Seismic signatures of heterogeneity from subducted basalts

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Products of chemical differentiation near the surface, such as oceanic crustal basalts, may be transported downward by subduction to give rise to chemical heterogeneity at depth. In the upper mantle, anhydrous metabasalts (e.g., eclogites) should be only slightly fast relative to ambient peridotite mantle, with a signature arising primarily from the thermal anomaly rather than composition. Hydrous metabasalts (e.g., lawsonite blueschists, lawsonite eclogites), on the other hand, should be significantly slow in the 100-250 km depth range, becoming faster (e.g., stishovite eclogites) below 250 km.

In the lower mantle, anhydrous metabasalts (e.g., perovskitites) should be fast, growing progressively more so with increasing depth. This signature arises from the compositional contrast, as the thermal signal is small and falls with increasing depth (as does the negative buoyancy anomaly). If dense hydrous phases persist to such depths, they may decrease this predicted velocity anomaly. It is important to note that these fast anomalies arise largely from the presence of free silica in metabasaltic mineralogies. Thus, onset of a $CaCl_2$-structured post-stishovite phase of silica may induce a drop in shear moduli resulting in slow shear velocity anomalies, and any subsequent stabilization of a PbO_2-structured post-stishovite phase of silica may yield larger fast anomalies.

These anomalies largely depend upon the survival of free silica phases, which are unstable in contact with the surrounding peridotite. In the lower mantle, for example, silica reacts with ferropericlase to form perovskite. Thus, these metabasalt mineralogies (free silica + perovskite) can persist only to the extent that they are preserved as armored relics from contact with surrounding metaperidotite (perovskite + ferropericlase). Therefore, efficient mixing in the deep mantle would cause decay in such velocity anomalies due not only to volumetric averaging but also to chemical reaction.

Mg isotope study of terrestrial and extraterrestrial materials

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We report high-precision Mg isotope measurements of terrestrial and extraterrestrial materials by multiple collector inductively coupled mass spectrometry (MC-ICP-MS). Analysed meteorite samples include carbonaceous chondrites (CC), ordinary chondrites (OC), basaltic eucrites, diogenites, mesosiderites, an angrite (SAH99555) and a basaltic shergottite (Zagami). Terrestrial materials include modern basalts (BHVO-1, Indian MORB), komatiites, mantle olivine and clinopyroxene and, lastly, Fe-Mn nodules from the Atlantic and Pacific oceans. Mg purification was accomplished by ion-exchange chromatography, using Bio-Rad AG50W-X12 resin on which >99% recovery of Mg is achieved. Samples were introduced into the MC-ICP-MS (VG Axiom) via a Cetac MCN-6000 nebuliser. We use a standard–sample–standard bracketing technique, and samples are analysed at least three time. Measured $^{26}Mg/^{24}Mg$ and $^{25}Mg/^{24}Mg$ ratios are reported as per mil deviation (δ) from the international Mg-isotopic standard SRM-980. The external reproducibility of our method, estimated from repeated analyses of an in-house Mg standard solution, is 0.05‰/amu. The integrity of the data generated with our analytical protocol was investigated by i) verifying that the chemical separation procedure does not fractionate Mg isotopes ii) ensuring that potential isobaric interference are negligible and iii) confirming that the influence of other elements such as Al, Na and Ca on instrumental mass fractionation is reduced to an insignificant level.

The overall variation in $\delta^{26}Mg$ and $\delta^{25}Mg$ in the 24 samples analysed is 4.79‰ and 2.48‰, respectively. The Mg isotopic compositions define a single mass fractionation curve on a three-isotope plot, with a slope of 0.5170 and intercept of -0.037. This is identical to the slope and intercept of Galy *et al.* (2000) defined from 61 terrestrial geological and biological samples. Most of the observed variation in our dataset is defined by the three Fe-Mn nodule samples, showing a range in $\delta^{26}Mg$ and $\delta^{25}Mg$ of 2.01‰ and 1.00‰, respectively, with isotopic compositions systematically lighter than seawater ($\delta^{26}Mg$<2.59‰). In contrast, samples derived from Earth's mantle have restricted $\delta^{26}Mg$ and $\delta^{25}Mg$ values of 4.22±0.08‰ and 2.15±0.07‰, respectively. The extraterrestrial materials define a slightly greater range of Mg isotopic compositions (0.8‰ for $\delta^{26}Mg$), with correlated variations between different classes of meteorites.

Reference

Galy, A, Young, E,D., Ash, R.D. & O'Nions, K. (2000) *Science* **290**, 1751-1753.