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Zircon Trace Element Geochemistry as a Tool for Au Mineralization Exploration in Igneous Rocks: A Case Study from the Sabzevar Area, NE Iran

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The Jalmabadan area is located in the northwestern part of the Sabzevar zone, in northeastern Central Iran. The dominant lithological units consist of volcanic lava flows and pyroclastic rocks, mainly breccia and agglomerate. In recent years, gold has been extracted from quartz veins hosted within these volcanic units. In this study, the trace element and rare earth element (REE) compositions of zircon crystals were determined for four andesitic igneous samples, including two intensely altered samples (JD1 and JD2) and two fresh to weakly altered samples (JD3 and JD4). Gold and copper mineralization is observed in samples JD1 and JD2, whereas the less altered samples show no evidence of mineralization. The internal morphology of zircon crystals was examined using cathodoluminescence (CL) imaging, and their chemical compositions were analyzed by LA–ICP–MS.

Although zircon crystals from all samples display broadly similar textural characteristics, their chemical compositions differ markedly between altered and unaltered rocks. The Th/U ratios of all analyzed zircons exceed 0.1 and fall within the typical range of magmatic zircons. However, zircons from the unaltered samples (0.4–0.6) exhibit higher Th/U ratios than those from the altered samples (0.10–0.25). The JD3 and JD4 samples contain higher concentrations of Sc, Y, Hf, and Th, whereas the altered samples are relatively enriched in Ti, Nb, Ta, U, Pb, and REEs (Fig. 1).

As noted above, zircons from the altered samples (JD1 and JD2) show higher total REE contents (ΣREE = 720–1000 ppm) compared to the other samples (ΣREE = 400–550 ppm). In chondrite-normalized REE patterns, zircons from the altered samples display a more pronounced negative Eu anomaly (Eu/Eu* = 0.07–0.17) than those from the unaltered samples (Eu/Eu* = 0.43–0.63) (Fig. 2). In addition, the slope of the normalized REE pattern in zircons from the unaltered samples (La_N/Yb_N = 0.001–0.002) is relatively steeper than in those from the altered samples (La_N/Yb_N = 0.08–0.17). The results of this study indicate that zircon trace element geochemistry can serve as a valuable tool in mineral exploration and in understanding the genesis of ore deposits.

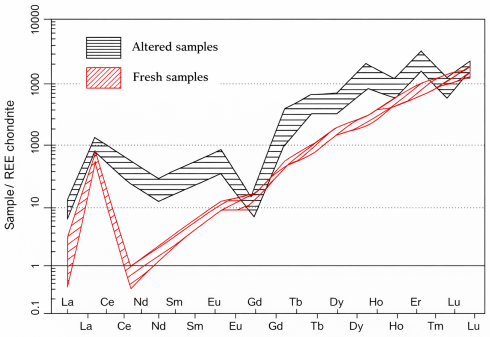


Fig. 2. Chondrite-normalized REE distribution patterns of zircon crystals from the studied samples.

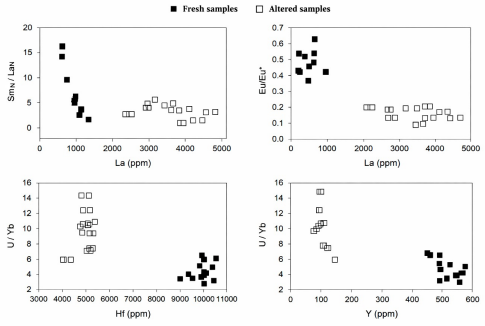


Fig. 1. Discrimination diagrams illustrating the trace element compositions of zircon crystals from altered rocks (□) and **unaltered** rocks (■)