Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36011

Tracing source of serpentinisation fluids in the Mariana Forearc using stable and radiogenic strontium isotopes

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Fluids released from subducting slabs play a fundamental role in mass transfer, redox evolution, and mantle wedge serpentinization, yet their sources and pathways within forearc region remain poorly constrained. Here, we combine radiogenic ($^{87}Sr/^{86}Sr$) and stable ($d^{88}Sr$) strontium isotope data to trace slab-derived fluids in the Mariana Forearc, exploring a unique sample suite recovered during the IODP Expedition 366. This suite includes clasts of subducted sediments and basalts, mantle wedge serpentinites, and co-existing pore fluids sampled emanating from multiple serpentinite mud volcanoes.

All solid and fluid samples display a narrow range of $^{87}Sr/^{86}Sr$ (0.705-0.706). In contrast, $d^{88}Sr$ values vary systematically with lithology, temperature, and mineralogical control. Metabasalts, especially, exhibit $d^{88}Sr$ values that differ from incoming plate compositions, demonstrating substantial fluid-rock interaction during transport through the subduction channel. Serpentinites show $d^{88}Sr$ values overlapping those of metabasalts from the same sites, whereas pore fluids are consistently heavier, defining a reproducible fluid-solid fractionation of $\Delta^{88}Sr_{fluid\text{-}solid} \approx 0.06$-0.11‰. These relationships indicate that the same slab-derived fluids responsible for altering detached slab clasts in the subduction channel also infiltrate and serpentinize the mantle wedge.

Mineral-specific Sr isotope fractionation factors suggest that sulphate minerals dominate Sr fractionation at shallow levels, while carbonate-controlled Sr budget prevails at greater depths. The chemical composition of pore fluids and serpentinites indicate that mud volcanoes located closer to the trench (shallower slab depths) are dominated by sediment-derived fluids released during diagenetic reactions. In contrast, for mud volcanoes further from the trench and above greater slab depths (~30 km), both chemical and isotopic data point to altered oceanic crust as the primary fluid source. Thermodynamic modelling suggests that significant dehydration reactions in altered oceanic crust do not occur until reaching blueschist-eclogite transition, at ≥80 km depths. Fluids released at these depths may therefore be transported over long distances along the subduction channel and represent the same fluid phase that infiltrates the mantle wedge, driving widespread forearc serpentinization.