Zircon and Apatite Geochemical Insights into Porphyry Cu Fertility in the Artvin District During Subduction–Collision Transition

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The Artvin-Bolnisi transect between NE Türkiye and Georgia hosts clustered VHMS, porphyry, and epithermal systems formed during Late Cretaceous–Eocene subduction- to collision-related magmatism. Volcano-plutonic centers in the Artvin district, the belt's western segment, contain several notable epithermal Au-Ag systems including Hod Maden, Derinköy, and Hızarlı and porphyry Cu-Mo(-Au) systems such as Ardala, Balcılı, and Dereiçi.

This study evaluates zircon and apatite geochemical characteristics of intrusions from the Artvin district to assess the variability in porphyry fertility from Late Cretaceous arc-related to Eocene collisional magmatism. Late Cretaceous samples were collected from host intrusions of the Balcılı porphyry Cu-Mo-(Au) prospect (~78 Ma and ~83 Ma) and the barren Pırnallı Pluton (~77.50 Ma), whereas Eocene samples represent pre-, syn-, and post-mineralization intrusions of the Ardala Cu-Mo-Au system (49.63 ± 0.41 Ma to 48.23 ± 0.47 Ma).

Zircons from the barren Pırnallı Pluton differ slightly from Balcılı host rocks, with lower Eu/Eu* (0.11 vs. 0.23), lower ΔFMQ values (–0.41 vs. +0.07–0.44), and higher zircon crystallization temperatures (821°C vs. 777–693 °C). Eocene Ardala zircons are characterized by higher Eu/Eu* (0.59–0.70), ΔFMQ (+0.33–1.26), and lower zircon crystallization temperatures (682–759 °C). Pre-mineralization zircons have notably higher Th/U, Dy/Yb, and crystallization temperatures (>750 °C), and lower Hf/Y and Ce/Nd, demonstrating their less evolved nature compared to syn- and post-mineralization intrusions. Ardala apatites also have elevated Cl/F and SO_3 concentrations than those from Late Cretaceous intrusions.

Our results, combined with published whole-rock lithogeochemical data, suggest an increasing trend in magma water contents and oxidation states along the Eastern Pontide orogen. Ardala parental magmas underwent amphibole-dominated fractionation within a thickened crust following collision. In contrast, less oxidized and relatively H_2O-poor magmas of Late Cretaceous intrusions of the Artvin district were emplaced within a thinner crust during arc extension and experienced plagioclase-dominated fractionation, thereby limiting Cu fertility.