Reservoirs or recycling?

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Formation of Earth's continental crust has left a clear chemical and isotopic imprint on the mantle. Simple 3-box (crust, depleted mantle, undepleted mantle) mass balance models show that between 20% and 60% of the mantle, depending primarily on the value of average crustal composition chosen, must have been largely depleted of highly incompatible elements by continent formation. These models predict the presence of significant volumes of undepleted mantle; a prediction that is becoming increasingly unpalatable in view of geophysical evidence for whole mantle convection and the lack of geochemical evidence for primitive mantle as a component for any terrestrial volcanism. Even the source of high $^{3}He/^{4}He$ appears to have Sr and Nd isotopic compositions indicative of a depleted "reservoir". Another option to consider is that the entire mantle has cycled through an ocean ridge system at some time in Earth history and consequently ALL the mantle has been partially melted to segregate into basalt and depleted peridotite. This assumption leads to a different 3-box mass balance model: 1) continental crust (and its mantle lithosphere), 2) all the basaltic oceanic crust formed over Earth history, and 3) the complementary depleted peridotite. Using an evolved average continent composition (Gao et al., GCA, 1998) and for "reservoir" 2, the global average MORB composition compiled from the PetDB database (Su and Langmuir, 2002) with a volume equal to 4.56 Ga of oceanic crust production assuming a constant rate equal to the modern rate, the calculated depleted mantle reservoir would have a major element composition nearly equal to that of the BSE with a slightly high (2.3%) Ca/Al ratio, a Th/U of 2.7 and, assuming a mean age of the basalt reservoir of 1.8 Ga, Sr Os and Pb isotopic compositions lying at the most depleted end of the MORB array. Corresponding 1.8 Ga basalt would plot close to the HIMU endmember in Pb. The MORB to HIMU isotopic array followed by many OIB could be produced by basalt:depleted-mantle proportions of 5:95 (MORB end) to 60:40 (HIMU end). Sr, Nd, Os and Pb isotopic compositions of FOZO fall at a mixing ratio of 40:60. Adding recycled continental components then can produce the 2 EM end members. Whether this "completely processed" mantle model can be reconciled with He and Ar data remains to be seen, but it offers the alternative explanation that the heterogeneity of mantle-derived magmas primarily reflects variable proportions of recycled basalt to depleted peridotite in the magma source rather than mixing between distinct, geographically-isolated, reservoirs.

$^{142}Nd/^{144}Nd$ precise determination in early Archean rocks

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The widespread existence of positive $\varepsilon^{143}Nd$ in Archean rocks suggests that the Earth's mantle experienced a major early differentiation. However, the timing and nature of this event remain uncertain, since metamorphism may have disturbed the Sm-Nd system of Archean rocks. In spite of this, a reliable $\varepsilon^{143}Nd = +2$ at 3.8 Ga can be estimated from well-preserved Isua units (Greenland) (Moorbath et al., 1996), suggesting that magmatic processes - extraction of a primitive crust and/or crystallization of a magma ocean - have massively affected the Hadean mantle.

^{146}Sm-^{142}Nd ($T_{1/2}$=103 Ma) systematics was expected to provide further constraints on these early events. However, ^{142}Nd anomalies in Archean rocks are not likely to exceed 40 ppm, while external precision achievable by TIMS was shown to be limited to 15-20 ppm (2σ) (Sharma et al., 1996). This has severely hampered unambiguous determination of small ^{142}Nd anomalies. To date, with the exception of one controversial $\varepsilon^{142}Nd$ anomaly of 33±4 ppm in a metasediment from Isua (Harper and Jacobsen, 1992), no terrestrial ^{142}Nd anomaly has been identified.

Here, we reconsider this issue using the new generation TIMS TRITON TI. From repeated analysis of the Nd standard AMES, we show that about 50% of the observed variability can be ascribed to improper correction of instrumental mass fractionation. This uncertainty can be simply eliminated provided that a second correction ratio (e.g. $^{150}Nd/^{144}Nd$) can be accurately measured. Under this condition, we were able to reach an external precision of 4 ppm (2σ) for both $^{142}Nd/^{144}Nd$ and $^{143}Nd/^{144}Nd$ (N=50).

Our results show that determination of ^{142}Nd excess as low as 10 ppm can be confidently determined in Archean rocks. Preliminary results obtained on samples from Isua (3,8 Ga) and Amitsôq (3.65 Ga) show no ^{142}Nd anomaly. We are currently analyzing well-preserved samples from the Isua felsic unit, and from the locality where a ^{142}Nd excess was reported. These results should provide new insights into the Hadean evolution of the Earth's mantle.

References

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