ca and Tb/La variation diagram of Feke Akkaya fluorites (Altuncu, 2009).

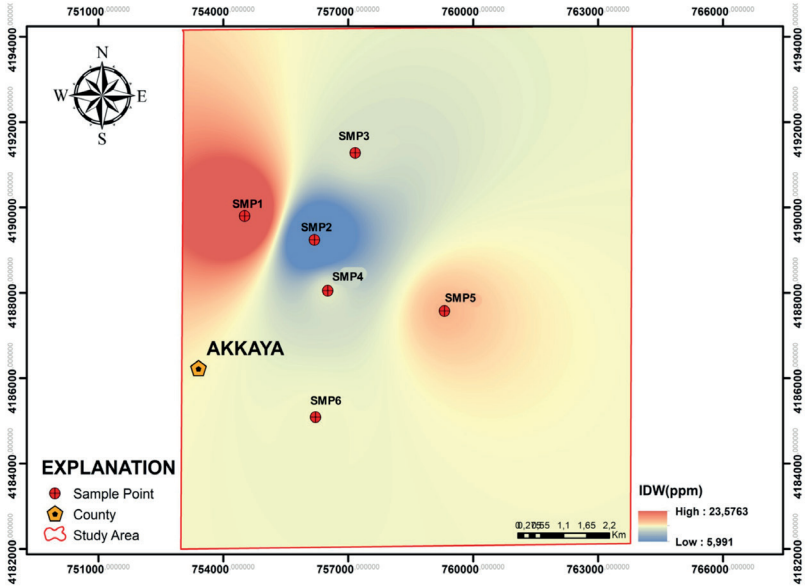


Figure 9. IDW (Inverse Distance Weighting) diagram of total REE values for Akkaya and its surroundings.

4.2. Assessment of rare earth element (REE) distributions using an IDW diagram

Sample (SMP) analyses were conducted on the working area of Feke and its surroundings (Table 1).

Total REE values are between 5.98 ppm and 23.58 ppm. In this regard, an IDW diagram has been prepared (Figure 9).

In the IDW diagram, the distribution density of REE values has been determined. Areas where mineralization occurs and potential areas have been identified.

The average value is 14.87 ppm. Strong negative Eu anomalies are observed in the majority of the samples. Eu/Eu* ratio is between 0.09 ppm and 1.21 ppm. The average is 0.49 ppm. It would be appropriate to attribute the strong negative Eu anomaly to the limestones in which the fluorite mineralization is located.

4.3. Fluorite mineralization and its relationship with tectonic lineaments

The Akkaya fluorite deposit is located on the eastern slope of the Katlar Ridge, about 1.5 km. east of Akkaya Village, within the Cambrian Değirmentaş Limestone, the deposit is, in the form of a vein with an N420E strike and 780SE dipping. The vein has a thickness between 0.50 and 2 m and a length of approximately 70 m (Figure 10a). Significant fluorite veins are also observed in outcrops different regions (Figures 10b, c, d, and e).

The transparency of fluorite in the study area is noteworthy, with a range of delicate hues including white, light blue, and light purple. The mineral composition of the fluorite vein is incredibly pure. Previous studies have suggested that fluorite mineralization is the result of fluorine remobilization in fractured

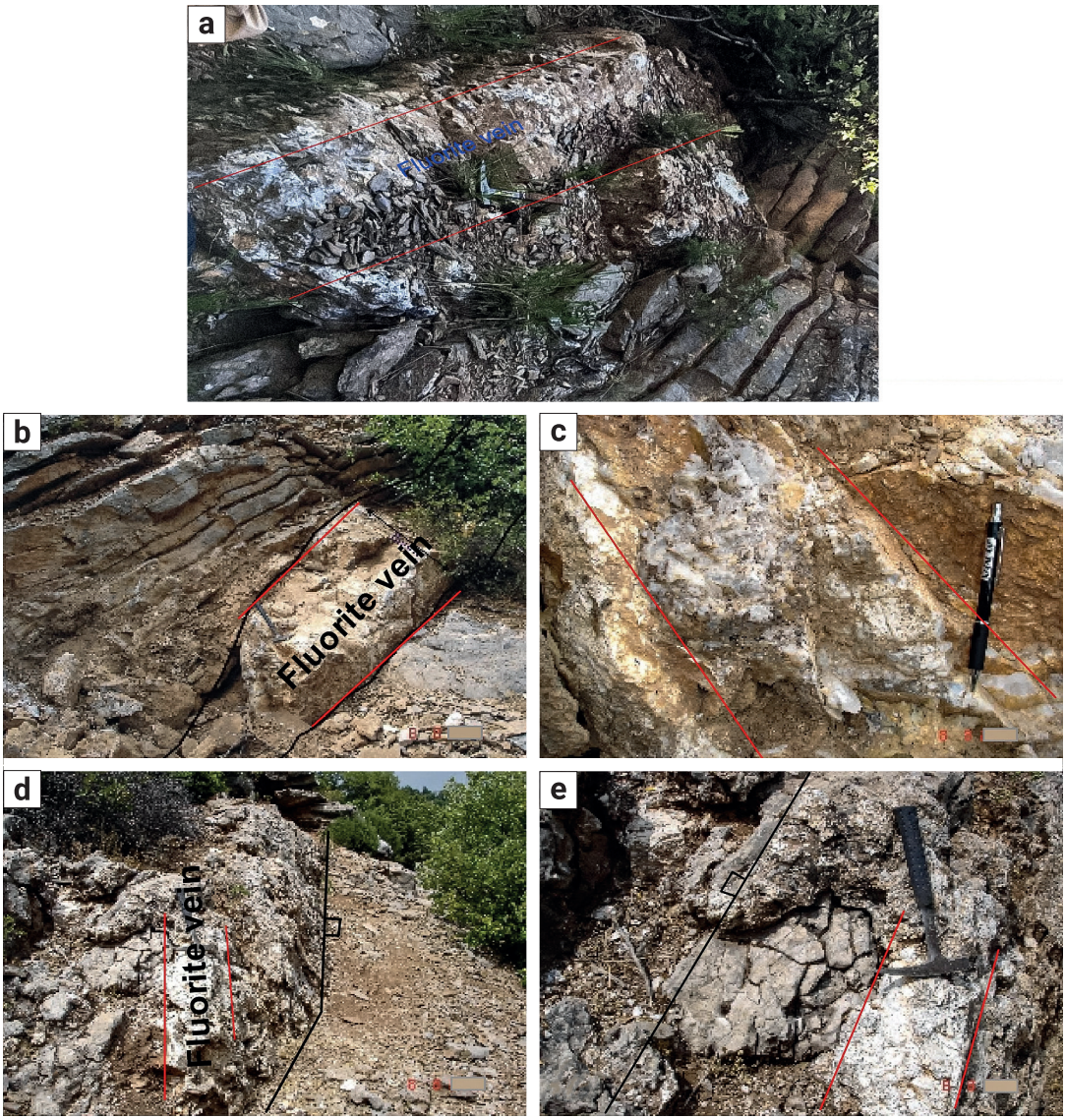


Figure 10. Akkaya (Feke-Adana) fluorite mineralization.

sedimentary rocks. In the study area, the fluorite veins are parallel or semi-parallel to the fault strikes, particularly in the region of normal faults (Figure 10d, e). This suggests a correlation between the tectonic linearities of the fault and fracture orientations, as well as the orientation of fluorite veins.

4.4. Evaluation of the relationship between lineament and fluorite mineralization

Mineralization is observed in areas of concentrated lineaments (Figures 11a, 11b).

The superimposition of lineament and veins orientation facilitated a comprehensive analysis, highlighting areas of increased lineament concentration that correlate with significant geological features. This integration enabled the identification of potential zones of interest for further exploration, particularly where the density of lineaments suggests a higher likelihood of structural complexity.

Fold axes, fault strike, and fractures are tectonic lines that form lineaments, distinct from morphological lines created by erosion.

4.5. Satellite-based assessment of identified lineaments and fluorite veins

The Rockwork software was also used to create rose diagrams of %L (percentage of total strike length) and %N (percentage of overall linearity) of the automatic lineaments (Figure 12 a, b). Because of the polyphase deformation, lineaments are dispersed in all directions, as seen in the graphs (Figure 12). The most intense strikes are N40-50°E, N70-80°E, and N80-90°W, N70-80°W (Figure 12a,b).

The most significant tectonic linear structures in the region are faults and fractures of the faults. The rocks in the area have been subject to polyphase deformation, particularly during the Alpine orogenesis period. As a result, these rocks are highly fractured and faulted. The Stereonet software was used to prepare the point-contour diagram, which evaluated the general strikes of these faults and fractures.The measurements of fluorite veins determined in the field were placed on the stereographic projection in Stereonet 3.02, and contour diagrams were prepared (Figures 12c, d).

According to this evaluation, the vein strikes of fluorite veins were found to be N78°W and N21°W near Akkaya. In the vicinity of Incirci, the fluorite vein strikes were determined as N8°W and N53°E. The fluorite vein positions indicate that they are located in fractures. Satellite-based tectonic lineaments are generally in good agreement. Mineralization is generally developed in areas where normal faults are present.

4.6. Mineralization and its relationship with tectonic lineaments

Tectonic lineaments were identified through satellite image

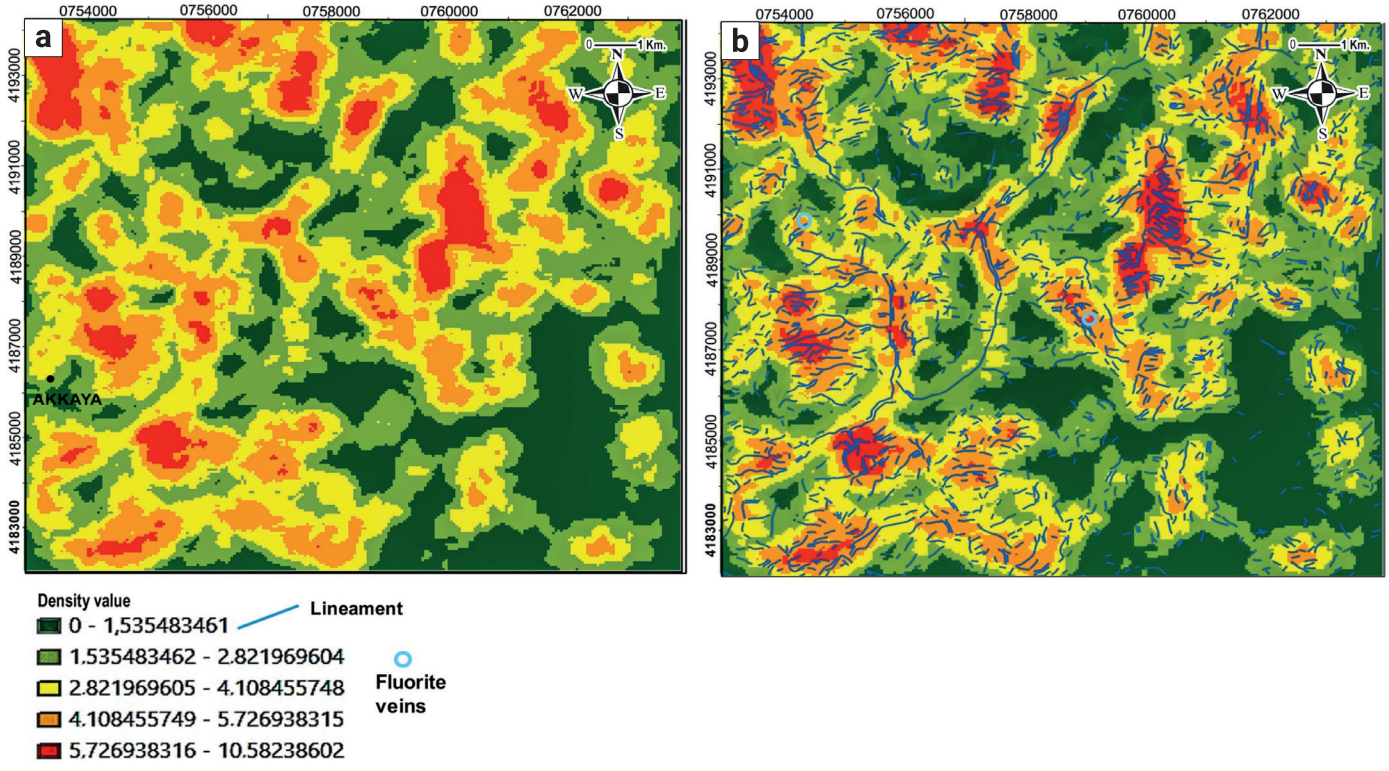


Figure 11. (a) Map of lineament density. (b) Map of lineament density and lineament.

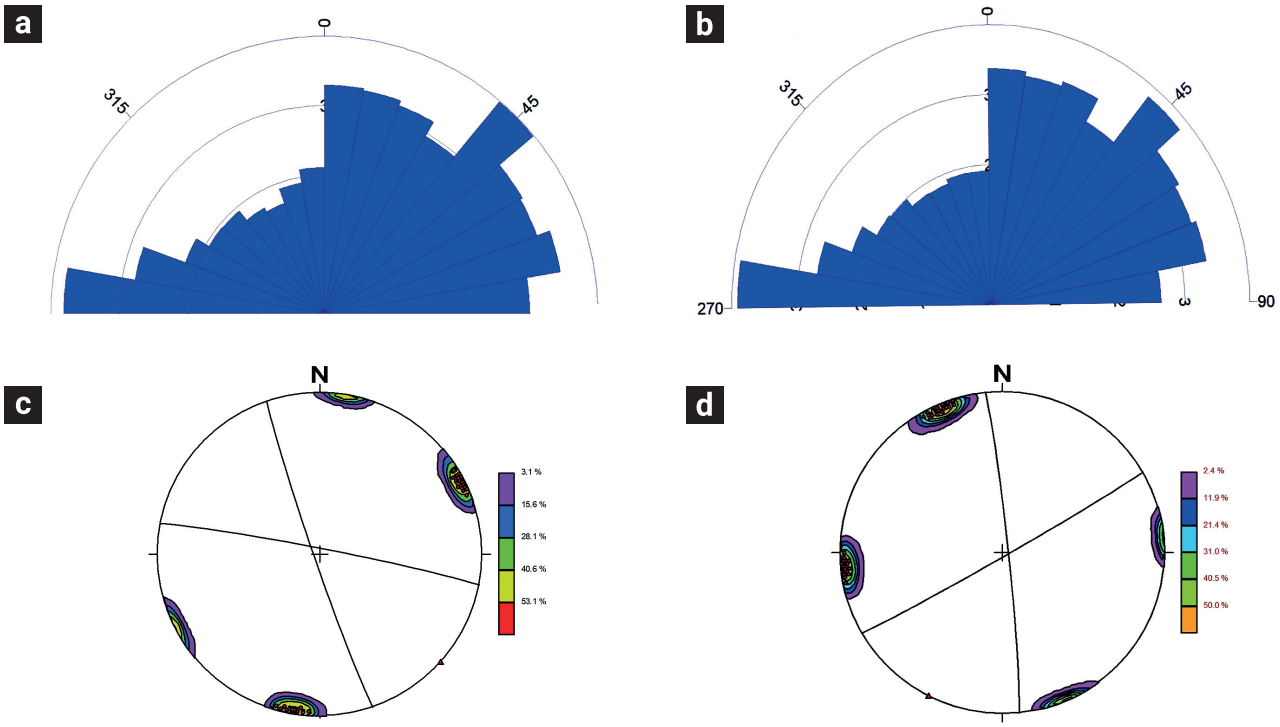


Figure 12. (a) %L: A rose diagram of lengths expressed as a proportion of total linear length. (b)%N: Rose diagram showing overall linearity percentage. (c) Pole-point contour diagram of fluorite vein strikes at Akkaya. (d) Pole-point contour diagram of fluorite vein strikes at Incirci.

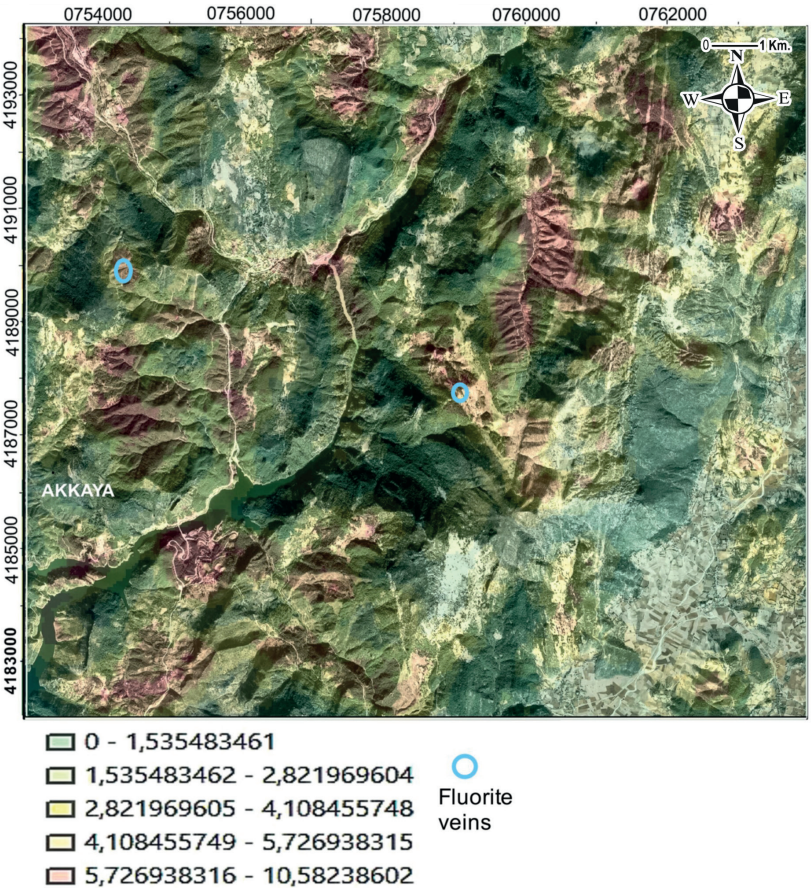


Figure 13. Satellite image with Lineament density.

and field data from the research area. Fluorite mineralization is generally more intense near Akkaya and Incirci villages, where normal faults and shear fractures are prevalent (Figure 13).

The analysis of fluorites in the study area showed that fluorite is mostly formed through hydrothermal processes and less commonly through sedimentary processes. Hydrothermal mineralization typically occurs through the accumulation of minerals in the cavities of faults and fractures (Belgrano *et al.*, 2016; Garofalo *et al.*, 2023).

5. Conclusions

This studies confirm the relationship between tectonic lineaments and fluorite deposits, showing that fluorite veins align parallel or semi-parallel to the fault strikes in areas with normal faults.

The study area has undergone polyphase deformation, particularly from Alpine orogenesis, resulting in various fault types; mineralization is more common in regions with normal faults and associated shear fractures. The extensional tectonic regime that followed the compressional one has fostered favorable conditions for ore deposits.

The lineament density in the study area coincides with the areas where fluorite mineralization has been observed.

During this field study, it was noted that fluorite mineral occurrences were often found in areas with a high concentration of faults and fractures. This was confirmed by the significant number of satellite lineaments in these areas.

The fact that fluorite mineralization is generally hydrothermal and not sedimentary in origin shows its relationship with tectonic activity and structures.

Using satellite images and field studies together in mineral exploration will be much more efficient. In addition, detailed fieldwork would be appropriate to support remote sensing studies and obtain more precise results.

This method can yield significant results when fault and fracture planes are filled with mineral-rich hydrothermal fluids and form vein-type mineralisation. The use of this method, particularly in vein-type mineralisation, will make a significant contribution to mineral exploration.

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7. References

Abdüsselamoğlu, Ş. (1958). *Sultandağı'nın 1/100.000 ölçekli jeolojik leveleri hakkında rapor* (No. 2669). MTA Enstitüsü.

Allmendinger, R. W., Cardozo, N., & Fisher, D. (2013). *Structural geology algorithms: Vectors and tensors*. Cambridge University Press.

Altuncu, S. (2009). *Türkiye florit yataklarının oluşumlarının karşılaştırmalı incelenmesi* [Doctoral dissertation, İstanbul Üniversitesi, Fen Bilimleri Enstitüsü].

Anthony, J. W., Bideaux, R. A., Bladh, K. W., & Nichols, M. C. (Eds.). (1990). Fluorite. In. Handbook of mineralogy. (Vol. III) (p. 205). Mineralogical Society of America.

Arian, M., & Reza, N. (2015). Lineament Tectonics and Mineralization in Tarom Area, North Iran. *Open Journal of Geology*, 5(3), 115. doi: **https://doi.org/10.4236/ojg.2015.53011**

Barhoumi, A., Belkhiria, W., Ayari, J., Hatira, N., Braham, A., & Dhaha, F. (2021). Tectonic controls on the salt diapir-related Mississippi Valley-type lead-zinc mineralization of Fej El Adoum ore deposit (Northern Tunisian Atlas): Constrains from detailed gravity and drill hole data. *Journal of African Earth Sciences*, 181, 104237. doi: **https://doi.org/10.1016/j.jafrearsci.2021.104237**

Belgrano, T. M., Herwegh, M., & Berger, A. (2016). Inherited structural controls on fault geometry, architecture and hydrothermal activity: an example from Grimsel Pass, Switzerland. *Swiss Journal of Geosciences*, 109, 345–364. doi: **https://doi.org/10.1007/s00015-016-0212-9**

Blumenthal, M. (1947). *Seydişehir-Beyşehir hinterlandındaki Toros Dağlarının Jeolojisi* (Seri D, No. 2). M.T.A. Yayını.

Capper, P. (2005). *Bulk crystal growth of electronic, optical & optoelectronic materials*. John Wiley and Sons.

Chen, Q., Zhao, Z., Zhou, J., Zeng, M., Xia, J., Sun, T., & Zhao, X. (2020). New Insights into the Pulang Porphyry Copper Deposit in Southwest China: Indication of Alteration Minerals Detected Using ASTER and WorldView-3 Data. *Remote Sensing*, 13(14), 2798. doi: **https://doi.org/10.3390/rs13142798**

Dean, W., & Monod, O. (1970). The Lower Palaeozoic Stratigraphy and Faunas of the Taurus Mountains Near Beyşehir, Turkey, Stratigraphy. Bulletin of the British Museum (Natural History) Geology, 19, 413-426.

Dean, W., & Özgül, N. (1994). Cambrian rocks and faunas, Hüdai area, Taurus Mountains, southwestern Turkey. *Bulletin-Institut royal des sciences naturelles de Belgique*, 64, 5-20.

Demircioğlu, R., Eren, Y., & Coşkuner, B. (2024). The Extraction and Structural Analysis of Lineaments Around Gülsehir (Nevşehir) Using GIS Methods. *Geofísica Internacional*, 63(4) , 1175–1191. doi: **https://doi.org/10.22201/igeof.2954436xe.2024.63.4.1725**

Demirkol, C. (1977). *Yalvaç-Akşehir dolayının jeolojisi* [Associate Professorship Thesis]. Selçuk Üniversitesi Fen Bilimleri Enstitüsü.

Demirkol, C. (1981). *Sultandağ kuzeybatısının jeolojisi y Beyşehir-Hoyran Napı ile ilişkileri* (TBAG-382) [Unpublished report]. Tübitak.

Demirkol, C. (1982). Stratigraphy of Akşehir-Yalvaç area and correlation with Western Taurides. *Journal of Geological Engineering*, 14, 3-14.

Demirkol, C. (1986). Sultandağ y dolayının tektoniği. *Bulletin of the Mineral Research and Exploration*, 107, 114.

Demirkol, C., & Yetiş, C. (1985). The geology and allochthonous units of the northwestern Sultandağ. *Journal of Geological Engineering*, 22, 3-10.

Demirtaşlı, E. (1967). *Pınarbaşı-Sarız-Mağara ilçeleri arasındaki sahanın litostratigrafi birimleri y petrol imkanları* (No. 1935). M.T.A. Enstitüsü.

El Galladi, A., Araffa, S., Mekkawi, M., & Abd-AlHai, M. (2022). Exploring mineralization zones using remote sensing and aeromagnetic data, West Allaqi Area, Eastern Desert, Egypt. *The Egyptian Journal of Remote Sensing and Space Science*, 25(2), 417-433. doi: **https://doi.org/10.1016/j.ejrs.2022.03.007**

Harris Geospatial Solutions. (2018). *Environment for Visualizing Images* (Version 3.1) [Software]. **https://www.harrisgeospatial.com/**

Environmental Systems Research Institute. (2024). *ArcGIS Pro* (Version 3.3) [Software]. **https://www.esri.com**

Fan, J., & Ni, C. (2023). Comparative Studies on the Extraction of Lineaments and Its Variability Based on an Improved Line Segment Tracking Method—Taking the Gaosong Ore Field in the Gejiu Gejiu Tin Ore Deposit as an Example. *Applied Sciences*, 13(3), 1314. doi: **https://doi.org/doi:10.3390/app13031314**

Garofalo, P. S., Scarsi, M., & Gundlach-Graham, A. (2023). Feedbacks between fast brittle faulting, hydrothermal fluid flow, and metal transport within carbonated ultramafics (Ligurian Western Alps, Italy). *Mineralium Deposita*, 58, 833–852. doi: **https://doi.org/10.1007/s00126-022-01142-y**

Güngör, T. (2013). Kinematics of the Central Taurides during Neotethys closure and collision, the nappes in the Sultan Mountains, Turkey. *International Journal of Earth Sciences*, 102(5), 1381-402. doi: **https://doi.org/10.1007/s00531-012-0854-4**

Ketin, I. (1966). Anadolunun Tektonik Birlikleri. *Bulletin of the Mineral Research and Exploration*, 66, 23-4.

Mahdi, A. M., Eldosouky, A. M., El Khateeb, S. O., Youssef, A. M., & Saad, A. A. (2022). Integration of remote sensing and geophysical data for the extraction of hydrothermal alteration zones and lineaments; Gabal Shilman basement area, Southeastern Desert, Egypt. *Journal of African Earth Sciences*, 194, 104640. doi: **https://doi.org/10.1016/j.jafrearsci.2022.104640**

Maleki, M., Niroomand, S., Farahbakhsh, E., Modabberi, S., & Tajeddin, H. A. (2021). Hydrothermal alteration and structural mapping of the Qolqoleh-Kasnazan shear zone in Iran using remote sensing data. *Arabian Journal of Geosciences*, 14, 1567, 1-14. doi: **https://doi.org/10.1007/s12517-021-07920-8**

Maude, R. (1987). Lineaments in enhanced Landsat images from a portion of west Wales. *Geological Journal*, 22(S1), 107-118. doi: **https://doi.org/10.1002/gj.3350220511**

Metin, S., & Bingöl, E. (1982). *Tufanbeyli-Sarız-Saimbeyli Yöresinin jeolojisi* (No. 7129). M.T.A. Enstitüsü.

Metin, S., Demirtaşlı, E., & Ayhan, A. (1983). Autochthons, parautochthons ophiolites of the eastern Taurus and Amanos mountains. In *International symposium on the geology of the Taurus belt, field guide book* (pp. 7-17).

Monod, O. (1977). *Recherches géologiques dans le Taurus occidental au sud de Beysehir (Turquie)* [PhD thesis]. Université Paris-Sud, Faculté des Sciences.

Okay, A. I., & Tüysüz, O. (1999). Tethyan sutures of northern Turkey. *Geological Society, London, Special Publications*, 156(1), 475-515. doi: **https://doi.org/10.1144/GSL.SP.1999.156.01.22**

Özgül, N. (1971). Importance of block motions in structured development of the northern Middle Taurus. *Bulletin of the Geological Society of Turkey*, 14(1), 85-101.

Özgül, N., Metin, S., & Dean, W. T. (1972). Doğu Toroslar'da Tufanbeyli ilçesi (Adana) dolayının Alt Paleozoyik stratigrafisi y faunası. *Maden Tetkik ve Arama Dergisi*, 79, 9-16.

Özgül, N., Metin, S., Göğer, E., Bingöl, İ., & Baydar, O. (1973). Tufanbeyli dolayının Kambriyen y Tersiyer kayaları. *Türkiye Jeoloji Kurumu Bülteni*, 16(1), 82-100.

Özgül, N. (1976). Toroslar'ın bazı temel jeoloji özellikleri. *Bulletin of the Geological Society of Turkey*, 19, 65-78.

Özgül, N. (1984). Stratigraphy and tectonic evolution of the Central Taurides. In *International Symposium on the Geology of the Taurus belt* (pp. 77-90).

Özgül, N., Bölükbaşı, S., Alkan, H., & Öztaş, Y. (1991). *Sultan Dağları-Sandıklı-Homa Akdağı yöresinin jeolojisi* (No. 3028). TPAO.

Özüş, A. S., & Yaman, S. (1986). Akkaya (Feke-Adana) Fluorit-Barit mineralleşmesi y köken sorunları. *Türkiye Jeoloji Kurumu Bülteni*, 29(2), 35-42.

Ray, S. F. (1999). *Scientific photography and applied imaging*. Focal Press.

RockWare Inc. (2019). *Rockwork* [Computer software].

Shirazi, A., Hezarkhani, A., & Pour, A. B. (2022). Fusion of lineament factor (Lf) map analysis and multifractal technique for massive sulfide copper exploration: The Sahlabad area, East Iran. *Minerals*, 12(5), 549. doi: **https://doi.org/10.3390/min12050549**

Tutkun, S. Z. (1984). Saimbeyli (Adana) yöresinin stratigrafisi. *Cumhuriyet Üniversitesi, Mühendislik Fakültesi Dergisi, Seri. A-Yerbilimleri*, 1(1), 31–40.