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Research Article

The Characteristics of Doğanşehir (Malatya-Turkey) Bauxite Mineralization in the Eastern Taurus Orogenic Belt Using Scanning Electron Microscopy (SEM)

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Abstract – The Taurus Orogenic Belt in Turkey is a prominent tectonic zone where significant occurrences of bauxite mineralization are observed. The bauxite deposits in Doğanşehir, located in Malatya, Turkey, are found as extensive bodies and lenses within the carbonate rocks of the Permian-Triassic Malatya Metamorphics, situated in the Eastern Taurus Orogenic Belt. The geological foundation of this region consists primarily of lithologies attributed to the Malatya Metamorphics. This unit mainly comprises schists, calc-schists, and marble, overlain by the Berit Metaophiolite of the Late Cretaceous-Eocene, the Maden Complex of the Eocene, the Doğanşehir Granitoid of the Early-Middle Eocene, and the Plio-Quaternary cover sedimentary units. Bauxite mineralization of oolitic and pisolitic nature is present within the Permian-Triassic carbonate rocks of the Malatya Metamorphics. These mineralizations occur in carbonate rocks containing fossils and are observed in the form of lens-shaped bodies. The bauxite lenses are covered by relatively thin, intermediate layers of Permian-Triassic carbonate rocks of the Malatya Metamorphics. With the advancement of technology, Scanning Electron Microscopy (SEM) has been utilized to analyze bauxite ores and determine the presence of elements within their crystal lattice structure. The point analysis and mapping technique were employed to identify the elements that might be present within the crystal lattice structure of the bauxite ores. SEM analysis of the samples using the mapping method revealed the distribution of elements such as Fe, Ti, Si, Al, and O, both before and after activation. The images indicate that bauxite exhibits a wide grain distribution, both below and above 50 µm. The elemental spectrum diagram demonstrates the presence of O, Al, and Si in the sample, and the detection of Fe, Ti, C, K, and Mg as well. By employing SEM analysis and the mapping method on the same samples, the distribution of Fe, Ti, Si, Al, and O elements within the structure was examined before and after activation. The images reveal that the elements Al, O, and Si display high density in specific regions before activation but show a more uniform distribution and similar structures after activation. Fe, Mg, and K exhibit a similar distribution pattern, while Ti and C exhibit different characteristics.

Keywords – Taurus Orogenic Belt, Bauxite, Malatya Metamorphics, SEM, Doğanşehir (Malatya-Türkiye)

I. INTRODUCTION

For decades, bauxite, a sedimentary rock that serves as the primary source of aluminum ore, has been of great interest to the scientific community. Understanding the intricate mineralogical and chemical composition of bauxite is crucial for enhancing its extraction, refining, and subsequent applications. Traditional characterization techniques have provided valuable information, but with the advent of advanced imaging technologies, researchers now have access to an unprecedented level of detail. Among these cutting-edge tools, Scanning Electron Microscopy (SEM) has emerged as a potent method [1] for mapping the intricate microstructure of bauxite.

Scanning Electron Microscopy (SEM) offers numerous advantages in bauxite analysis, primarily due to its capability to generate high-resolution, three-dimensional images. This technique allows for the visualization of surface topographies of the material, while also providing detailed information about the elemental composition. By employing SEM, a sample can be bombarded with a focused electron beam, and the resulting signals can be captured to determine the elemental composition. Leveraging these capabilities, researchers can investigate microstructural variations in bauxite deposits, identify mineral phases, and analyze the spatial distribution of crucial elements [2-4].

According to Bárdossy [5] and Bárdossy and Aleva [6], bauxite deposits can be categorized into three primary groups based on their genetic characteristics: lateritic, tikhvin, and karstic types. Among the main three types of bauxite deposits, namely karstic, lateritic, and tikhvin, Turkey predominantly possesses karstic-type deposits, with a lesser occurrence of laterite-type deposits [7]. The concentration of bauxite deposits in Turkey is predominantly observed in eight provinces, of which six are situated in the Anatolide-Tauride region. Additionally, one province is located in the Arabian Platform, and another province is found in the Pontides [7].

From a structural perspective, the Tauride Belt in Turkey is characterized by the prevalence of autochthonous and nappe structures. Within this belt, Turkey possesses a diverse array of bauxite deposits, varying in age and formation types. Among these deposits, the karst type stands out as particularly significant. The Tauride Belt can be further subdivided into the Western, Central, and Eastern Taurus Mountains, which comprise geological units where tectonic slices are juxtaposed [8]. The research area focused on in this paper is situated within the Eastern Tauride Belt, renowned for its tectonic activity and the presence of bauxite deposits within carbonate rocks. The initial investigations of the bauxite occurrences in Doğanşehir were carried out by the General Directorate of Mineral Research and Exploration [9]. This paper aims to explore the scope and significance of utilizing SEM to investigate the complex structures and elemental composition found in the bauxite deposits of Doğanşehir.

II. MATERIALS AND METHOD

The Scanning Electron Microscopy (SEM) analysis was carried out at the Munzur University SEM/XRD Advanced Analysis Laboratory using a Rigaku X-Ray Diffraction device. This advanced analysis and characterization instrument allows for in-depth examination of micron and nano-sized objects or particles (ranging from 50 to 60 microns) by magnifying them up to a maximum of 1,000,000 times using a variety of lenses. In this study, the point and mapping method were employed to identify the potential elements present in the crystal lattice structure of the bauxite sample.

A. *Geological Background and Mineralization*

Turkey is composed of several major tectonic units, namely the Pontides, Anatolides, Taurides, and the Arabian Platform [10]. The Taurid block, which forms part of Turkey's geological framework, consists of Cambrian basement rocks that are overlain by Paleozoic to Early Tertiary successions [11].

The Tauride Belt, located in southern Turkey, is a part of the Alpine Himalayan mountain orogeny belt. The Doğanşehir region in Malatya is situated within the Eastern Tauride Belt. The basement of this region is formed by the Permo-Triassic Malatya Metamorphics. Overlying this unit are the Late Cretaceous-Eocene Berit Metaophiolite, Eocene Maden Complex, Early-Middle Eocene Doğanşehir Granitoid, and Plio-Quaternary sedimentary units [12].

The Malatya Metamorphics are in a tectonic and intrusive relationship with the Doğanşehir Granitoid and are tectonically associated with the Maden Complex [13]. Ertürk et al. [14] analyzed the isotope and geochemical data of young volcanic rocks and concluded that felsic rocks were generated within an upper crustal post-collisional tectonic setting.

The Malatya Metamorphics, which are extensively distributed in the area, have been regarded by several researchers as units similar to the Keban Metamorphics and as the southern extensions of the Keban Metamorphics [8, 15-16]. The dominant lithologies within the Malatya Metamorphics consist of muscovite schist, albite hornblende epidotic schist, quartz muscovite schist, phyllites, and marbles.

The Permo-Triassic carbonate rocks contain oolitic and pisolitic bauxite mineralizations. These mineralizations are found within carbonate rocks that also contain fossils and are observed in the form of lens-shaped bodies. The bauxite lenses are covered by relatively thin, intermediate layers of Permo-Triassic carbonate rocks.

III. SCANNING ELECTRON MICROSCOPY (SEM)

Figures 1, 2, and 3 display the SEM images of bauxite samples obtained from the field. These images reveal a broad distribution of grain sizes in the bauxite, both below and above 50 µm.

The elemental spectrum diagram and corresponding table for these images are presented in Figures 4, 5, and 6. The analysis results indicate the presence of oxygen (O), aluminum (Al), and silicon (Si) in the sample. Additionally, other elements such as iron (Fe), titanium (Ti), carbon (C), potassium (K), and magnesium (Mg) were also detected (Figures 4, 5, and 6).

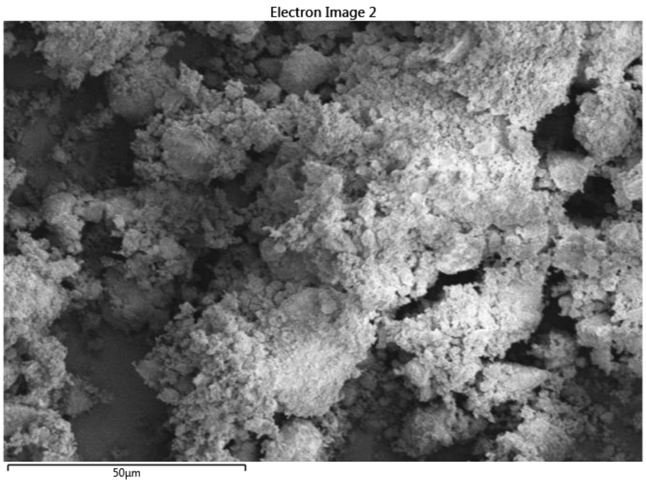

Fig. 1 SEM image of bauxite

From the analysis of Sample 1, it is observed that aluminum (Al) constitutes 14.58% of the sample by weight and 10.37% atomically. The oxygen (O) content is notably high, while the levels of silicon (Si), titanium (Ti), magnesium (Mg), and potassium (K) are relatively low (Table 1).

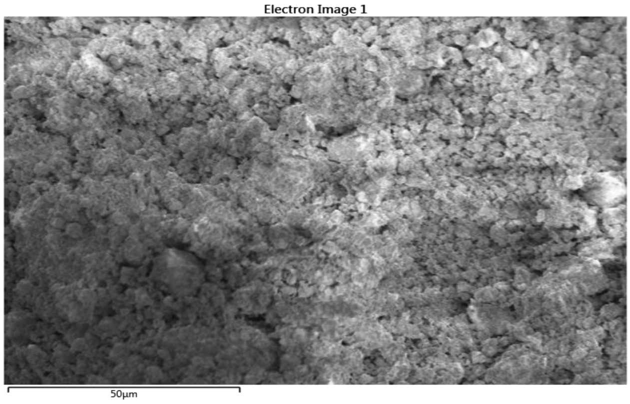

Fig. 2 SEM image of bauxite

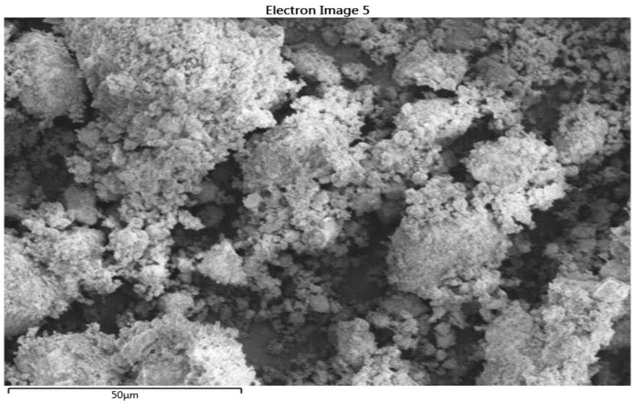

Fig. 3 SEM image of bauxite

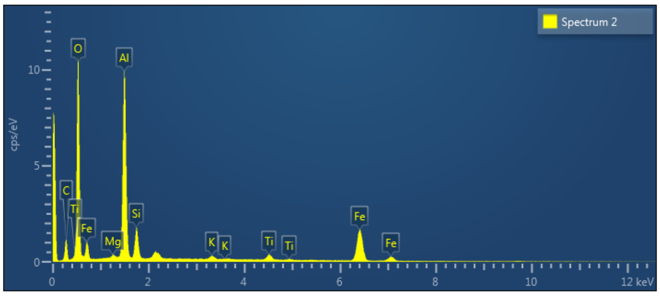

Fig. 4 Spectrum diagram

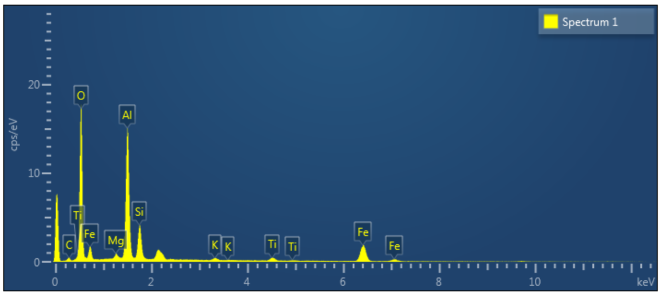

Fig. 5 Spectrum diagram

From the analysis of Sample 2, it is observed that aluminum (Al) constitutes 17.99% of the sample by weight and 13.74% atomically. The oxygen (O) content is notably high, while the levels of silicon (Si), titanium (Ti), iron (Fe), carbon (C), magnesium (Mg), and potassium (K) are relatively low (Table 2).

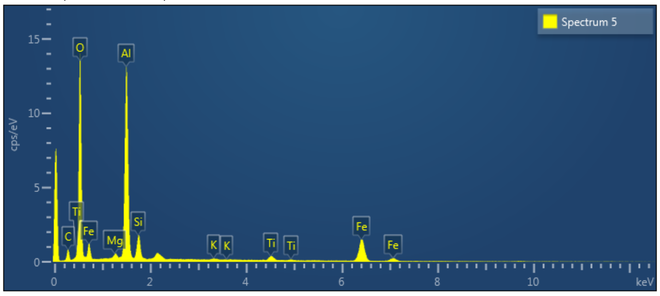

Fig. 6 Spectrum diagram

Table 1 Spectrum values of first bauxite sample

Element	Line Type	Weight %	Weight % Sigma	Atomic %
O	K series	45.27	0.30	54.34
Al	K series	14.58	0.12	10.37
Si	K series	2.51	0.05	1.71
Fe	K series	19.43	0.21	6.68
Ti	K series	1.30	0.06	0.52
C	K series	16.25	0.42	25.99
K	K series	0.46	0.04	0.23
Mg	K series	0.21	0.03	0.16
Total		100.00		100.00

Table 2 Spectrum values of first bauxite sample

Element	Line Type	Weight %	Weight % Sigma	Atomic %
O	K series	52.25	0.34	67.29
Al	K series	17.99	0.15	13.74
Si	K series	5.18	0.08	3.80
Fe	K series	17.78	0.22	6.56
Ti	K series	1.39	0.07	0.60
C	K series	0.67	0.05	0.57
K	K series	0.56	0.04	0.30
Mg	K series	4.17	0.46	7.15
Total		100.00		100.00

From the analysis of Sample 3, it is observed that aluminum (Al) constitutes 17.89% of the sample by weight and 12.84% atomically. The oxygen (O) content and carbon (C) are notably high, while the levels of silicon (Si), titanium (Ti), iron (Fe), magnesium (Mg), and potassium (K) are relatively low (Table 3).

By utilizing SEM analysis of the same samples, the distribution of iron (Fe), titanium (Ti), silicon (Si), aluminum (Al), and oxygen (O) elements within the structure was further investigated using the mapping method (Figure 7, 8, 9). The figures demonstrate that prior to activation, the elements Al, O, and Si were concentrated in specific regions, whereas after activation, they exhibited a more uniform distribution and displayed similar structures. On the other hand, elements such as Fe, Mg, and K exhibited a similar distribution pattern, while Ti and C exhibited distinct characteristics.

Table 3 Spectrum values of first bauxite sample

Element	Line Type	Weight %	Weight % Sigma	Atomic %
O	K series	52.25	0.34	67.29
Al	K series	17.99	0.15	13.74
Si	K series	5.18	0.08	3.80
Fe	K series	17.78	0.22	6.56
Ti	K series	1.39	0.07	0.60
C	K series	0.67	0.05	0.57
K	K series	0.56	0.04	0.30
Mg	K series	4.17	0.46	7.15
Total		100.00		100.00

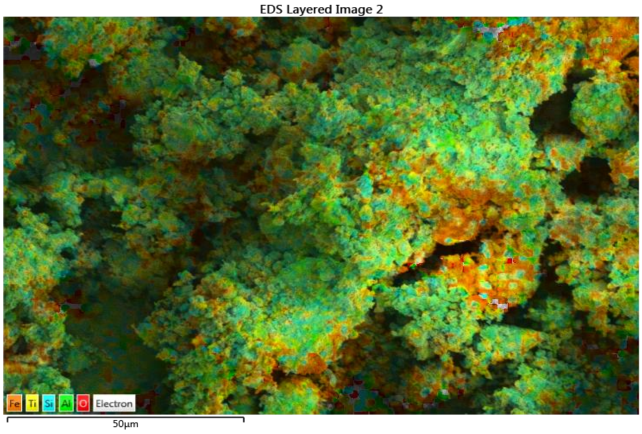

Fig. 7 SEM image of bauxite using the mapping method

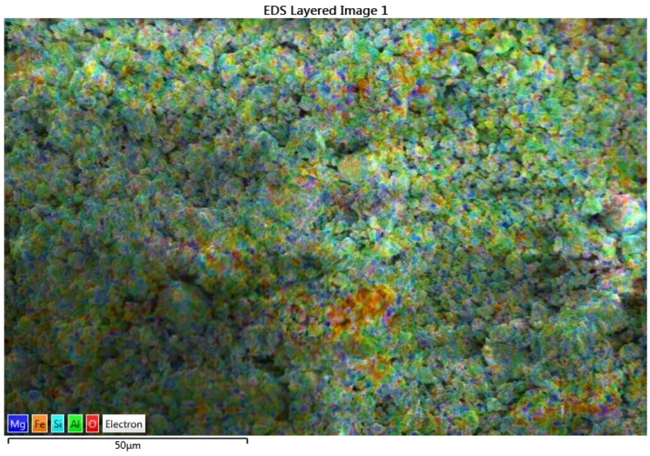

Fig. 8 SEM image of bauxite using the mapping method

During the mapping process, each element was individually analyzed using SEM, and its unique color and patterns were characterized. The elemental map patterns of the three samples are depicted in Figures 10, 11, and 12. While the elemental distribution in each sample shows similarities, distinct characteristic distributions are also observed. These images further demonstrate that the overall elemental composition of the various bauxite samples is similar.

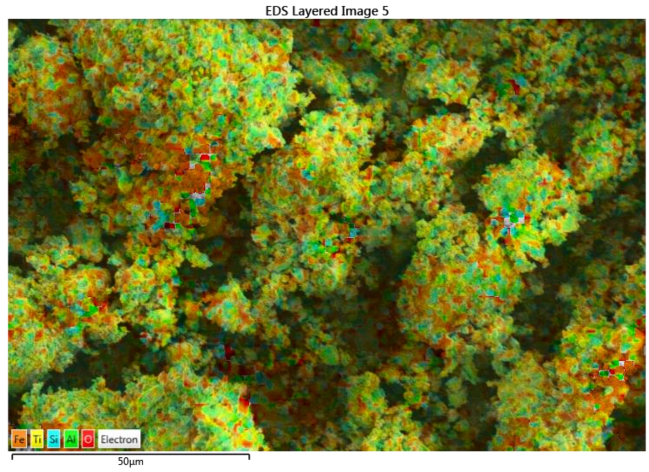

Fig. 9 SEM image of bauxite using the mapping method

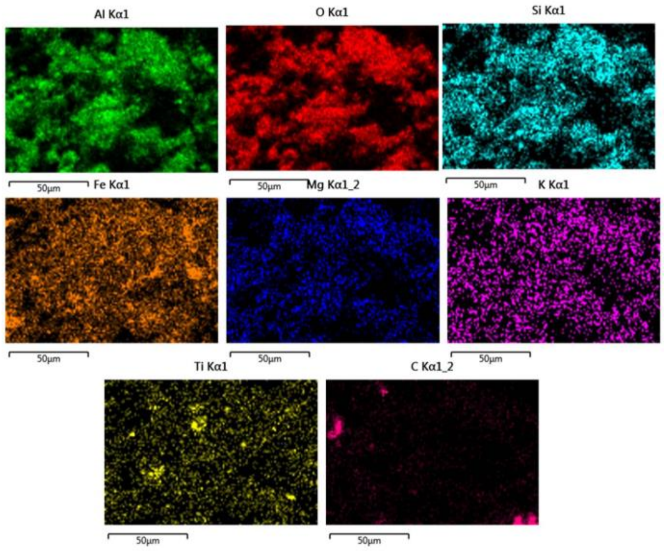

Fig. 10 Representative SEM image of bauxite's elemental compositions using the mapping method

In this article, we aim to investigate the scope and significance of employing Scanning Electron Microscopy (SEM) to explore the complex structures and elemental composition found in Doğanşehir bauxite. We will delve into the principles underlying SEM, emphasizing its advantages over other microscopy techniques. Additionally, we will explore the diverse applications of SEM that have propelled bauxite research to new frontiers.

Moreover, SEM-based elemental mapping techniques offer a comprehensive understanding of the geochemical processes associated with bauxite formation. By analyzing the spatial distribution of elements in relation to mineral assemblages, researchers can unravel the intricate interplay of geological, geochemical, and hydrological factors that influence the formation of bauxite deposits. This valuable knowledge aids in refining geological models, improving exploration strategies, and may even lead to the identification of previously unknown deposits.

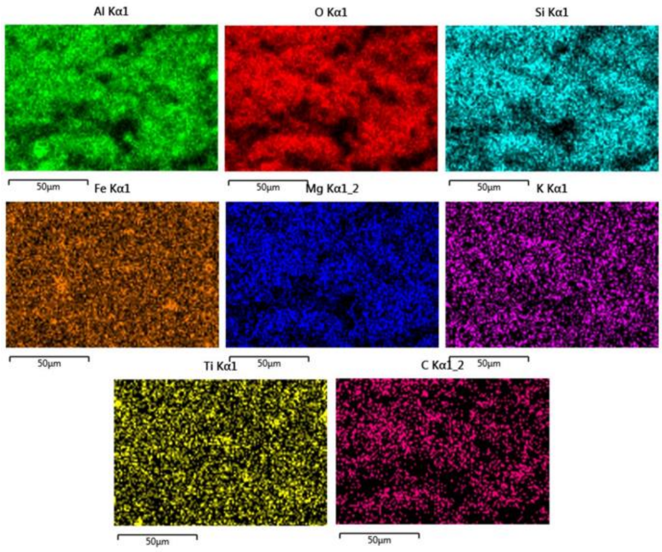

Fig. 11 Representative SEM image of bauxite's elemental compositions using the mapping method

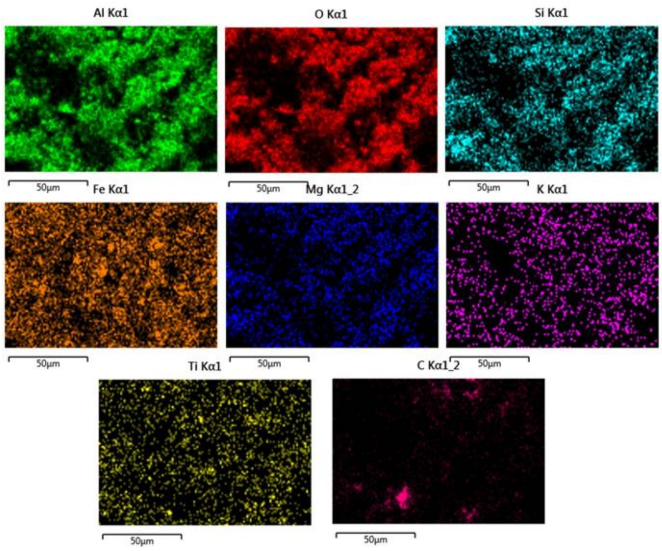

Fig. 12 Representative SEM image of bauxite's elemental compositions using the mapping method

IV. DISCUSSION

The insights derived from SEM analysis have significant implications for the bauxite industry. In-depth understanding of the microstructure of bauxite enables better characterization of the ore, assisting in the selection of suitable mining and processing techniques. Additionally, SEM analysis allows for the identification of detrimental minerals or impurities that can affect the quality and efficiency of alumina production. This information helps in developing strategies to mitigate these challenges, resulting in improved refining processes and enhanced aluminum yields.

V. CONCLUSION

In conclusion, the application of Scanning Electron Microscopy (SEM) has revolutionized the study of bauxite by providing a deeper understanding of its microstructure, mineralogical composition, and elemental distribution. The high-resolution visualization and analysis capabilities offered by SEM have wide-ranging implications throughout the entire life cycle of bauxite, including mining, processing, refining, and applications. As research in this field advances, SEM remains a valuable tool for enhancing our knowledge of bauxite, driving innovation, and promoting sustainability within the aluminum industry.

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