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Two distinct primordial mantle sources beneath Iceland

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Iceland is located on a divergent plate boundary separating the Eurasian and North American plates. Iceland's primary volcanic activity is attributed to an active hotspot commonly interpreted to be fed by a deep-seated mantle plume tapping several mantle components, including a single high 3He/4He source.

Here, we present 182W/184W data combined with 3He/4He ratios and Pb isotopic compositions of samples erupted within the Neovolcanic zone in Iceland, as well as samples from older parts of the Icelandic crust. The short-lived Hf-W isotopic system (where 182Hf decays to 182W with a half-life of ∼9 Ma) is a useful tool to study early-Earth processes that took place within the first ∼60 Ma of solar system formation. Hafnium can be fractionated from W by metal-silicate segregation or silicate crystal-liquid fractionation processes, leading to the formation of reservoirs with significantly different Hf/W ratios. Mantle domains with different W isotopic compositions would have been formed only if the fractionation processes took place while 182Hf was still alive. Hence, the measured W isotopic composition of a plume-derived rock may be used as an indicator of a primordial mantle source.

Measured 182W/184W ratios of Iceland samples show deficits in 182W of up to 13 ppm compared to that of the ambient, modern upper mantle. The W isotopic data correlate negatively with 3He/4He ratios revealing two separate W-He trends, suggesting two sample groups. One group (Group I) is characterized by moderately high 3He/4He of up to 25 RA and 182W deficits of up to 13 ppm. This trend is similar to trends for ocean island basalts from the Hawaiian and Samoan plumes. A second group (Group II) is characterized by high 3He/4He ratios of up to 41 RA showing smaller deficits in 182W of up to 9 ppm. These results indicate the existence of two potential high-3He/4He sources with different W isotopic signatures beneath Iceland. This interpretation is supported by Pb isotopic compositions obtained for the same sample suite, where samples from Group I are characterized by higher 206Pb/204Pb ratios (∼19.1) than samples from Group II (∼18.5).

Our results suggest the presence of two deep-seated mantle source reservoirs beneath Iceland, each characterized by its own distinct W isotopic signature different from that of the mean present-day upper mantle. These reservoirs hence must have formed within the first 60 Ma of solar system formation, likely incorporating primitive He with high 3He/4He ratios. The different Pb isotopic compositions of the two sample groups further indicate that the two early-formed source reservoirs had distinct U-Th-Pb systematics. The present data set may provide new insights into the formation and long-term preservation of source reservoirs of mantle plumes.