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Geochemical constraints on critical metals in the Jajarm bauxite deposit in Northeastern Iran

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Two types of bauxite lenses and horizons are found in the Jajarm mining area: A-type and B-type. The B-type bauxite lenses and horizons occur as stratiform orebodies between the shallow-marine platform carbonate of the early–middle Triassic Elika Formation and the siliciclastic and molassic sedimentary rocks of the late Triassic Shahmirzad Formation from the Shemshak Group. Lithium concentrations in the ore samples vary significantly between profiles I and II, ranging from 7.9 to 3780 ppm (mean 593.6 ppm) in profile I and 94.8 to 723 ppm (mean 392.9 ppm) in profile II. Ore samples with moderate Al_2O_3 contents (30–40 wt%) and moderate Al_2O_3/SiO_2 ratios (< 2) show markedly higher Li and REE contents. This enrichment is likely due to the preferential uptake of REE and Li by clay minerals via isomorphic substitution and surface adsorption during kaolinization and early-stage lateritization. The Jajarm deposit is thus not only a major source of Al, but also holds significant potential as a strategic resource for critical metals, such as Li, TiO_2, Ga, Nb, Ta, V, and REE. This highlights its importance as a key exploration target for future mining endeavors focused on these essential elements.

Keywords Karst-type bauxite deposit, Critical metals, Lithium-rich ores, Jajarm, Northeastern Iran

Increasing global demand for strategic metals has stimulated research on their prospecting, distribution, and enrichment mechanisms. In this context, karst-type bauxite deposits have been attracting attention as an important source of critical metals. Host of several critical elements, including Li, Ga, V, Ti, Zr, Hf, Nb, Ta, and rare earth elements (La–Lu, hereafter REE), gives further consideration to karst-type bauxite deposits, especially across the western Tethyan belt and Iran to the east[1]. Recent studies on karst bauxite deposits in China have led to valuable exploration strategies for Li[2,3].

The Iranian bauxite deposits are hosted within karstic sinkholes developed in late Paleozoic and Mesozoic marine carbonate associated with the Palaeo- and Neo-Tethys Oceans[4]. According to the classification of bauxite deposits based on bedrock lithology and the global distribution of bauxite deposits by[5] they are categorized as karst-type and belong to the Irano–Himalayan bauxite belt. These deposits have undergone a complex geodynamic evolution during greenhouse periods[4]. Recent studies reveal that the Iranian bauxite deposits are enriched in specific critical elements. For example, the Soleiman Kandi deposit in northwestern Iran is enriched in V, Co, Ga, and particularly Ta[6]; the Nasr-Abad deposit in the same region is enriched in V, Ga, and Ni[7]; and the Gano deposit in the eastern Alborz Mountains is enriched in Ga, V, and Nb[8]. These enrichments have been attributed to the contribution of mafic source rocks in the Soleiman Kandi and Nasr-Abad deposits, and to monzonitic rocks at the base of the Elika Formation in the Gano deposit. Despite the enrichment of critical metals in the Iranian bauxite deposits, there has been little attention given to large-scale metal extraction, which presents a significant opportunity for future economic exploitation.

The Alborz Mountains are a significant metallogenic zone, hosting large karst-type bauxite deposits, including the Jajarm and Gano deposits, along with several smaller karst bauxite deposits. Previous studies on the Jajarm deposit have primarily focused on the geochemical characteristics and ore genesis of the deposit[9]. In this study, we present new and comprehensive geochemical and mineralogical data from the Jajarm Li-rich bauxite deposit in northeastern Iran. The main aims of the research are to (1) define the distribution of critical metals, such as Ga, Nb, Ta, Li, and REE, within the bauxite horizons, (2) advance the understanding of the mineralization processes of these critical metals, and (3) identify factors controlling the concentration and enrichment of

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