

# Metal mobility of critical elements and redox controls in magmatic-hydrothermal systems

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Critical minerals are essential elements for society, and with advancing technologies the need for different commodities ever evolves creating a highly dynamic environment, where new technologies drive the surge for finding more resources and control global markets. In natural systems, critical elements are commonly enriched in magmatic-hydrothermal systems where hydrothermal fluids generally play a crucial role in concentrating critical elements. Our capability to predict their mobility in hydrothermal fluids is limited by the availability of thermodynamic data for individual aqueous and/or gaseous species, in particular, at elevated temperature and pressure relevant to ore genesis. The role of water as a solvent is key to understanding metal transport in aqueous fluids, which can be decompressed from a liquid-like to a vapor-like fluid density above the critical temperature and pressure without crossing phase boundaries. The region of supercritical fluids further elevates current challenges in predicting and understanding metal transport in magmatic-hydrothermal systems, highlighting the need for new equations of state and thermodynamic models. Here, we present new experimental data from metal solubility and spectroscopic Raman studies of Te in low-density and supercritical fluids and Nd and Dy in supercritical fluids. Experimentally derived thermodynamic data [1-3] are implemented into the GEM-Selektor [4] code package and combined with the MINES thermodynamic database [5] for simulating natural processes. Simulations using the hydration model [1] indicate that metal mobility in vapor-like and intermediate-density fluids strongly depends on pressure and temperature. As a result, these fluids can deposit large amounts of metals without undergoing phase separation upon decompression. The efficiency of mineral precipitation from low and intermediate-density fluids therefore diverges from that of liquid-like fluids, for which cooling and/or fluid-rock reaction (pH) is driving mechanism for mineral precipitation. This work is supported by the U.S. Department of Energy under Award DE-SC0022269.

[1] Hurtig et al. (2021) *Econ. Geol.* 116(7), p. 1599-1624.

[2] Hurtig et al. (2024) *Econ. Geol.*, in press.

[3] Adams (2023), MSc thesis, NMT.

[4] Kulik et al. (2013), *Comput. Geosci.* 17, 1-24.

[5] Gysi et al. (2023), <https://doi.org/10.58799/mines-tdb>.