Iron Isotope Fractionation as Indicator of Mantle Processes

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We analysed several suites of mantle peridotites and basalts from different tectonic settings to investigate the effect of mantle processes (fertile, refractory and metasomatised) on Fe isotope composition. High precision measurements (≈ 0.04‰ on δ^{56}Fe 2SD) were done using high resolution MC-ICP-MS with Cu for mass bias correction, sufficient to resolve small differences between minerals and rocks equilibrated at high temperatures [1]. δ^{56}Fe in the bulk peridotites ranges from -0.12 to +0.17 (except a single sample with δ^{56}Fe = -0.42). Metasomatic enriched peridotites yield higher average δ^{56}Fe (+0.07) than refractory peridotites with Mg# > 0.91 (δ^{56}Fe = -0.02). Fertile lherzolites display average δ^{56}Fe of +0.02. All mantle samples together display a negative correlation between the Fe isotope composition and the Mg# [2], an index of the degree of melt extraction and/or post-melting interaction with evolved melts. A negative correlation of and fO_2 [2] was observed for only one locality (Lesotho). Basalts (MORB, OIB and IAB) are isotopically heavier than peridotites with δ^{56}Fe varying between 0.04 and 0.24 with an average of 0.11. OIBs appear to be slightly heavier than MORBs, though their mean values (of the current data set) do not differ outside 95% confidence level.

These findings imply Fe-isotope fractionation during partial melting in the mantle, with an enrichment of heavy Fe in the melts. Assuming either batch or fractional melting, a fractionation factor $\alpha_{mantle-melt}$ of ≈ 1.0001 (resulting in $\Delta_{mantle-melt}$ of ≈ 0.1) can be estimated from the difference in average Fe isotope compositions of basalts and fertile mantle [1]. The correlation of Mg# and δ^{56}Fe of all investigated peridotites taken together implies a similar $\alpha_{mantle-melt}$. However, most individual localities imply higher fractionation factors between 1.0001 and <1.0004. We propose that isotopic re-equilibration between melts and host peridotites during melt percolation as well as mixing of melts from depleted mantle with those from fertile or metasomatised mantle decrease the difference in Fe isotope composition between average mantle and basalts. Such processes are indicated in particular by Fe-enriched xenoliths from Tok (SE Siberia) [3], which show increasingly heavy Fe isotope values at higher degrees of reaction with evolved melts.

References

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[3] Ionov D.A. et al., CMP **150**, 335-353 (2005).