Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35887

Tectonic Modulation of Hydrothermalism, Reactive Melt Flow, and Mantle Refertilization at a Slow-Spreading Ridge: Evidence from the MARNOK Area (24.0–25.2°N, Mid-Atlantic Ridge North of the Kane Fracture Zone)

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The MARNOK area (24.0–25.2°N), immediately north of the Kane Transform Fault along the Mid-Atlantic Ridge, represents a structurally segmented slow spreading ridge system comprising six accretionary segments separated by non-transform discontinuities. Along axis variations range from magmatically robust segments with prominent axial volcanic ridges to tectonically dominated domains characterized by asymmetric accretion. In segments 2 and 5, large offset normal faults associated with detachment systems exhumed deep-seated lithologies, exposing mantle peridotites on the ridge flank at 24.5° and 25°N.

We investigate these two newly discovered abyssal peridotite occurrences. Abyssal peridotites are commonly used to estimate mantle melting beneath mid-ocean ridges, yet shallow melt–rock interaction may overprint primary melting signatures. A key question is whether extreme chemical variability reflects heterogeneous mantle melting reactive melt migration within the shallow lithosphere. Peridotites recovered from a single 338 m dredge display exceptional Cr spinel variability (XCr = 25.9–59.9), spanning more than half of the entire Mid-Atlantic Ridge range. Interpreted solely through fractional melting models, such variability would imply unrealistic melting contrasts recorded at such a local, outcrop-scale. Gabbro-veined and metasomatized samples show systematic Ti enrichment in spinel and pyroxenes and Na enrichment in clinopyroxene, consistent with melt infiltration and chemical re-equilibration. Even samples lacking macroscopic melt addition exhibit cryptic metasomatism and related Ti enrichment trends, indicating that reactive porous flow extends beyond dyke-related interaction. Instead, mineral-scale systematics indicate pervasive reactive melt flow. Two dunite populations further constrain melt evolution. One records MORB-like interaction with high Ti in spinel and elevated Ca in olivine, consistent with channelized melt flux. The other shows low Ti and low XCr spinel, reflecting reaction with a more depleted melt fraction.

In addition to widespread melt-rock reaction, the secondary mineral assemblage and whole-rock REE systematics indicate extensive serpentinization associated with the formation of amphibole, chlorite, talc, carbonatite veins, and local Cu mineralization. In this tectonic context of a segmented slow-spreading environment controlled by non-transform discontinuities, we evaluate that exhumation faults strongly enhance reactive melt-rock reaction in the shallow mantle, followed by extensive water-rock interaction.