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Connections between the Sr isotope geochemistry of seawater, island arc volcanic rocks, and Earth's mantle

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A major effort in solid Earth geochemistry dating to the beginning of Claude Allegre's career has been documenting the isotopic evolution of Earth's mantle for Sr, Nd and Hf. Progress was made on establishing mantle evolution curves for Nd and Hf, whereas the parallel effort for Sr isotopes was largely abandoned. There is agreement about what $^{87}Sr/^{86}Sr$ applies to the earliest Earth (≈ BABI) and to modern "depleted mantle", but there is difficulty in connecting these two points with reliable initial Sr isotope ratios (iSr) of mantle-derived igneous rocks. Most measured iSr values appear to be too high, which was noted 40 years ago but it remained unclear whether the issue was early rapid $^{87}Sr/^{86}Sr$ evolution due to late accretion of high-Rb/Sr material, higher bulk-Earth Rb/Sr, relatively late Rb-depletion of the upper mantle, or unreliability of measured iSr due to post-crystallization alteration or other processes. A unique characteristic of Sr is the relatively high concentration in seawater, so that seawater-mediated alteration increases the oceanic crust $^{87}Sr/^{86}Sr$, and oceanic crust is likely to be involved in the generation of island arc (IA) magmas. Ancient IA rocks are readily available for tracking mantle evolution, and their Nd and Hf isotopes are not significantly affected by seawater-oceanic crust interaction. These considerations lead us to conclude that efforts to define a mantle evolution curve for Sr have been frustrated mainly by the involvement of seawater-derived Sr in IA magma generation. We find support for this hypothesis from iSr values of Phanerozoic IA rocks. Measured iSr values of arc rocks correlate with paleo-seawater $^{87}Sr/^{86}Sr$ and Sr concentration (Bednarick et al., PNAS, 2024), which suggests a well-defined and long-lived contribution of seawater Sr to IA magmas. This effect, which varies through the Phanerozoic and the Precambrian, complicates assessment of mantle Sr evolution using ancient IA rocks but confirms one source of Sr in arc magmas. Injection of seawater Sr into the mantle could significantly affect the mantle as a whole or only the contemporary IA rocks. Sr isotopes in ophiolites is another way to test the hypothesis, since ophiolites are also typically arc-related.