

The geochemical behavior of thallium in mantle-derived basalts

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This project aimed to investigate the how the element thallium (Tl) is partitioned in the mantle. Because Tl has the same ionic size and charge as the alkali metals potassium, rubidium and cesium, it has been hypothesized that it would follow these elements. This hypothesis was supported by the strong co-variation between Tl and the alkali metals in the continental crust.

We developed a new high-precision laser ablation mass spectrometry method that enables analysis of very low Tl concentrations in primitive mantle derived basalts. We used the method to determine Tl and many other element concentrations in more than 100 mid ocean ridge basalts.

Contrary to previous hypotheses, we discovered that Tl has a constant ratio to the element cerium (not cesium!) in the mantle. This finding can only be explained if Tl is almost exclusively controlled by the minor mineral sulfide during mantle melting. Thallium is therefore classified as a chalcophile (sulfur-loving) element in the mantle, whereas it is lithophile (silicate-loving) in the continental crust.

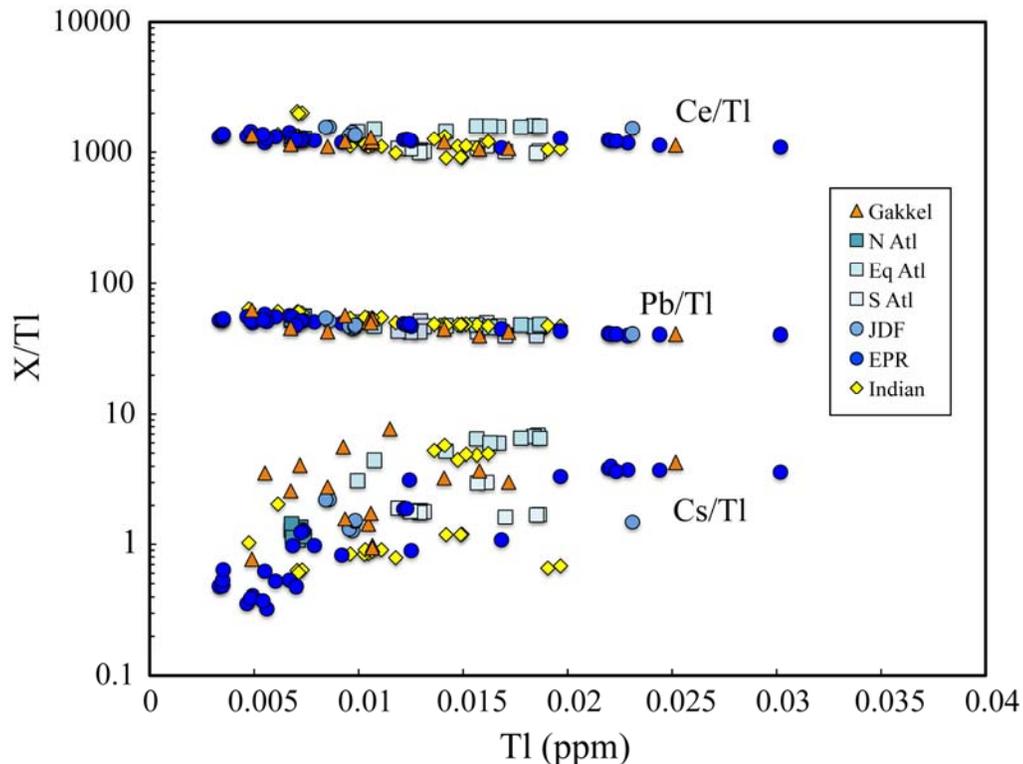


Figure 1: Cerium, lead and cesium ratioed to thallium versus Tl concentration.

Symbols are grouped by geographical region. Circles signify samples from the Pacific Ocean, where dark blue represents the East Pacific Rise (EPR) and light blue the Juan de Fuca Ridge (JDF). Squares signify samples from the Atlantic Ocean, beige is South Atlantic (S Atl), pale blue is Equatorial Atlantic (Eq Atl) and turquoise is North Atlantic (N Atl). Triangles signify samples from the Arctic Ocean (Gakkel). Diamonds signify samples from the Indian Ocean (Indian).

We have used the relationship between cerium and thallium to calculate how much sulfur is present in the mantle. We find that there is 195 ± 25 $\mu\text{g/g}$ of sulfur in the mantle. Our result represents the first globally robust determination of the sulfur abundance in the mantle.

The sulfur content of the mantle is important because it exists almost exclusively as sulfide in the mantle. Although this mineral represents less than 0.1% by volume of the mantle, it accounts for almost the entire budget of economically important ore forming elements such as silver, copper and the platinum group elements. In order to understand transfer of these elements between the mantle and the crust (where we are able to mine them) we, therefore, need to know how much sulfide the mantle contains. Our research has therefore provided a new benchmark value that will aid future studies of chalcophile elements in the mantle.

The study of Tl in mantle rocks is part of a larger project to investigate recycling of crustal material into the mantle at subduction zones and how this process has impacted the composition of the mantle today and in the past. The results from this study can be used to frame new questions on how material is transported from the Earth's surface to the deep mantle and it is planned that PI Nielsen will write two proposals to NSF in the coming year to obtain support for these new investigations.

Results from this study have been published in the journal *Geostandards and Geoanalytical Research* (Nielsen and Lee, 2013) and a second manuscript will shortly be submitted to *Earth and Planetary Science Letters* (Nielsen et al., 2013).

References:

- Nielsen, S.G., Lee, C.T.A., 2013. Determination of thallium in the USGS glass reference materials BIR-1G, BHVO-2G and BCR-2G and application to quantitative Tl concentrations by LA-ICP-MS. *Geostand. Geoanal. Res.* 37, 337-343.
- Nielsen, S.G., Shimizu, N., Lee, C.T.A., Behn, M., 2013. The sulfur abundance of the upper mantle constrained by trace element ratios. *Earth Planet. Sci. Lett.* submitted.