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Stable strontium isotopes ($\delta^{88/86}Sr$) as fluid tracers in serpentinized mantle wedge

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During subduction, fluid-rock interaction in the mantle wedge, driven by slab-derived fluids, plays a crucial role in material cycling between Earth's crust and mantle. However, the extent of this interaction and the origins of the fluid remain debated, demanding the need for sensitive and robust fluid tracers. Here we present $^{87}Sr/^{86}Sr$ and $\delta^{88/86}Sr$ data for samples from IODP Expedition 366 in the Mariana Forearc, encompassing three mud volcanoes (MV)–Yinazao, Fantangisna, and Asut Tesoru. These MVs reflect an estimated depth-to-slab ranging from ~12-18 km and temperatures of ~80-250°C, providing insight into shallow mantle wedge fluid-rock interactions. The Sr isotope variations preserved by metasediment, metamafic, and ultramafic clasts, alongside pore fluids, enable us to document the progressive evolution of the fluid sources as a function of variations in temperature-pressure.

The $^{87}Sr/^{86}Sr$ composition of the clasts and pore fluids vary from 0.70495 to 0.70611 but exhibit no systematic trends. In contrast, systematic variations in $\delta^{88/86}Sr$ are observed among samples from different MVs. The $\delta^{88/86}Sr$ of the limestone is the heaviest of all measured (0.630 ± 0.013 ‰), whereas metabasalts exhibit relatively lighter values (0.145 ± 0.004 ‰). The $\delta^{88/86}Sr$ of serpentinized harzburgites decreases with increasing distance from the trench, from 0.493 ± 0.118 ‰ at Yinazao, to 0.184 ± 0.078 ‰ at Fantangisna and 0.143 ± 0.091 ‰ at Asut Tesoru. Pore fluids follow the same trend as ultramafic clasts, with slightly heavier $\delta^{88/86}Sr$ in Yinazao (0.575 ± 0.020 ‰), intermediate values in Fantangisna (0.307 ± 0.010 ‰), and the lightest values in Asut Tesoru (0.194 ± 0.021 ‰). Notably, pore fluids exhibit heavier δ88/86Sr values compared to serpentinized harzburgites from the same locality, with overall $\Delta^{88/86}Sr_{fluid\text{-}serp}$ ranging between 0.050 and 0.123.

The combined use of $^{87}Sr/^{86}Sr$ and $\delta^{88/86}Sr$ suggests serpentinization in the shallow portion of the mantle wedge (i.e. <13 km) is primarily influenced by sediment-derived fluids. Sediment contribution then decreases with increasing depth as mafic-derived fluids become more dominant. This study demonstrates the utility of $\delta^{88/86}Sr$ as a tracer for fluid-rock interactions under elevated metamorphic conditions, offering new perspectives on fluid dynamics in subduction zones.