Tungsten isotopic compositions of Ethiopian and Aden Bay basalts and the Samoan ocean island: implications for core-mantle interaction in their source

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Tungsten has five stable isotopes, which have masses of 180, 182, 183, 184, and 186. Tungsten-182 is produced by β-decay of the extinct nuclide ^{182}Hf, which has a relatively short half-life of 8.9 million years (Vockenhuber *et al.* 2004). Because the abundance of ^{182}Hf is low, the expected variation of ^{182}W in natural samples is extremely small. The ^{182}W/^{184}W isotope ratio is, therefore, commonly shown as m^{182}W in parts per million (ppm) relative to the value for a standard: μ^{182}W (ppm) = (^{182}W/^{184}W$_{sample}$/^{182}W/^{184}W$_{standard}$ −1) ×10^{6}.

Hafnium is a lithophile and W is a siderophile; therefore, during segregation of the Earth's core, Hf remained in the silicate phase and W preferentially partitioned to the metal phase. It is expected that such Hf-W fractionation occurred prior to the extinction of ^{182}Hf on the early Earth and in lunar and meteorite bodies. Various investigators have reported positive and negative anomalies in μ^{182}W values relative to the present-day mantle value (μ^{182}W = 0) in terrestrial rocks. Most ancient rocks older than 2.5 Ga generally show relatively uniform μ^{182}W values of +10 to +15 (Willbold *et al.* 2011, Touboul *et al.* 2012, Touboul *et al.* 2014, Willbold *et al.* 2015, Liu *et al.* 2016, Rizo *et al.* 2016, Dale *et al.* 2017, Mundl *et al.* 2018, Puchtel *et al.* 2018, Reimink *et al.* 2018, Tusch *et al.* 2019). Some komatiites such as Schapenburg and Komati have negative μ^{182}W value and μ^{182}W that is unresolved from modern value, respectively (Touboul *et al.* 2012, Puchtel *et al.* 2018). On the other hand, certain ocean island basalts have negative μ^{182}W values (−25 to 0; *e.g.*, Mundl *et al.* 2017, Mundl-Petermeier *et al.* 2019, Rizo *et al.* 2019, Mundl-Petermeier *et al.* 2020).

In this study, we obtained the highly precise W isotope data for the Ethiopian and Samoan basalts to discuss core-mantle interaction beneath these locations. To identify the small variations in the μ^{182}W values of natural samples, an extremely precise method is required. Recent improvements in our techniques for analysis of W isotopes, including both the chemical procedures used for sample treatment and the mass spectrometric methods (Takamasa et al., under review), may facilitate the detection of small variations in W isotope ratios. We obtained accurate μ^{182}W for a basalt reference material (JB-2). Analysis of the Loihi basalt, which has a high ^{3}He/^{4}He ratio (35Ra), yielded a μ^{182}W value lower than the present-day mantle value, which is consistent with the results of previous study and demonstrate the reliability of the method we developed.

We applied our analytical technique for Samoan basalts. Though Mundl et al. (2017) mentioned that the W and He isotope data are also located on the line produced by the Hawaiian basalts, our data possess a different correlation curve from the Hawaiian one. It indicates that the isotopic signatures of the source of the Samoan in the deep mantle are different from those of the Hawaiian one or that the He and W fractionation occurs in the source regions, probably the core-mantle boundary. Tanaka (2002) reported

the existence of Ultra Low Velocity Zone (ULVZ) at the lowermost mantle beneath Samoa and unordinary scatter in the lower mantle beneath the Samoan islands, which implies the ascent of lowermost mantle to the surface.

We also analyzed the W isotope of the Ethiopian basalts and the Aden Bay mid-ocean ridge basalts and found the small negative μ^{182}W for them. Similar to the Hawaiian and Samoan basalts, Afar plume, the source of the Ethiopian basalts, which also affects the Aden Bay basalts are likely to be derived from the core-mantle boundary and may contain the core material with the negative μ^{182}W.

Keywords: core-mantle interaction, 182W/184W isotope, Ethiopian basalt, Samoan basalt, Hf-W decay system, He isotope

