Magmatic Fertility and Timing of the Dalli Gold-Rich Porphyry Deposit, Central Iran: Geological Insights and Exploration Implications

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Dalli is a recently discovered, gold-rich porphyry copper deposit with a proven reserve of 17 million tonnes grading 0.7 g/t Au and 0.5% Cu. It is situated within Iran's main volcanic arc, part of the central segment of the Tethyan orogenic belt. The deposit was identified through spectral analysis of ASTER satellite imagery. Dalli comprises two principal porphyry centres composed of quartz diorite intrusions emplaced into porphyritic andesites within a northeast-trending tectonic corridor. These rocks exhibit intense potassic, quartz-sericite, and silica alteration associated with Cu-Au mineralization. Mineralization occurs primarily as disseminated sulfides and within quartz-hematite-magnetite stockworks and veins. Gold is present as free grains and as inclusions within pyrite and chalcopyrite. A strong magnetic signature associated with potassic alteration, and a distinct Cu-Au geochemical association serve as a key exploration vector at the Dalli deposit. This study presents a comprehensive LA-ICP-MS U–Pb geochronology and trace element analysis from the magmatic suites at the Dalli deposit to characterize zircon geochemical signatures indicative of magmatic fertility. The results exhibit elevated Sr/Y (49–61) and Eu/Eu (0.89–0.92) ratios, consistent with signatures typical of porphyry systems. Zircon trace element compositions are also characterized by high Eu/Eu (0.3–0.8), (Ce/Nd)/Y (0.01–0.3), and 10,000 × (Eu/Eu*)/Y (2–15), comparable to those of world class fertile porphyry suites such as the Sar-Cheshmeh and Qulong Cu deposits along the Tethyan metallogenic belt. The zircon geochronology of mineralized quartz diorite and andesite porphyry units yields magmatic crystallization ages of 15.4–16.0 Ma. These findings demonstrate that the Dalli Oligo-Miocene intrusions are magmatically fertile and justify further deep drilling to evaluate their full mineral potential. Zircon trace element ratios effectively fingerprint fertile magmatic suites and provide new constraints on magmatic events' timing and metallogenic fertility, enhancing exploration models for gold-rich porphyry-style mineralization.