Thallium isotopic variability within sulfides and K-bearing silicates

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Thallium has only two isotopes, ^{203}Tl and ^{205}Tl. Considering the small relative mass difference (<1%), fractionation might not be expected. However, with two valences possible and anticipated bonding disparities between sulfides and silicates, Tl isotope fractionation between coexisting minerals may in fact be non-trivial. Indeed, terrestrial samples have revealed an overall variability of more than 3‰, equivalent to 30ε, with some of the largest fractionations seen in hydrothermal environments. Despite these data, the specifics of thallium geochemical variability and isotope systematics are essentially unexplored at present. This study presents new Tl concentration and isotope composition data between coexisting minerals from a variety of igneous and hydrothermal systems to better understand the partitioning of Tl between mineral phases at a range of scales.

A suite of rocks from various hydrothermal and ore-forming settings were examined, encompassing a variety of geologic environments and global localities. These include epithermal gold, pegmatites, and granites, among others. Coexisting minerals from samples were analyzed, focusing on K^+-bearing phases such as micas and feldspar, and sulfides such as pyrite, chalcopyrite, and pyrrhotite. Over 150 minerals were analyzed for Tl concentrations, and from those, so far, over 75 have been analyzed for Tl isotopes. Solution Tl concentration and isotopic data from pure Tl fractions obtained by anion-exchange chromatography were collected on a Micromass Isoprobe MC-ICP-MS. A typical crustal whole rock Tl concentration averages 0.7 ppm; samples here display Tl concentrations that vary by more than three orders of magnitude, from 0.2 ppm to nearly 200 ppm, with up to 5x enrichment in mica versus coexisting K-feldspar.

Additionally, isotopic values from this study vary significantly, with greater than 10ε variability. ε^{205}Tl ranges from -7.8 to +5.1, a significant deviation from the value of ε^{205}Tl = -2.1 ± 0.3 reported for average continental crust. Preliminary evidence suggests Tl variability is primarily governed by the partitioning of Tl^+ into K^+-bearing phases, with limited chalcophile behavior at low sulfidation states. This discernable fractionation (> 4ε^{205}Tl) between coexisting minerals demonstrates the complex geochemical behavior of Tl within a variety of geologic settings at multiple scales.