The Helium Isotopic Evolution of the Earth

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Recent partitioning experiments indicate that helium may be more compatible than its radioactive parents, U and Th [1]. In this case, depleted residues of melting would have low parent/daughter ratios and their $^4He/^3He$ ratio would not change substantially with time.

In this scenario, a peak in the histogram of $^4He/^3He$ in OIB corresponds to the age of prior mantle depletion of the OIB source. There are three primary peaks in the $^4He/^3He$ of OIB at 29k (24Ra), 40k (20Ra) and 56k (14Ra) (where 29k=29,000). These peaks are robust, and can be seen in both global compilations of $^4He/^3He$ in OIB as well as in individual OIB datasets. The ages that these peaks represent depend upon the degassing history of He. If He degasssing is rapid, relative to the production rate of ^4He, then the isotopic evolution will be linear, starting at 6k at 4.6 Ga and evolving to a present day mantle value of 90k (8 Ra, the dominant peak seen in MORB and present in many OIB).

Using this evolution curve, the three peaks at 29k, 40k and 56k correspond to ages of 3.3, 2.7 and 1.9 Ga, respectively. These ages precisely match the ages of continental crust (CC) growth peaks derived from crustal area/age relationships and zircon age histograms [2]. The correlation has an R^2 of 0.9995 and predicts an initial $^4He/^3He$ ratio for the Earth that is within error of previous independent estimates [3].

The correlation between the He and CC peaks, as well as between estimates of the initial isotopic composition of the Earth, is highly unlikely to be a coincidence. It strongly implies that the above isotopic evolution model is correct and that He is more compatible than U and Th, at least at the degrees of melting that produced the OIB source depletions (which may have been high relatively high 1.9 to 3.3 billion years ago).

The evolution model has fundamental implications for mantle chemical evolution and geodynamics: 1) all of the mantle that is sampled by oceanic basalts is highly degassed, 2) most OIB have ancient depleted mantle components in their source, many have several, suggesting that ancient depleted mantle is collecting (for very long timescales) and being swirled together (but not homogenized) in the OIB source region, perhaps at the core-mantle boundary, 3) there is no evidence in He isotopes for an undegassed mantle reservoir, and therefore no evidence for layered mantle convection.

References

[1] Parman S.W., et al. (2005) *Nature* **437,** 1140-1143.
[2] Kemp A.I.S., et al. (2006) *Nature* **439,** 580-583.
[3] Niemann H.B., et al. (1996) *Science* **272**, 846-849.