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CHARACTERIZATION OF COMPLEX BAUXITE ORE - PART III

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Abstract

This paper presents the microstructural and micro-chemical characterization of a complex bauxite ore using Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDS). The experimental methodology involved high-precision sample embedding, grinding, and diamond polishing followed by quantitative spot analysis and elemental mapping at an operating voltage of 20 kV. The EDS results across multiple spectra successfully identified the key mineral phases, confirming that the ore matrix is dominated by oval and elliptical grains of aluminum hydroxides, specifically boehmite or diaspore, ranging from 20 to 400 µm. Furthermore, the microanalysis reveals extensive structural intergrowth, where the primary aluminum phases regularly enclose and incorporate tight fine-grained impregnations of iron oxides, predominantly hematite, alongside titanium dioxide modifications such as rutile or anatase, and localized calcite inclusions. These detailed microstructural features and encapsulation characteristics provide critical mineralogical data necessary for understanding phase distribution and predicting mineral liberation behavior in industrial utilization.

***Keywords**: Bauxite ore; SEM-EDS microanalysis; Boehmite; Hematite intergrowth; Phase identification.*

1. INTRODUCTION

Bauxite remains the primary and global mineral source for alumina and aluminum production, making its processing vital for modern metallurgical industries [1]. However, the progressive depletion of high-grade deposits shifts industrial focus toward complex, low-grade, and highly heterogeneous ore bodies. These alternative raw materials typically exhibit intricate mineral textures and fine grain sizes, presenting significant technical challenges during downstream concentration and chemical digestion.

To overcome these barriers, macro-physical sizing must be paired with precise microstructural and textural investigations within mineral processing flowsheets. The efficiency of metallurgical separation processes directly correlates with the liberation degree of target minerals and their intergrowth patterns with waste phases [2]. Within

this framework, bulk macro-analyses are insufficient for understanding the behavior of complex matrices, as sub-micron textures heavily influence grinding requirements, locking tendencies, and chemical reactivity.

Scanning Electron Microscopy combined with Energy Dispersive X-ray Spectroscopy (SEM-EDS) serves as a foundational diagnostic tool to evaluate these micro-level ore properties and phase distributions [3]. This characterization identifies potential element partitions, structural defects, and exact textural relationships between aluminum-bearing phases and iron-rich contaminants. Quantifying these micro-chemical variations and grain boundary relations is essential for predicting processing bottlenecks and defining optimal separation parameters. Consequently, a comprehensive SEM-EDS analysis forms the necessary baseline for evaluating the elemental and spatial characteristics of the raw bauxite matrix.

2. EXPERIMENTAL

Experimental procedure is performed on technological samples of complex high-iron bauxite ore from a specific locality. For electron microanalysis (EMA) on the SEM-EDS microscope, a mineral sample was prepared embedding mineral grains of medium density into epoxy resin, with a preparation surface area of approximately 10 cm². The obtained specimens were ground using silicon carbide with grain sizes of 38, 30, 20, 15, and 12 μm, and finally polished with diamond suspension of 6, 3, and 1 μm.

For EMA analysis, the prepared specimens were gold-coated using a JEOL JFC-1300 Auto Fine Coater. The chemical compositions of the minerals were obtained using a scanning electron microscope (SEM) model JSM IT 300LV (JEOL, Japan), coupled with an energy-dispersive X-ray spectroscopy (EDS) detector (model: OXFORD Instruments, X-max) and Aztec software (version 3.1). A voltage of 20 kV was used during analysis. The analyses were performed using internal standards, and the elemental contents were normalized to 100%. The detection limit for the analyzed elements is approximately 0.1 wt.%.

3. RESULTS AND DISCUSSION

During the analysis of each sample, initial mapping of the examination field was performed in order to determine the distribution/presence of different mineral chemical components and thus phases that would be analyzed. The EDS images with elemental distribution maps are shown in Figures 1-2 and spectrum analyses in Tables 1 and 2.

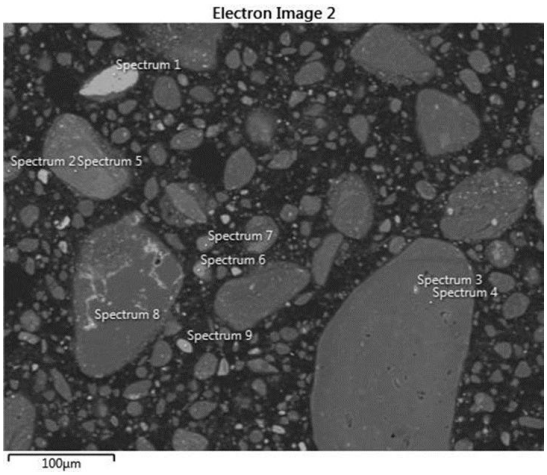


Figure 1. *SEM BSE image with marked locations where EDS analysis was performed on the bauxite sample (magnification 250×)*

Table 1. *Chemical composition (EDS analysis) – of bauxite sample (Figure 1)*

Spectrum	O	Al	Ca	Ti	Fe	Total
Spectrum 1	32.51	0.95		1.96	64.58	100.00
Spectrum 2	58.84	0.24	40.30		0.63	100.00
Spectrum 3	45.86	1.53		51.34	1.27	100.00
Spectrum 4	53.53	38.53		1.12	6.81	100.00
Spectrum 5	50.31	34.57		0.59	14.53	100.00
Spectrum 6	39.01	13.24		3.38	44.37	100.00
Spectrum 7	39.23	22.56	1.14	1.22	35.85	100.00
Spectrum 8	41.11	11.84		0.72	46.34	100.00
Spectrum 9	31.52	1.32		2.53	64.63	100.00

Based on the quantitative EDS elemental maps and spot analysis presented in Table 1, the mineral phases across the selected locations of Figure 1 were identified as follows:

- **Spectrum 1 & 9:** Represent hematite matrix characterized by minor traces of Ti.
- **Spectrum 2:** Confirms the presence of calcite, defined by high Ca and O content.
- **Spectrum 3:** Corresponds to rutile/anatase titanium dioxide phases, showing minor traces of Fe and Al from the surrounding aluminous matrix.
- **Spectrum 4 & 5:** Represent the primary aluminum-bearing phases, identified as boehmite/diaspore, containing minor iron and titanium substitutions.
- **Spectrum 6 & 8:** Indicate hematite areas containing minor aluminum signals due to embedding within the surrounding boehmite/diaspore grains.
- **Spectrum 7:** Reflects an intergrown mixture of boehmite/diaspore and hematite phases, with minor traces of Ti.

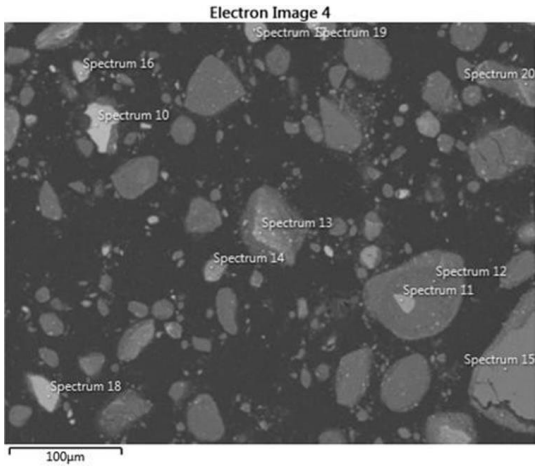


Figure 2. *SEM BSE image with marked places where EDS analysis was done in bauxite sample (magnification 270×)*

Table 2. *Chemical composition (EDS analysis) – of bauxite sample (Figure 2)*

Spectrum	O	Al	Ca	Ti	Fe	Total
Spectrum 10	38.95	1.73		5.34	53.98	100.00
Spectrum 11	46.93			52.47	0.59	100.00
Spectrum 12	48.88	46.37		0.76	3.99	100.00
Spectrum 13	47.77	21.93		2.05	28.26	100.00
Spectrum 14	37.20	13.29		2.13	47.38	100.00
Spectrum 15	57.24		42.18		0.57	100.00
Spectrum 16	39.10	8.94		1.07	50.89	100.00
Spectrum 17	35.20	4.20		2.57	58.03	100.00
Spectrum 18	34.55	1.63		2.30	61.52	100.00
Spectrum 19	33.51	1.58		1.39	63.52	100.00
Spectrum 20	52.03	30.71		0.54	16.73	100.00

Based on the quantitative EDS analysis results presented in Table 2, the mineral phases across the selected locations of Figure 2 were identified as follows:

- **Spectrum 10, 18 & 19:** Represent hematite matrix with Al and Ti admixture.
- **Spectrum 11:** Corresponds to rutile/anatase phase.
- **Spectrum 12:** Represents boehmite/diaspore with Fe and Ti admixture.
- **Spectrum 13:** Reflects an intergrown mixture of boehmite/diaspore and hematite, with Ti admixture.

- **Spectrum 14, 16 & 17:** Indicate hematite with Al admixture (originating from the boehmite/diaspore matrix in which it is found) and Ti admixture.
- **Spectrum 15:** Confirms the presence of calcite.
- **Spectrum 20:** Represents boehmite/diaspore with Fe admixture (originating from finely dispersed hematite) and Ti admixture.

Based on the examination of this sample under an optical microscope and the results of the EMA analyses, the following can be stated. The sample is dominated by hypidiomorphic to xenomorphic oval and elongated (elliptical) grains of aluminum hydroxides (boehmite or diaspore), ranging in size from 20 to 400 μm.

These aluminum hydroxide grains often enclose, incorporate, or contain impregnations of other grains, most commonly iron oxides (hematite, possibly magnetite), as well as titanium oxides (rutile or anatase), and possibly sphene (a calcium and titanium silicate). This composition corresponds to a classic example of a bauxite ore sample.

4. CONCLUSION

The systematic SEM-EDS microanalysis confirms that the bauxite ore sample corresponds to a highly heterogeneous mineral matrix dominated by oval and elliptical aluminum hydroxide grains, specifically boehmite or diaspore, with size distributions ranging from microscopic to several hundred micrometers. Elemental spot mapping reveals extensive structural intergrowth, showing that these primary aluminum-bearing phases frequently enclose and incorporate fine impregnations of iron oxides, predominantly hematite, alongside titanium dioxide phases like rutile or anatase, and minor calcite. The close textural binding and micron-level encapsulation of hematite inside the aluminum matrix represent a critical engineering characteristic of this ore, indicating that sharp physical separation will be highly dependent on the grain boundary liberation achieved during processing.

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