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From Yellowstone to Australia: Identifying mechanisms for generating low-δ18O silicic magmas on Earth

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Low-δ18O rhyolites have been a petrological conundrum as they reflect silicic magma generation in the shallow and relatively cold upper crust (<400 ℃), a region thought to be unfavorable for the production of large melt volumes. Their genesis is therefore crucial in understanding what keeps large silicic magma reservoirs in the upper crust alive over timescales of millions of years.

Low-δ18O rhyolites along the Yellowstone hotspot track have been interpreted as crustal melts, derived from material that was hydrothermally altered at high temperatures (150-400 ℃). Investigation of the hydrothermally altered rock record suggests that alteration does neither significantly change whole-rock compositions nor lead to higher water contents. Simulations by rhyolite-MELTS and partial melting experiments (750-1000 ℃, 1-2 kbar) reveal that the lack of hydrous alteration minerals and resulting low water contents hinder melting, suggesting that low-δ18O rhyolites are more likely produced by ~30-40% assimilation of hydrothermally altered silicic rocks into a mantle-derived magma. Experiments show no fractionation of oxygen isotopes during incipient melting, indicating that partial melt inherits the bulk δ18O of the hydrothermally altered source material.

We apply these findings to other occurrences of low-δ18O silicic magmas (e.g. in Australia, Iceland, South Africa, Kamchatka, Nevada), in order to identify general mechanisms for the production of low-δ18O silicic magmas on Earth. Low-δ18O settings can either be linked to assimilation of pre-existing hydrothermally altered crust, or (more commonly) to assimilation of syn-magmatically altered rocks. Assimilation of syn-magmatically altered rocks is promoted in shallow, large-scale, long-lived caldera-forming silicic reservoirs that host extensive high-temperature hydrothermal systems, and produce hot (>800℃) and dry A-type magmas. The apparent scarcity of low-δ18O silicic magmas on Earth suggests that coincidence of these factors is rare, and is most likely encountered in Yellowstone-type systems. The large volumes of 18O-depleted rhyolite in early sections of the Yellowstone hotspot track represent an exceptional case, where both syn-magmatic and pre-existing alteration concur, leading to assimilation of material that was extremely low in δ18O (< -5 ‰).

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