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Li Isotope Evolution of the Mantle from Analyses of Mantle Xenoliths

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Stable isotope fractionation is dominated by low temperature processes, and variations in stable isotope ratios have been used to implicate unequivocally the involvement of surface material. It has long been a goal to use stable isotopes to investigate the role of recycling in the development of ocean island basalt OIB and mid-ocean ridge basalt MORB sources. Given even modern plate recycling rates, all of the upper mantle can potentially have been processed through the near surface environment as oceanic crust through the course of Earth History and thus have been significantly affected by seafloor alteration. Such a process should cause a temporal evolution of certain stable isotope ratios in the mantle, and cast light on where recycled material ultimately resides. It might be hoped to use oxygen isotopes for such a task, but since the sense of oxygen isotope fractionation in the oceanic crust is equal and opposite in the upper and lower portions, oxygen isotopes do not help evaluate the bulk recycling of oceanic lithosphere. Li on the other hand is an element that is both isotopically fractionated and strongly enriched during sea-floor alteration. Moreover, preliminary work suggests some of this Li survives subduction zone processing and is recycled into the deep mantle. Thus, here we attempt to track the Li isotope evolution of the upper mantle, which should yield a record of the long term refertilisation of the upper mantle with altered oceanic crust.

Li is present in the mantle itself in concentrations amenable to analysis. Thus we have undertaken a study of mantle Li isotope evolution by examining the Li isotope ratios of olivine from peridotites with different model ages, from 3.2Ga to the present. This provides a more pristine sample than ancient volcanics, yet gives age constraints sufficient to assess gross patterns of evolution. Mantle xenoliths were investigated from two different volcanic settings: oceanic lithosphere beneath La Palma and continental lithospheric mantle beneath Siberia. La Palma peridotites represent modern mantle whereas the Siberian continental peridotites have Re-Os model ages between 3.2 and 0.4Ga (Pearson et al., 1995). Li isotope ratios ($^{7}Li/^{6}Li$) of olivines were analysed by Thermal Ionisation Mass Spectrometry using Li_3PO_4 on double Re filaments. Li isotope compositions are reported as $\delta^{7}Li$ values relative to NIST L-SVEC standard. Measurements have a reproducibility precision of ±1.5‰ (2 s.d.).

$\delta^{7}Li$ values of olivine from the oceanic peridotitic xenoliths from La Palma vary between ~ +4 and +7‰ and are comparable or heavier than MORB ($\delta^{7}Li_{MORB}$ = +3.4 to +4.7‰, Chan et al. 1992, +4.6 to +6.5‰, Tomascak and Langmuir 1999), compatible with notion that the young oceanic crust of La Palma is underlain by MORB lithosphere. Although olivine-melt isotopic fractionation is likely to be small, no work has been undertaken to quantify this effect, and so we use the La Palma xenolith olivine data as our modern upper mantle reference, against which to compare our other olivine data. Li isotope compositions of olivines from old continental lithosphere beneath Siberia range to significantly lower $\delta^{7}Li$ than the oceanic lithosphere. Most noteworthy is the peridotite with a model age of 3.2 Ga which has a $\delta^{7}Li$ value of around +0.5‰, whilst the peridotite with the youngest model age (0.4 Ga) has a Li isotope composition comparable to MORB.

These preliminary results show a trend of increasing $\delta^{7}Li$ in the mantle with time; the oldest peridotite has the lightest Li isotope composition for olivine, while the youngest (represented by oceanic peridotites) tend to have equal or higher $\delta^{7}Li$ values compared to MORB. Such evolution is in the sense expected for recycling of altered oceanic crust which is about 10‰ heavier than fresh MORB. A crude calculation, assuming recycling at present spreading rates of oceanic crust with the upper 500m altered to the composition reported by Chan et al. (1992), into the upper 670km of mantle requires ~3Ga to shift the Li isotope composition from the measured value in the oldest peridotite to modern day MORB. This is a highly encouraging result, and we are undertaking further work to confirm these initial data.

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