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Petrogenesis of Miocene ultrapotassic magmatism in the eastern Pamir: evidence for crustal underthrusting and crust-mantle interaction

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The Pamir orogen, situated at the northwestern end of the Himalayan–Tibetan orogen, serves as a critical natural laboratory for studying lithospheric-scale processes during continent–continent collision. Widespread Mesozoic and Cenozoic magmatism in the region records the complex tectonic reorganization of the southern Eurasian margin. This study investigates Miocene (ca. 11 Ma) volcanic rocks from the Dunkeldyk area in the eastern Pamir to constrain the petrogenesis and tectonic drivers of post-collisional magmatism. We present integrated petrography, whole-rock geochemistry, Sr–Nd isotopes, and multimineral U–Pb geochronology from a suite of phonolites, rhyolites, and pseudoleucite-bearing tephritic phonolites.

The Dunkeldyk volcanic suite, as revealed by its mineralogical and geochemical characteristics, is classified into rhyolites (SiO_2 = 69–73 wt%), phonolites (SiO_2 = 57–61 wt%), and tephritic phonolites (SiO_2 = 49–55 wt%). These rocks display potassic to ultrapotassic compositions, with K_2O ranging from 7 to 14 wt.% and Na_2O between 0.1 and 3.9 wt%. Their MgO content is notably low (0.05–3.5 wt%), while Fe_2O_3 concentrations are comparatively elevated (2.1–8.7 wt%), and CaO spans a broad interval (1.2–13.6 wt%). Distinctive features include enrichment in large-ion lithophile elements and light rare earth elements, pronounced Ba–Sr enrichment (Ba = 1,778–7,481 ppm; Sr = 181–10,805 ppm), and evolved isotopic signatures (ε Nd = –15 to –8.6). This data indicates a hybrid magma source involving intense crust–mantle interaction. Ti-in-Zircon and Zr-in-Rutile thermometers show higher crystallization temperatures for phonolites compared to tephritic phonolites. These temperatures alongside isotopic modelling suggest that the primary magmas were generated by the partial melting of lower crustal lithologies at mantle depths, followed by interaction with the surrounding mantle peridotite to produce the more mafic tephritic phonolite end-members. Our results support a geodynamic model in which the Pamir lower crust was underthrust to mantle depths, triggering melting and subsequent hybrid magma generation during the late Miocene.