The sulfur abundance of the mantle deduced from trace element ratios

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Mantle sulfides play a key role in constraining fluxes of chalcophile elements to the Earth's surface and strongly influence the U/Pb and Re/Os radiogenic isotope tracers during mantle melting. The sulfur content of the mantle, however, is difficult to determine owing to its scarce abundance and difficulty in establishing its behavior during Earth accretion and subsequent core formation. Previous studies have therefore relied mostly on sulfide and/or chalcophile element abundances in exhumed mantle samples or S content of mantle melts.

We present trace element concentration data for 97 mid ocean ridge basalt (MORB) glasses that cover all major spreading centers. Our data reveal that the ratio between the elements thallium (Tl) and cerium (Ce) is nearly constant in MORB, providing strong evidence that the depleted MORB mantle (DMM) has essentially uniform Ce/Tl. We argue that Tl and Ce are controlled by residual sulfide and clinopyroxene, respectively, during mantle melting due to their highly differrent ionic charges and radii.

We have performed models of fractional mantle melting, which reveal that the tight relationship between Ce and Tl in MORB is only reproduced if the ratio between clinopyroxene and sulfide in the upper mantle varies by less than 10%. In addition, the rate of melting for these two phases must be nearly identical as otherwise melt depletion and refertilization processes would lead to Ce/Tl fractionation.

These model results allow us to establish the relationship $[S]_{DMM} = SCSS \times M_{cpx} / R_{cpx}$, where SCSS is the sulfur concentration of a silicate melt at sulfide saturation, R_{cpx} is the melt reaction coefficient that determines the rate at which clinopyroxene is removed during melting and M_{cpx} is the modal abundance of clinopyroxene in the DMM. Using this equation, we calculate that the average upper mantle sulfur concentration is 195 ± 25 μg/g.