

The behavior of Th in REE-bearing hydrothermal fluids

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Rare Earth Element (REE) mineralization is frequently associated with Th due to its tendency to substitute into REE-bearing minerals. Owing to its inherent radioactivity, the presence of Th in REE deposits is one of the main factors influencing their economic feasibility. Consequently, in developing geochemical models that predict the enrichment of the REE, understanding the physicochemical conditions that lead to the depletion of Th is also a requirement.

Hydrothermal fluids are widely accepted to play a major role in mobilizing and concentrating the REE to ore quantities. The mobilization of Th in hydrothermal fluids, however, has been essentially unknown owing to the lack of thermodynamic data for Th speciation at elevated temperatures. Moreover, conventional wisdom dictates that Th-bearing phases are insoluble, and Th is often assumed to be an immobile component in natural aqueous systems. Paradoxically, the occurrence of REE hydrothermal deposits with high concentrations of Th challenges this paradigm and strongly suggests the possibility of aqueous mobilization under certain conditions.

In this study, we demonstrate experimentally that Th can, indeed, become extremely soluble at the moderate temperatures of 175-250°C in sulfate-bearing aqueous fluids (0.05-0.5m Na₂SO₄) owing to the formation of the highly stable Th(SO₄)₂ complex. The incorporation of thermodynamic data derived for this complex into existing REE hydrothermal models [1] demonstrates that the mobilization and near complete removal of Th from a REE ore can be achieved through successive flushing of sulfate-bearing hydrothermal fluids. The simulation suggests that as a guideline for an exploration strategy for Th-depleted REE ore deposits, in choosing among potentially REE-rich targets, preference should be given to targets for which there is evidence of intensive, pervasive alteration of sulfate-rich fluids, required for the removal of Th.

[1] Migdisov et al. (2019) *J. Chem. Thermodyn.* **128**, 305–319.