What Controls Titanium Stable Isotope Fractionation During Magma Evolution?

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Titanium (Ti) is a highly immobile, refractory lithophile element. Preliminary studies of its stable isotope composition in geological samples have shown its sensitivity to oxide-melt equilibrium [1,2]. Ti predominantly exists in 5-fold coordination in silicate melts [3], but occupies a 6-fold coordination in Fe-Ti oxides [3], which drives its isotopic fractionation [2]. Previous work [1,2] has demonstrated a progressive enrichment in heavy Ti isotopes (expressed as δ^{49}Ti) during magmatic differentiation due to crystallisation of Fe-Ti oxides. However, due to the limited data available, it is unclear if other controls also exist.

Here, we present a comprehensive set of Ti stable isotope data for a range of differentiation suites from tholeiitic, calc-alkaline and alkaline magma series. δ^{49}Ti values for alkaline plume differentiation suites range from +0.005 ± 0.028‰ to +2.315 ± 0.032‰ and -0.010 ± 0.030‰ to +0.640 ± 0.022‰ for arc settings. Evolved lavas from plume settings display significantly heavier δ^{49}Ti values compared to arc lavas of similar silica contents despite both having comparable fractions of Ti left remaining in the melt (fTi). Calc-alkaline arcs also display a slight enrichment in heavy δ^{49}Ti relative to tholeiitic arc suites. The larger magnitude of Ti isotope fractionation in plume settings could potentially be related to the preponderance of ilmenite over titanomagnetite in the crystallising assemblages of plume lavas compared to arc lavas. Such difference would hint towards the Ti isotope fractionation factor between ilmenite and melt being larger than that between titanomagnetite and melt which could explain the enrichment in heavy δ^{49}Ti in plumes relative to arcs at low fTi. Further work will be aimed at determining isotopic fractionation factors of Ti between silicate melts and Fe-Ti oxides using both natural and experimental samples to examine the varying control of titanomagnetite vs. ilmenite during magma evolution.

[1] Millet M.-A. and Dauphas N. (2014) JAAS 29(8):1444-1458. [2] Millet M.-A. et al. (2016) EPSL449:197-205. [3] Farges F. et al. (1996) GCA 60(16): 3023-3038.