

Mg isotopic evidence for the mélange model and high $\delta^{26}\text{Mg}$ values of the arc system

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Two main debates in arc magmatic systems focus on (1) whether magma generation follows the mélange model or fluid/melt model and, (2) whether heavy Mg isotopic signatures are derived from magmatic differentiation, subducted slabs, or serpentinite. Surface-exposed arc lavas, often used to address these questions, lose critical source signatures after multi-stage processes, including slab–wedge interaction, wall-rock contamination, and magmatic differentiation, and later surficial alteration. In contrast, felsic plutonic rocks (i.e., granites) preserved in the lithospheric mantle provide a more direct record of crust-to-mantle mass transfer, offering a detailed understanding of these debates in the arc system. Here, we report Mg isotope data for granitic rocks intruding into the mantle section of Oman-UAE ophiolites. These granitic rocks show similarities to the S-type granite characteristics such as potassic ($\text{K}_2\text{O}/\text{Na}_2\text{O} = 0.86$ to 1.77), peraluminous ($\text{ASI} = 1.03$ to 1.16), low $\text{CaO}/\text{Al}_2\text{O}_3$ ratios (0.04 to 0.14) and high Th/Yb ratios (1.96 to 48.99), but with lower Fe-index ($\text{Fe}^* = 0.17$ to 0.77) and lower Rb/Sr ratios (0.06 to 0.20). These granitic rocks display $\delta^{26}\text{Mg}$ values ranging from -1.10‰ to -0.10‰ , significantly lighter than the mantle value ($-0.25 \pm 0.04\text{‰}$). These extremely light Mg isotopic values (as low as -1.10‰ vs. mantle value of $-0.25 \pm 0.04\text{‰}$) require the incorporation of carbonate-rich sediments into their source. Due to the high solidus temperature of sedimentary carbonate ($>1000^\circ\text{C}$) compared to typical slab-wedge conditions ($<800^\circ\text{C}$), mélange rocks likely trapped carbon-rich materials during subduction. As these mélange diapirs rose into the hotter shallow mantle wedge, partial melting released sedimentary carbonate signatures with extremely light Mg isotopes. Qualitative analyses and simulations suggest $>40\%$ sediment mixing with $<60\%$ highly altered oceanic crust (AOC), with minimal serpentinite involvement, driving preferential transfer of light Mg carriers into the mantle wedge while leaving behind heavy Mg reservoirs (AOC/ serpentinite) to dominate the elevated mature arc $\delta^{26}\text{Mg}$ signatures.

