Titanium isotope heterogeneity in the Earth's mantle

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Titanium isotopes provide a powerful tool for tracing igneous processes such as magmatic differentiation. The Ti isotope composition of terrestrial rocks varies by up to ~2.10‰ in the $^{49}Ti/^{47}Ti$ ratio [1, 2]. Mantle-derived magmas have nearly homogeneous $\delta^{49}Ti$ that are predominantly within error of the bulk silicate Earth estimation [2, 3]. In contrast, significant Ti isotope variations of ~0.26‰ are observed for peridotites, displaying $\delta^{49}Ti$ both lighter and heavier than basaltic rocks [2]. To constrain the origin of these variations, we determined the Ti isotope composition of samples from a continuous section from the Horoman peridotite massif (Japan), previously analysed for Mg and Li isotopes [4]. The samples range from fertile plagioclase lherzolite to depleted harzburgite and also comprise metasomatically overprinted peridotites.

Sample processing and analysis follow the protocol of [5]. A ^{47}Ti-^{49}Ti double-spike is added to the samples and Ti is purified via a three-step ion-exchange procedure. Isotope analyses are performed on a Thermo Scientific Neptune Plus MC-ICP-MS at ETH Zurich. Our average analytical precision is ~0.015‰ for $\delta^{49}Ti$, determined on USGS reference material BHVO-2.

Our data show a wide spread in $\delta^{49}Ti$ of ~0.55‰. The isotopically lightest samples have Ti isotope compositions within uncertainty of the estimate for BSE, whereas heavy $\delta^{49}Ti$ are in the range of differentiated, intermediate to silicic rocks. These variations do not correlate with melt depletion indices (e.g. Al_2O_3) and are thus not related to partial melting and melt extraction. Instead, trace element signatures (e.g. Nb/Th, Rb/Sr) indicate that fractionated Ti isotope compositions are likely associated with mantle wedge metasomatism above the Hidaka subduction zone. Hence, the Ti isotope compositions of the Horoman peridotites trace mantle contamination with metasomatic agents carrying a crustal signature.

[1] Deng et al. (2019) PNAS, 116.4, 1132–1135. [2] Mandl (2018) PhD thesis, ETH Zurich. [3] Millet et al. (2016) EPSL, 449, 197–205. [4] Lai et al. (2015) GCA, 164, 318–332 [5] Williams et al. (2014) LPSC, 45, 2183.