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Optical remote sensing application of Kızılcaören-Sivrihisar (Eskişehir) REE-Thorium Deposit

Cihan Yalçın[*1], **Orkun Turgay** [2]

[1]Ministry of Industry and Technology, General Directorate of Industrial Zones, Worldbank PIU, Ankara, Türkiye
[2]Jeomodel, Ankara, Türkiye

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Abstract

The Kızılcaören-Sivrihisar rare earth element (REE)-Thorium deposit is situated within the Eskişehir Province of Türkiye. The deposit in question represents the sole commercially viable rare earth element-thorium (REE-Th) source within Türkiye, thus rendering it a significant supplier of these crucial minerals. The Kızılcaören-Sivrihisar REE-Thorium deposit exhibits a captivating mineral assemblage that possesses the potential to unlock valuable resources. Within the geological composition, a complex interplay of minerals takes place, involving fluorite, bastnäsite, and barite. The Kızılcaören-Sivrihisar deposit can be effectively mapped using optical remote sensing techniques. This phenomenon can be attributed to the fact that the deposit exhibits several discernible characteristics that can be identified through the utilization of optical remote sensing techniques. This study demonstrates the presence of fluorite-bearing zones, which are characterized by the fluorite index. The present investigation provides evidence for the concurrent presence of divalent iron alongside fluorite. Quartz is also present within this ore-bearing zone. Magnesite and calcite are also found within the serpentinitic-mafic zone in the study area. In conclusion, the study area successfully identified the ore-bearing fluoritic zone through the application of remote sensing processing using ASTER L1T data. The aforementioned studies have demonstrated that optical remote sensing possesses significant potential as a valuable instrument for the examination and assessment of the Kızılcaören-Sivrihisar REE-Th deposit. The utilization of optical remote sensing enables the mapping of deposits, the identification of their extent, and the evaluation of their economic development potential.

1. Introduction

In the field of Earth sciences and mineral resource exploration, Optical Remote Sensing has emerged as a revolutionary technology, shedding light on novel approaches for detecting and characterizing crucial mineral deposits. Rare Earth Elements (REE) and Thorium deposits are of great importance due to their diverse applications in advanced technologies and sustainable energy systems. By harnessing the capabilities of light and electromagnetic radiation, Optical Remote Sensing offers a novel methodology for the non-invasive examination and evaluation of subterranean resources. This introduction explores the significant applications of Optical Remote Sensing in understanding the complexities of REE-Thorium deposits. It emphasizes the crucial role of Optical Remote Sensing in mapping geological characteristics, estimating the potential of resources, and informing strategic decision-making for a more efficient utilization of resources in the future. As we embark on this expedition, we will unveil the intricate relationship between technology and geology, which is reshaping the landscape of mineral resource management and fostering a new era of sustainable development.

With the development of remote sensing technology in recent years and the emergence of new methods accordingly, the separation of mineral deposits such as REE and radioactive raw materials can now be done successfully with ASTER data. In this article, the geological map of Kızılcaören Thorium-REE deposit and the mapping of minerals accompanying the ore minerals are explained. ASTER L1T is used for remote sensing

* **Corresponding Author**

*(cihan.yalcin@sanayi.gov.tr) ORCID ID 0000-0002-0510-2992
(orkun.turgay@aol.coml) ORCID ID 0000-0001-6958-3628

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data for making mineralogical and geological mapping of the study area.

Despite considerable REE developments in Türkiye (e.g., Eskişehir-Kızılcaören, Malatya-Kuluncak, Sivas-Karaçayır), there is still no agreement on the petrogenesis of REE in these places due to a lack of previous investigations (Çimen et al., 2020).

The primary constituents of major and strategic radioactive elements include uranium and thorium. Applications are pursued in order to locate these elements due to their prevalence in numerous geological locations. Based on prior research (Şaşmaz, 2008), it has been determined that the primary sites for the enrichment of radioactive elements in Türkiye are situated in the western region of Anatolia.

The Eskişehir-Kızılcaören deposit is situated in the northwestern region of Türkiye and encompasses a mineral assemblage consisting of fluorite, bastnäsite, and barite. The Kızılcaören region has been recognized as a significant rare earth element (REE) deposit in Türkiye due to its average tenor weight of 2.78% and estimated REE content of approximately 4.67 million metric tons (Mt) (Kaplan, 1977; Öztürk et al., 2019). The area of the mineralization in question was first identified in 1959 using airborne gamma-ray spectrometry, as a result of the radioactivity emitted by thorium (Gültekin et al., 2003).

According to Nakoman (1979) four types Th-REE mineralization was identified. The classification primarily relies on the mineral paragenesis.

A study by Çimen et al., (2020) suggests that the rocks that host the REE-Th mineralization in the Eskişehir-Kızılcaören consist of hydrothermal metasomatized carbonatite and limestone, respectively.

The Kızılcaören-Sivrihisar REE-Thorium deposit in the Eskişehir region is noteworthy for its abundant concentration of Rare Earth Elements (REE) and Thorium, making it an intriguing topic for research. By harnessing the complex interaction between light and electromagnetic radiation, Optical Remote Sensing emerges as a pioneering approach, providing a non-intrusive and comprehensive understanding of the geological intricacies associated with this deposit. This paper delves into the specific application of Optical Remote Sensing in the context of the Kızılcaören-Sivrihisar REE-Thorium deposit.

2. Method

Pre-processing and image enhancement steps were employed in the remote sensing application of one of Türkiye's well-known REE-Thorium deposit.

Firstly preprocessing was applied to the ASTER L1T satellite imagery dataset of the deposit. In preprocessing, VNIR(Visible infrared bands) and SWIR(Shortwave infrared bands) clipped and radiometric calibration applied on these bands, later VNIR and SWIR bands stacked then IARR atmospheric correction applied on stacked VNIR and SWIR bands in ENVI Software. Radiometric calibration was also applied on TIR (Thermal Infrared bands), later Thermal Atmospheric correction (TAC) applied before Emissivity Correction in ENVI. All the preprocessing completed with atmospherically corrected VNIR and SWIR bands stacked to the atmospherically corrected and Emissivity corrected TIR data. Vegetation index (b3-b2)/(b3+b2) applied for vegetation mask created and applied to the final ASTER data for preprocessing is completed with masking on the final data for image processing (image enhancement) process for the discrimination of mineralogical and geological units of the study area.

2.1. Image Processing (Image Enhancement) Step

Image processing or image enhancement application is made for mineralogical mapping and alteration mapping, rock type mapping is the must. For this reason, Mafic Minerals detected by (b12/b13)*(b14/b13) Carbonaceous rocks (CI) were detected with (b13/b14) formulae for limestone and dolostone and Quartz (QI) detected with (b11/(b10+b12)*(b13/b12) for silicification Quartz bearing rocks (QRI) are detected with (b10/b12)*(b13/b12) formulae. Hydroxyl bearing (OH) minerals are detected with b4/b5 In addition Fluorite bearing zones detected by FI(Fluorite Index) with (b8/b6)*(b5/b3) from Hafez et al., (2021), Magnesite is detected by (b6+b8)/(b7+b9) formula and ferrous(II)Iron was detected by(b5/b3)+(b1/b2) and ferrous hydroxides is detected by (b6+b8)/b7, serpentine rich rocks is detected with (b7+b9)/b8 formulae with band arithmetic methods In ENVI software. Later these ratios were combined. And also decorrelation stretch was used for image processing step in the study area.

3. Results

Figure 1 represents the general geological situation of the study area. In Figure 2. Bluish zones contain ferrous iron (divalent iron) and light green zones represent carbonaceous (calcite) zones. In Figure 1 bright zones contain calcite, magnesite and few divalent irons.

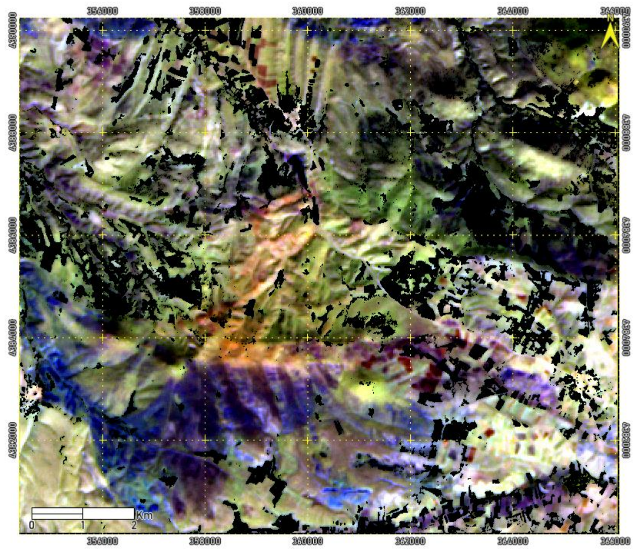

Figure 1. General rock discrimnation of the study area with RGB 7-4-2 combination

Figure 2 contains thorium bearing ore zones are represented by bluish zones. Bright green and greenish zones contain carbonates like calcite and magnesite. Pink and reddish zones contain divalent iron.

Figure 3 contains fluoritic zones in reddish and orange zones have the thorium related minerals and green areas represent the magnesite (magnesium carbonate) zones. In Figure 2, Hydroxyl bearing alteration minerals exist in the bluish and bright blue zones. Figure 3 contains fluoritic zones in reddish and orange zones have the thorium related minerals and green areas represent the magnesite (magnesium carbonate) zones.

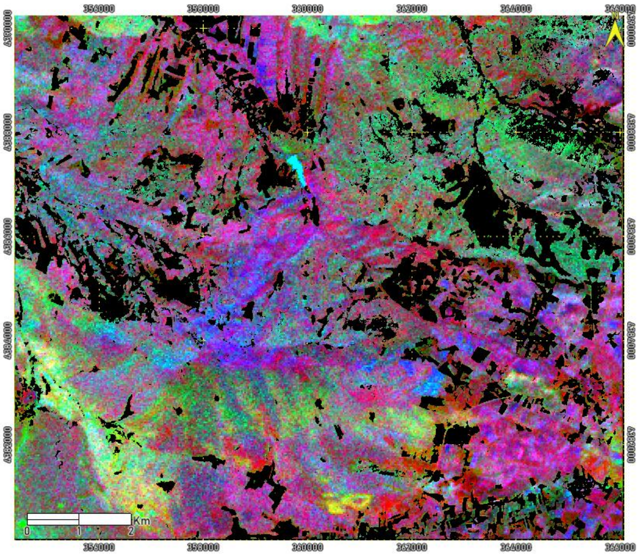

Figure 2. Magnesite-Calcite-Ferro(II)Iron in RGB band math combination image of study area

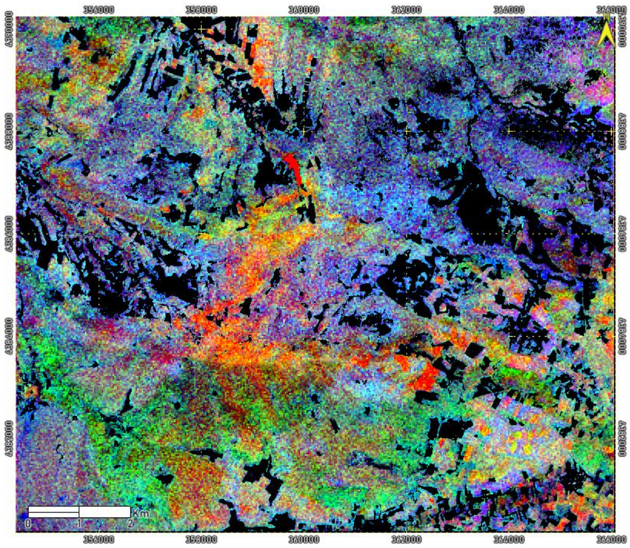

Figure 3. Fluorite-Magnesite-OH in RGB band math combination image of study area

Figure 4 contains fluoritic zones in reddish and orange zones have the thorium related minerals and blue zones represent the magnesite (magnesium carbonate) zones.

Figure 5 contains fluoritic zones in blue and bluish and orange zones have the thorium related minerals and green zones represent the magnesite (magnesium carbonate) zones. Blue zones represent Quartz bearing or quartzitic rocks.

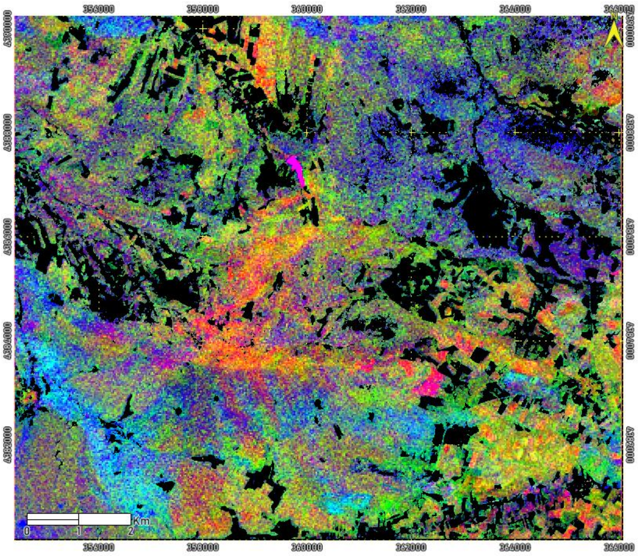

Figure 4. Fluorite-Magnesite-Serpentine RGB band math combination image of study area

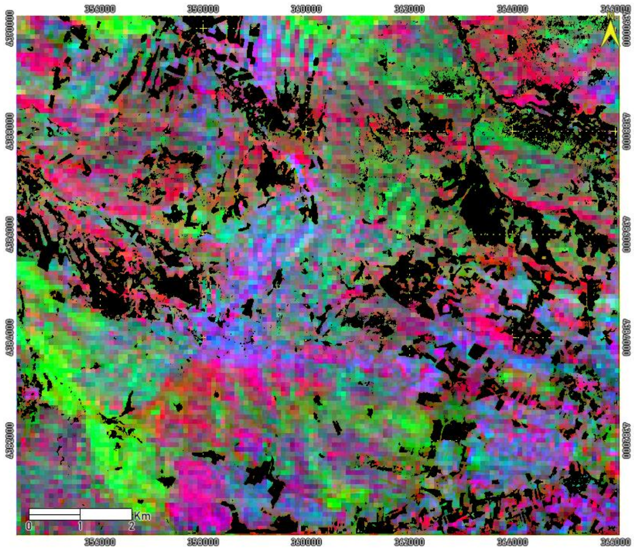

Figure 5. QRI-MRI-Fluorite in RGB band math combination image of the study area.

4. Discussion

The Kızılcaören-Sivrihisar REE-Thorium deposit exhibits a captivating mineral assemblage that possesses the potential to unlock its valuable resource. In the geological composition, a complex interplay of minerals takes place, involving fluorite, bastnäsite, and barite. The combination of these distinct minerals presents a compelling narrative regarding the origin and development of the deposit, providing invaluable knowledge about its historical context and economic importance.

The interdependent association among the three minerals, namely fluorite, bastnäsite, and barite, provides significant insights into the dynamic geological processes that influenced the formation of the Kızılcaören-Sivrihisar deposit. The utilization of Optical Remote Sensing, which possesses the capability to identify and differentiate minerals through their distinctive spectral characteristics, has emerged as a pivotal instrument in comprehending the complex dynamics of mineral interactions. The technology assists in the identification of the distribution, concentration, and potential economic significance of these minerals within the geological matrix of the deposit by capturing their distinct reflectance patterns. By examining the mineral composition of fluorite, bastnäsite, and barite, we can enhance our comprehension of the genesis of the deposit and establish a foundation for effective resource management strategies.

5. Conclusion

The previous studies have established a correlation between fluoritization and the presence of thorium and rare earth elements (REE) in the study area. This study demonstrated the presence of fluorite-bearing zones using the fluorite index. The study demonstrates the coexistence of divalent iron with fluorite. Quartz is also present within this zone containing ore. The study area also contains deposits of magnesite and calcite within the serpentinitic-mafic zone.

In summary, the study area has successfully identified ore-bearing fluoritic zones through the utilization of remote sensing techniques.

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