

Magmatic Evolution and Fertility Constraints of the Miocene Sayacık Porphyry Au Prospect: A Comparative Study with the Kışladağ Porphyry Au Deposit, western Türkiye

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The Uşak district in western Anatolia is a key region within the Western Tethyan Metallogenic Belt, hosting the world-class Kışladağ porphyry Au deposit (>17 Moz) and the nearby Sayacık prospect, located approximately 6 km apart. Both deposits developed within the Miocene Beydağ Volcanic Complex (BVC) and are similar in terms of their host lithologies and hydrothermal alteration and mineralization styles, although mineralization at Sayacık is sub-economic. This study compares zircon trace element and Hf isotope compositions from intrusive phases to explain the factors contributing to the seemingly less fertile nature of the Sayacık prospect.

Previous research at Kışladağ indicates that mineralization is associated with a series of high-K calc-alkaline to shoshonitic monzonitic porphyry intrusions emplaced in a post-collisional extensional setting. Zircon U-Pb geochronology of five distinct magmatic phases revealed that Kışladağ magmatism developed within ≤ 0.4 M.y. (14.76–14.36 Ma), with grades decreasing from 0.87 g/t Au in the earliest intrusions to 0.28 g/t Au in the latest.

Parental intrusions at Sayacık are geochemically similar monzonitic porphyries, featuring stockwork and vein textures with widespread tourmaline-white mica alteration. In-situ U-Pb dating of zircons from five weakly mineralized (up to 0.3 g/t Au) monzonite samples at Sayacık yielded Concordia ages between 14.25 and 13.92 Ma, coeval with Kışladağ's late intrusions. Zircon trace and rare earth element (REE) concentrations indicate crystallization temperatures from 709°C to 732°C, with the highest temperatures recorded in the oldest samples. REE_{zircon} ratios (Eu/Eu* ~ 0.55 – 0.58 , Ce/Ce* ~ 78 – 159 , Dy/Yb ~ 0.28 – 0.35 , Ce/Nd ~ 19 – 31) and estimated ΔFMQ values (1.55–2.00) from Sayacık are broadly similar to Kışladağ, whereas ϵ_{Hf} values from -2.83 to -2.40 demonstrate mantle contributions.

Early stages of magmatic development of the BVC had a high potential to generate a world-class porphyry-style mineralization (like Kışladağ). Despite similar alteration and mineralization styles as well as comparable magmatic fertility based on zircon geochemistry, the uneconomic mineralization at Sayacık reflects an apparent temporal decline in magmatic fertility within the BVC. Progressive depletion of the fertile magma reservoir —