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Magmatic processes leading to the formation of porphyry copper deposits in long-lived arc systems: Insights from the Miduk and Sarcheshmeh deposits, Iran

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The Urumieh-Dokhtar magmatic arc (UDMA), Iran, is host to numerous porphyry systems, including the large Sarcheshmeh and Miduk deposits. However, the formation of economic porphyry Cu mineralisation is largely confined to the Miocene and the southeastern arc segment. Magmatic processes causing the formation of economic porphyry deposits are examined based on drill core samples of the Miduk and Sarcheshmeh deposits and a compiled arc-wide geochemical and isotopic dataset of Eocene-Miocene magmatic rocks.

Neodymium isotope ratios suggest a similar mantle source for all studied arc magmas, which show Cu, Mo and Pb contents comparable to the depleted mantle. The samples from Miduk and Sarcheshmeh display higher $^{87}Sr/^{86}Sr$ (0.70450-0.70577) and $^{206}Pb/^{204}Pb$ (18.579-18.718) values and trace element ratios (e.g., Th/Nd, Pb/Ce) compared to MORB, indicating slab influence by a sediment component, as also observed in barren arc magmas. In addition, the Miduk and Sarcheshmeh samples exhibit felsic, adakite-like signatures (high La/Yb, Sr/Y) and show high Sr and P contents, whereas the barren arc magmas and subeconomic porphyry systems display calc-alkaline, arc-like signatures (low La/Yb, Sr/Y, Sr, P). The adakite-like signatures were previously attributed to garnet fractionation due to extensive crustal thickening during continent collision in the southern part of the UDMA. Our data lack evidence for garnet fractionation in the porphyry-related samples and geophysical data do not support major differences in crustal thickness (~45 km) along the arc. However, REE systematics ($(La/Sm)_N$, $(Ce/Yb)_N$) might indicate a possible involvement of residual garnet in the source of the fertile porphyry magmas. Instead, the fertile Miduk and Sarcheshmeh magmas were water-rich, as indicated by amphibole-dominated crystallization, compared to the barren arc magmas, where plagioclase dominates the fractionation sequence.

We conclude that the formation of economic porphyry mineralisation in the southeastern arc segment is linked to prolonged, focused, and static magmatism. This process was possibly enhanced by the higher water contents in the magmas caused by the subduction of potentially Sr- and P-rich sediments. By contrast, arc migration in the central UDMA suppressed the formation of large porphyry deposits. This study therefore contributes to a better understanding of the magmatic and geodynamic controls of porphyry deposit formation.