5.1.12

High ^{3}He/^{4}He and solar Ne in OIB: Should we wonder?

F. ALBARÈDE

Ecole Normale Supérieure, 46 allée d'Italie, 69364 Lyon
Cedex 7, France (albarede@ens-lyon.fr)

For two decades, the contrasting He isotope compositions of MORB and OIB were at the core of conflicting mantle convection models. All body wave models vividly depict lithospheric plates penetrating the ~660 km discontinuity, such as the Farallon and the Tethyan plates. In contrast, the presence of He with high ^{3}He/4He and, even more importantly, of solar Ne in OIB attest to the presence of undegassed material at depth. The question I will address here is how much primordial He and Ne it takes to qualify the entire lower mantle as 'undegassed'. Current models of tracer redistribution by convection do not answer this question and are limited to the description of a whole range of regimes with variable extents of layering. In order to tackle this problem, I first formulated the master equation of a residence time distribution theory, which shows that, at steady-state, the length of time different parcels of mantle survive extraction and degassing from a well-stirred mantle is exponentially distributed. The mean residence times in the whole mantle are simply assessed by dividing the bulk silicate Earth inventories of these elements by their flux into the oceanic lithosphere: the residence times of incompatible refractory lithophile elements are all in excess of several Gy, which indicates that the mantle as a whole is vertically zoned. Whole-mantle mixing destroys the primitive signature of the average lower mantle on the time scale of the residence time of the primitive nuclides, but still leaves some small parcels untouched for potentially very long periods of time, longer than the age of the Earth. From available isotopic data, we assess that the lower part of an unhindered convective mantle may contain up to several percent primordial material. If, as some convection models show, the 660 km discontinuity is a partial hindrance to vertical mixing, this proportion may become significantly higher. The most likely texture of the lower mantle is an intricate layering of material recycled from the surface and primordial material, while its chemical composition is geochemically enriched with respect to the upper mantle. This simple concept accounts for the coexistence of the primordial character of rare gases, the recycled character of lithophile-element isotope compositions in OIB, their apparent lack of ^{142}Nd anomalies, and the missing component inferred from a number of geochemical systems. The marble cake incorporates different ingredients at different depths: mostly residual mantle and recycled oceanic crust at the top and more oceanic plateaus and primordial material at the bottom.

5.1.13

Isotopic heterogeneity in the mantle: In search of the final explanation

S.B. JACOBSEN, J.B. KELLOGG AND R.J. O'CONNELL

Dept. Earth and Plan. Sci., Harvard University, Cambridge,
MA 02138, USA (jacobsen@neodymium.harvard.edu)

Since the 1960's, it has been known that the mantle is isotopically heterogeneous. However, mid-ocean ridge basalts (MORBs) that make up the bulk of the oceanic crust (OC) exhibit a relatively uniform isotopic composition. With the use of the Sm-Nd isotopic system, it became clear that their mantle source had been depleted by melt extraction to form the continental crust (CC) over geologic time. This source was therefore named the depleted mantle (DM). Mass balance considerations based on Nd and Sr isotopic data showed that the DM extended through only ~30% of the mantle, and that the lower mantle could in principle mostly be primitive and undifferentiated. These models depended on using the most frequent Nd and Sr isotopic values of MORBs as estimates of average DM source composition. Basalts from ocean islands show a much wider range in isotopic composition than MORBs. By considering Nd, Sr and Pb isotope data for these two groups of basalts, it was shown that the isotopic composition space could be described rather well by four isotopic components: DMM, HIMU, EMI, EMII. Also many of the data arrays pointed toward an isotopic component called FOZO, that was suggested to comprise the lower mantle. Such a composition of the lower mantle would imply that the Earth has a non-chondritic Sm/Nd ratio. We have extended the reservoir models to take into account mantle heterogeneities by keeping track of all subreservoirs in DM. In our model DM, we consider four classes of subreservoirs: residues after CC and OC melt extraction as well as recycled CC and OC. These are real components, but their variability in Sr, Nd and Pb isotope compositions is much larger and different from the observed isotopic variations in young basalts. The results of our current analysis show that apparent isotopic components (DMM, HIMU, EMI, EMII) are non-existent or fictitious components/reservoirs, while the most frequent MORB isotopic compositions faithfully record the average composition of the depleted mantle (DM). We show that the isotopic composition of FOZO corresponds closely to the average composition of the "matrix" in the DM, which consists of small length-scale subreservoirs (<15km). Thus, FOZO is not the lower mantle, there is no need for revision of the size of the DM, and it is still possible to have an Earth with a chondritic Sm/Nd ratio. Our model, which allows both for averaging of source heterogeneities during sampling as well as homogenization of source heterogeneities owing to mantle mixing through time, yields a new understanding of the isotopic variability in ocean basalts.