

## **Geochemistry of mineralizing fluids in the T zone, Thor Lake rare-metal deposits, Canada: Implications for hydrothermal HFSE mineralization**

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The T Zone, a rare-metal (Y-REE-Nb-Ta-Zr-Be) mineralized body at Thor Lake, NWT, Canada, is a pegmatite that has experienced a strong hydrothermal overprint. An unusual type of primary fluid inclusion assemblage (FIA) is defined by the distribution of fluid inclusions in HFSE- or Be-mineral-rich pseudomorphs within optically-continuous coarse-grained quartz. These FIAs either define, or are restricted to, the pseudomorphs, and commonly define their boundaries. Primary FIAs also define growth zones in quartz and possible primary inclusions occur in three-dimensional arrays in bastnäsite-(Ce).

All of these FIAs comprise aqueous, liquid-rich inclusions with or without solid phases; CO<sub>2</sub> and CH<sub>4</sub> are present in trace amounts in some FIAs. Inclusions related to zircon precipitation have homogenization temperatures of 100 – 400 °C and salinities of 12 – 24 wt. % NaCl<sub>equiv</sub>, respectively. Cathodoluminescence imaging of quartz in zircon-dominated pseudomorphs indicates that the character of the fluid evolved during development of these pseudomorphs, which is reflected in the temperature and salinity. The fluids responsible for bastnäsite precipitation have homogenization temperatures of 219 – 332 °C and salinities of 4 – 27 wt. % NaCl<sub>equiv</sub>, respectively. The FIAs related to replacement of K-feldspar, and precipitation of xenotime and late phenakite all have low homogenization temperatures ( $\leq 180$  °C) and moderate salinities (mostly 20 – 25 wt. % NaCl<sub>equiv</sub>). Trapping conditions were estimated using microthermometric data, Ti-in-quartz thermometry and quartz-polythionite oxygen isotope thermometry. The trapping conditions (342 – 404 °C and 0.4 – 1.9 kbar) for FIAs defining Ti oxide-dominated pseudomorphs calculated using isochoric projections and TitaniQ geothermometry is consistent with the conditions (360 °C and 0.7 – 1.3 kbar) obtained using isochores and quartz-polythionite oxygen isotope thermometry. Estimated temperatures for Zr mineralization range from ~ 150 °C to 500 °C, whereas REE mineralization (principally bastnäsite) occurred from ~ 250 °C to 400 °C, and temperatures of Be and Y mineralization were < 250 °C. These data illustrates that the hydrothermal modification of the T Zone was not caused by a single fluid event and that the mineralizing fluids in the T Zone had variable character.

Both EDS analysis of evaporate mounds and LA-ICP-MS analysis of individual inclusions show that the mineralizing fluids were dominated by Na and Cl, with lesser K and trace amounts of Ca and S. This suggests that the “fluorite-precipitation” hypothesis proposed for many HFSE deposits is not applicable to the T Zone. Our data demonstrates that significant HFSE were dissolved in the fluids permeating the T Zone. Fluids with temperatures of ~ 150 – 250 °C and salinities of ~ 20 – 25 wt. % NaCl<sub>equiv</sub> contain the highest Ti (2764 ppm), Nb (286 ppm), Zr (55 ppm), Y (263 ppm) and Ce (584 ppm) concentrations. Our results also indicate that Ti, Nb, Zr, Y and LREE, can be quite mobile in relatively low-temperature hydrothermal environments. Unlike analogous HFSE deposits, such as Strange Lake, Ilímaussaq and Tamazeght, precipitation of HFSE minerals in the T Zone resulted from multiple fluid events involving aqueous fluids that were largely devoid of CO<sub>2</sub> and CH<sub>4</sub>.