The source and consequence of neon isotope heterogeneity in the mantle

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The unambiguous resolution of the Ne isotopic composition of the convecting mantle ($^{20}Ne/^{22}Ne$=12.2-12.5) from magmatic CO_2 natural gas samples is indistinguishable from the trapped Ne-B component in meteorites (Ballentine et al., 2005). This contrasts with values of $^{20}Ne/^{22}Ne$>13.0 resolved in samples from the Kola Peninsula ancient plume province (Yokochi and Marty, 2004), which in turn is similar to the Solar Nebula value. While Ne isotopes significantly higher than $^{20}Ne/^{22}Ne$=12.5 have not been observed in any other plume system (with the exception of one sample from Iceland, that on re-analysis was not repeated), because of the nature of atmospheric contamination to typical OIB samples we have to consider the possibility that the source of plumes in general has a different Ne isotopic composition to that of the convecting mantle.

There are no viable mechanisms (e.g. air recycling, radiogenic, isotopic fractionation) that can reduce a Solar $^{20}Ne/^{22}Ne$~13.8 to the Ne-B value of 12.5. Confirmation of a Ne isotope difference between the plume and convecting mantle sources would require us to completely re-evaluate models that source the non-radiogenic noble gases in the convecting mantle from a volatile-rich plume source reservoir. The consequences in this case are both the requirement for preservation of the high $^{20}Ne/^{22}Ne$ plume source since soon after accretion; and negligible contribution of this volatile source to the convecting mantle. In the former case, release of Solar Nebular volatiles into the D'' region of the mantle, or preservation of nebular volatiles in D'' since accretion are possibilities. In the latter case, numerical simulations of plume entrainment of a deep denser layer qualitatively point to preferential transport of this material to the near surface where it can be degassed and not significantly contribute to the convecting mantle budget.

References

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A comparison of methods for modeling geochemical variability in the Earth's mantle

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Numerial models of isotopic and chemical heterogeneity of the Earth's mantle fall into three categories. First, several authors have used chemical tracers within a full thermo-chemical convection calculation (e.g., Christensen and Hofmann, 1994, van Keken and Ballentine, 1999; Xie and Tackley, 2004). Second, Kellogg et al. (2002) and Kellogg (2004) proposed an extension of the traditional geochemical box model calculations in which numerous subreservoirs were tracked within the bulk depleted mantle reservoir. Third, Allegre and Lewin (1995) described a framework in which the variance in chemical and isotopic ratios were treated as quantities intrinsic to the bulk reservoirs, complete with sources and sinks.

Results from these three methods vary, particularly with respect to conclusions drawn about the meaning of the Pb-Pb pseudo-isochron. We revisit these methods in an attempt to arrive at a common understanding.

We conclude that the parameterization of Allegre and Lewin (1995) is overly simplified with respect to the Earth. The association of pseudo-isochrons with stirring times is not robust. However, the extended box model approach agrees strongly with the thermochemical convection models. Going forward, an approach that uses the extended box models to explore parameter space while using full convection models to evaluate permissible parameter combinations may be the most fruitful. Furthermore, these results suggest a hybrid approach that combines the two methods, allowing us to investigate heterogeneity on all length scales in a single self-consistent model.