

SEG 100 Conference: Celebrating a Century of Discovery

ST.167

Ore-Forming Processes in Critical Mineral Deposits: Can We Link Hydrothermal Experiments to Exploration in the Field?

Alexander P. Gysi^{1, 2}

1. New Mexico Bureau of Geology and Mineral Resources, New Mexico Tech, Socorro, NM, USA, 2. Department of Earth and Environmental Science, New Mexico Tech, Socorro, NM, USA

Rare earth elements (REEs) mineral deposits are commonly found in carbonatite and (per)alkaline igneous systems (e.g., Bayan Obo in China and Strange Lake in Canada) where REE transport, partitioning, and deposition occurs via a complex interplay between magmatic and hydrothermal processes. Field observations yield important clues about the mineralogy and geochemistry of these deposits, but our understanding of the relationships between ore-forming processes and alteration zones is still quite rudimentary in comparison to porphyry deposits. The hydrothermal fluids are characterized by an enrichment in alkalis and are commonly more F rich and S poor, with Cl^- , F^- , CO_3^{2-} , and/or SO_4^{2-} as the dominant ligands controlling REE mobility. Fluid-rock interaction associated to the formation of REE deposits results in the observed exotic alteration styles such as fenitization (alkali metasomatism) and Ca-F metasomatism. The deposition of REEs is also controlled by hydrothermal carbonate, fluoride, and phosphate minerals (e.g., monazite-(Ce) and bastnäsite-(Ce)), which can form in a wide temperature range. Many questions remain, however, unresolved, which makes it difficult to interpret geochemical data sets of these ore deposits: What fluid types control the transport of REEs in different deposits? Are these fluids acidic/alkaline? Why do we find deposits enriched in either light/heavy REEs? How can hydrothermal fluids mobilize, fractionate, and further concentrate the REEs?

The complex behavior of the REEs can be captured via well-constrained hydrothermal laboratory experiments. For this purpose, a new Ore Deposits and Critical Minerals Research Laboratory was established at the New Mexico Bureau of Geology and Mineral Resources. Solubility data generated from our experimental laboratory are implemented in the MINES thermodynamic database (<https://geoinfo.nmt.edu/mines-tdb/>) and permit predicting fluid-rock interaction scenarios at depth as a function of pressure, temperature, and fluid compositions. These modeling predictions can be linked to field observations at various scales, particularly vein microtextures, alteration styles, and rock/mineral geochemistry. Batch-type experiments indicate that the solubility of synthetic monazite (La to Gd) and xenotime (Y, Tb to Lu) is higher than previously described between 100° and 250°C. Simulations of xenotime solid solutions in a quartz-muscovite vein reproduce the observed chondrite-normalized REE signatures of natural xenotime-(Y). Comparison of the simulations with data compiled from the Pea Ridge IOA-REE deposit in Missouri and from the Bear Lodge carbonatite in Wyoming indicates that both temperature and fluid salinity play a significant role in modifying the REE signatures of xenotime. At high temperature (>250°–300°C), the simulated xenotime solid solutions display a depletion in Er, Tm, Yb, and Lu similar to the Bear Lodge deposit, whereas at lower temperature, xenotime signatures are comparable to the Pea Ridge deposit and are enriched in the heavy REEs. Hydrothermal mixing experiments permit further synthesizing REE-doped calcite, fluorite, and apatite crystals between 100° and 300°C, providing new insight into REE mineral-fluid partitioning. Using these novel approaches, I will show how REE signatures in minerals can now be linked to temperature-dependent alteration styles and bulk-rock geochemistry in carbonatites and alkaline igneous systems with applications to exploration vectoring in critical mineral deposits.