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Mantle HIMU reservoir does not arise from crustal recycling

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The HIMU mantle reservoir gives rise to oceanic islands and island chains, such as St. Helena in the Atlantic and the Australs in the Pacific, that have exceptionally high $^{206}Pb/^{204}Pb$ isotope ratios. Various workers have speculated that this reservoir might represent anciently subducted oceanic crust. This idea arises because mid-ocean ridge hydrothermal activity enriches the oceanic crust in U and impoverishes it in Pb, thus raising its $^{238}U/^{204}Pb$ (μ) ratio and, eventually, the $^{206}Pb/^{204}Pb$ ratio. A second characteristic of HIMU oceanic island basalts is relatively low $^{87}Sr/^{86}Sr$, which implies the HIMU reservoir has low Rb/Sr. While the effect of hydrothermal activity on Rb/Sr is probably small, both weathering and sedimentation clearly increase the Rb/Sr ratio of subducted crust. Thus subduction of oceanic crust could produce a HIMU-like reservoir only if the dehydration and melting occurring in the subduction zone exacts substantially more Rb than Sr from the subducting slab. To evaluate this possibility, we have calculated the extent to which U, Pb, Rb, and Sr are recycled into the mantle in subduction zones using a mass balance approach. We calculate 'deep mantle flux' by subtracting the flux of material to island arc volcanism from the subducting slab (the 'arc flux') from the flux of oceanic crust and sediment into the subduction zone at the trench (the 'trench flux').

Of 5 arcs examined so far, only two (Marianas and Izu-Bonin) show μ in the 'deep mantle flux' substantially higher than bulk silicate Earth (BSE); values in two others (Tonga and Kuriles) are substantially less than BSE in two others. Thus oceanic lithosphere subducted in the deep mantle does not always have high μ. Furthermore, subduction zone processes beneath the arc do not systematically lower the Rb/Sr ratio of the subducting slab; on average, the Rb/Sr ratio of the 'deep mantle flux' is not significantly different that that of the 'trench flux'. Consequently, in all subduction zones except Tonga, the Rb/Sr ratio of the deep mantle flux is too high to produce a HIMU-like reservoir. In Tonga, the Rb/Sr ratio of the subducting slab is low due to the very thin layer of sediment being subducted (70 m). However, this slowly accumulating sediment has very low μ (0.8) and the μ in the 'deep mantle flux' is consequently also low (~3.6). Thus in none of the 5 arcs we have studied does the deep mantle subduction flux have parent daughter ratios requisite to generation of HIMU-like material.

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HRDM: The common high $^3He/^4He$ reservoir in Earth mantle

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The high $^3He/^4He$ of mantle plume-derived volcanic rocks is evidence that a mantle reservoir that has remained relatively unprocessed since Earth accretion. The trace element and isotopic composition of this reservoir puts constraints on Earth origin and evolution. Tertiary olivine phenocryst-bearing basalts erupted by the proto-Iceland plume from Baffin Island, E. and W. Greenland, W. Scotland and N.W. Iceland produce a linear trend in He-Nd and He-Sr isotope space that extends to $^3He/^4He$ ~ 50 R_a. The $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$ and trace element composition of the high $^3He/^4He$ end-member appear to be large volume melts of depleted mantle indistinguishable from North Atlantic MORB. In He-Nd isotope space, plume basalts with olivine $^3He/^4He > 8$ R_a either define linear mixing with the high $^3He/^4He$ end of the proto-Iceland plume trend (e.g. Samoa), or mix from low $^3He/^4He$-variable $^{143}Nd/^{144}Nd$ to points on the trend, but never cross it (e.g. Hawaii, Galapagos). Depleted mantle, rather than exotic components like FOZO, is the common source of high $^3He/^4He$ in mantle plumes. Generating high $^3He/^4He$ by mantle depletion is difficult, and any process must explain why the depleted mantle that melts beneath mid-ocean ridges has the uniform, low value. It can be generated by mixing between normal depleted mantle and <5% primordial He-rich mantle, and we have previously dubbed this reservoir the He-recharged depleted mantle (HRDM). The HRDM may have formed at a mid-mantle thermal boundary layer between convectively isolated reservoirs. However this is inconsistent with whole mantle convection that is necessary to explain, for instance, seismological evidence for the penetration of subducting slabs through the 670 km seismic discontinuity. We will test the possibility that the HRDM is a relic of earlier two later convection regime.