Isotope signatures and models of the Earth'sinner structure: what are problems?

Ichiro Kaneoka[1]

[1] ERI, Univ. Tokyo

Many models have been proposed for the inner structure of the Earth. However, there are gaps between the geophysical model based on recent seismic tomography and the geochemical model based on knowkedges from material sciences including isotope ratios. I will review the information on radiogenic isotopes which give constraints on the geochemical model and discuss their significance.

In the geophysical model, whole mantle convection model is quite popular now based on such an observation that some slabs seem to penetrate into the lower mantle as revealed by the seismic tomography. On the other hand, various geochemical models have been proposed based on geochemical propreties of MORB(MId-oceanic ridge basalt) and OIB(oceanic island basalt), including isotope ratios such as Sr,Nd,Pb,Os,noble gases and so on. Since different source materials are assumed in these models, they do not always reflect whole mantle convection. However, what solid isotope ratios require is that the MORB magma source should be depleted in incompatible elements and the OIB magma source should be less depleted, but do not require any constraint on the geometry about the distribution of such magma sources. However, noble gas isotope ratios give additional and significant constraints which cannot be obtained by solid isotope ratios alone.

To represent the noble gas isotope ratios which give constraints in constructing a model of the inner structure of the Earth, the 3He/4He ratio is mostly used since atmospheric contamination is almost negligible in case of He isotopes. MORBs in all oceanic areas show relatively uniform 3He/4He ratios of about 8 times of the atmosperic value, while most OIBs show higher values up to about 40 times of the atmospheric value. This can be interptreted most straightly that the OIB magma source retains the primordial 3He more abundantly than the MORB magma source. This requires that the former should keep more primordial character than the latter, which is a basis that the less degassed lowewr mantle is the source material for OIBs in the two-layered geochemical model. However, such a simple interpretaion is not compatible with the geophysical model which assumes whole mantle convection. To overcome this point,various trials have been performed. However, they do not seem to succeed in satisfying the nble gas isotope constraints. In these several years, D.Anderson's group argues that the 3He/4He ratios of MORBs and OIBs can be explained by assuming as mixtures of two components with the higher and lower 3He/4He ratios and the degree of uniformity reflects the different degree of partial melting of such components. They insists on that their model is compatible with the geophysical model. However, their model also includes many problems. For example, observed 3He/4He raios of OIBs seem to reflect the tectonic conditions and show systematic regional differences. We have not found any high 3He/4He ratios as expected even in mantle xenoliths. In their model, portions with high 3He/4He ratios are scattered as patches or thin filaments in the mantle. However, it is difficult to imagine that primordial noble gases could be retained in such portions since the formation of the Earth until present, because He is chemically inert and quite mobile.

Constraints from He can be also obtained from Ne,Ar and Xe isotpe ratios. To be compatible with such noble gas constraints, primordial noble gases should be retained in reasonable amounts of materials in the lower part of the lower mantle, where volatile elements might be also retained. However, not all the lower mantle has such characteristics. If primordial materials remain as some irregular figures in the lower part of the lower mantle, it does not incompatible with the geophysical model.