Replacement Processes Involving HFSE Minerals in the T-Zone, Thor Lake Deposit, NWT

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Summary

This work presents a preliminary textural study of the replacement processes involving HFSE minerals in the T-Zone, Thor Lake rare-metal deposit, NWT. The important HFSE-bearing minerals in the T-Zone include bastnäsite-group minerals, zircon, columbite, and xenotime. Petrographic analysis reveals that many of the HFSE minerals in the T-zone occur in fine-grained pseudomorphs. This indicates that hydrothermal replacement was important in their precipitation. Earlier minerals replaced and pseudomorphed by zircon (together with monazite in some cases) or bastnäsite exhibit a prismatic to rhombic habit, and are hypothesized to be amphiboles. The mineralogical variability and textural characteristics of the pseudomorphs indicates that HFSE were highly mobile and that hydrothermal processes were required for the concentration of these elements.

Introduction

The Thor Lake rare-metal deposit is one of the largest peralkaline pluton-related HFSE mineral deposits in the world, and mainly comprises two mineralized zones, namely the Lake Zone and the T-Zone. The enrichment of heavy rare earth elements (HREE) relative to light rare earth elements makes it distinctive from other HFSE mineral deposits. This study focuses on the T-Zone, which is a zoned mineralized body that shows hydrothermal characteristics, and is aimed at understanding the origin of HFSE minerals in the this magmatic-hydrothermal system and the role that fluids played in HFSE concentration.

Geologic Setting

The Thor Lake rare-element (Y-REE-Nb-Ta-Be-Zr-Ga) deposits are hosted by an assemblage of metasomatically altered peralkaline syenite and granite. The host rocks are the youngest units in the Aphebian Blatchford Lake Intrusive Complex, located about 100 km southeast of Yellowknife, NWT, Canada (Trueman et al., 1984, 1988; Pedersen et al., 2007). The Blatchford Lake igneous complex, interpreted as having formed during the development of the Authapuscow aulacogen, consists of five plutonic phases, which are, from oldest to youngest: Caribou Lake Gabbro, Whiteman Lake Quartz Syenite, Hearne Channel Granite and Mad Lake Granite, Grace Lake Granite and Thor Lake Syenite (Davidson, 1978, 1982). Recently, a nepheline syenite, which was initially identified by gravity modeling (Birkett et al., 1994) and which hosts the Lake Zone, has been delineated by drilling, and has been identified in field outcrops south of Thor Lake (Pedersen, 2009, personal communication).

T-Zone Geology

The T-zone mostly occurs in the Thor Lake syenite, but extends for approximately 1 km into the Grace Lake granite. The T-Zone comprises two spatially separate sub-zones, the North T Zone and South T Zone, each of which is lithologically zoned. These zones comprise, from core to rim, a Quartz Core Zone, Upper Intermediate Zone (UIZ), Lower Intermediate Zone (LIZ), and Wall Zone (Trueman et al., 1984, 1988; Pederson et al., 2007).

The Quartz Core Zone is predominately composed of massive quartz, with local concentrations of polylithionite, carbonates, and bastnäsite-group minerals. The UIZ is characterized by massive quartz, with coarse-grained euhedral polylithionite, albite, and phenakite. Accessory minerals include fluorite, chlorite, carbonates, magnetite, zircon and bastnäsite-group minerals. The LIZ exhibits a gradational contact with the UIZ and contains granite and/or syenite xenoliths in it. The common minerals in the LIZ include quartz, albite, amphibole, biotite, carbonates, and magnetite. Zircon, columbite, fluorite, xenotime, and thorite are present in accessory amounts. The Wall Zone is strongly albitized and composed of coarse-grained K-feldspar, radiating albite (cleavelandite) and massive quartz, with fluorite, magnetite, biotite and columbite in accessory amounts. Locally, pegmatitic textures are preserved in the Wall Zone.

Reserve estimates indicate 0.46 million tonnes grading 11.1% BeO, 0.17% Y_2O_3, 0.28% REO, 0.58% Nb_2O_5 and 0.05 million tonnes grading 0.28% REO in the North T Zone; and 1.13 million tonnes grading 0.62% BeO, 0.1% Y_2O_3, 0.2% REO and 0.46% Nb_2O_5 in the South T Zone (Trueman et al., 1988; Sinclair et al., 1992).

HFSE Minerals in the T-Zone

The important HFSE-bearing minerals in the T-Zone include bastnäsite-group minerals, zircon, columbite, and xenotime. These minerals are invariably fine-grained and generally occur as a replacement of earlier minerals, including as pseudomorphs. Key textural characteristics are as follows:

Bastnäsite-group minerals (bastnäsite, synchysite, parisite) commonly occur with fluorite and quartz in the UIZ, and generally replace and pseudomorph earlier minerals, including polylithionite, and an unknown mineral with a rhombic habit (Fig. 1).

Zircon occurs in significant quantities (up to ~10%), and can broadly be classified into two textural types: (1) isolated euhedral crystals in fluorite or massive quartz and (2) aggregates that define pseudomorphs. Zircon of the first type is distributed in both the UIZ and LIZ and exhibits distinct growth zonation. Zircon of the second type is mostly present in the UIZ and occurs as aggregates of fine grained, subhedral to euhedral crystals that have partially pseudomorphed earlier euhedral minerals that had a prismatic to rhombic habit. These zircon crystals also commonly display well defined growth zonation. Such pseudomorphs are normally located in a quartz matrix (Fig. 1). Monazite occurs in some zircon pseudomorphs. In these pseudomorphs, the zircon-monazite aggregates are mainly concentrated at the margins of the pseudomorphs (Fig. 2). This indicates that reaction between fluids and the original mineral was important for the precipitation of monazite and zircon. In the UIZ, textural relationships also indicate that zircon postdates polylithionite. Moreover, zircon-bearing pseudomorphs are also observed in the host granite.

Columbite occurs in the Wall Zone, LIZ and UIZ as: (1) fine-grained euhedral to subhedral single crystals and (2) anhedral crystals in fractures or pores in zircon crystals or interstitial to zircon (Fig. 3). Bastnäsite-group minerals occur in fractures in columbite grains (Type 1). Xenotime occurs in the LIZ either as fine-grained aggregates with thorite and hematite in a quartz matrix, or as intergrowths with isolated zircon crystals (Type 1 above).

Beryllium mineralization mainly occurs in the UIZ. The principle Be-bearing mineral is phenakite, which is paragenetically late and generally replaces quartz.

Conclusions

Many of the HFSE minerals in the T-zone occur in fine-grained pseudomorphs (e.g., Fig. 1), indicating that hydrothermal replacement was very important in their precipitation. In addition, some textures (Fig. 1b) suggest open-space precipitation and therefore dissolution of the earlier mineral. Within the T-zone, the original mineral has been completely replaced and is unidentified. However, interfacial angles ranging from 109 to 148 degrees (mean of 131 degrees), along with the prismatic to rhombic habit of the pseudomorphs, are consistent with replacement of an amphibole. This is supported by the observed replacement of arfvedsonite by fluorite and zircon in the UIZ. The mineralogical variability and textural characteristics of the pseudomorphs indicates that HFSE were highly mobile and that hydrothermal processes were required for the concentration of these elements.

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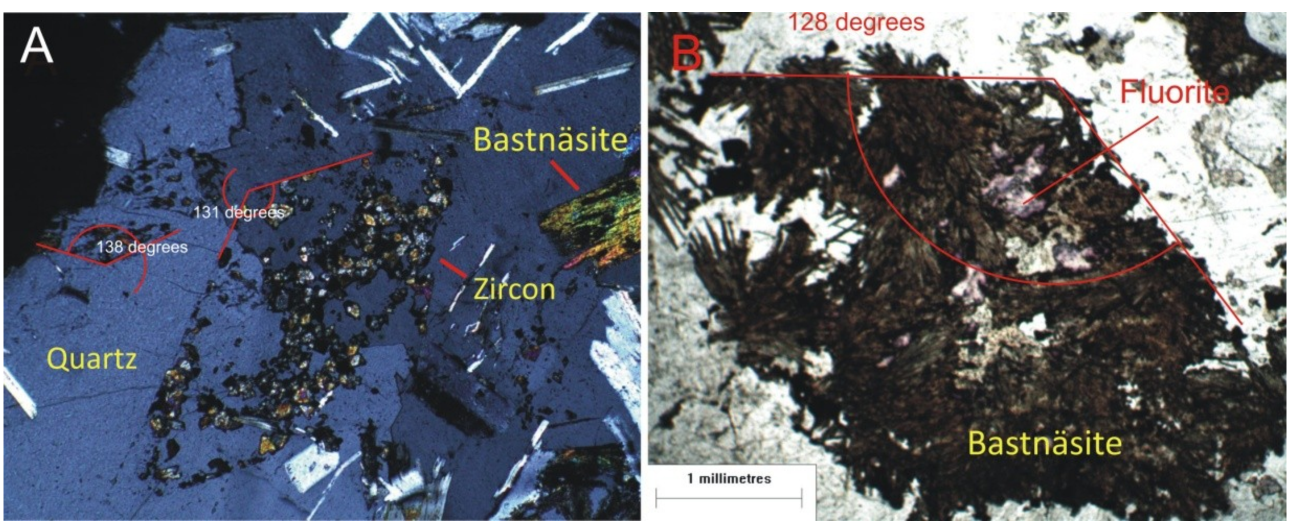

Fig. 1 Photomicrographs of zircon-bearing pseudomorphs and a bastnäsite-bearing pseudomorph in a quartz matrix in the UIZ. Note the radiating bastnäsite aggregate rooted on the pseudomorph wall in (B), suggesting open space precipitation.

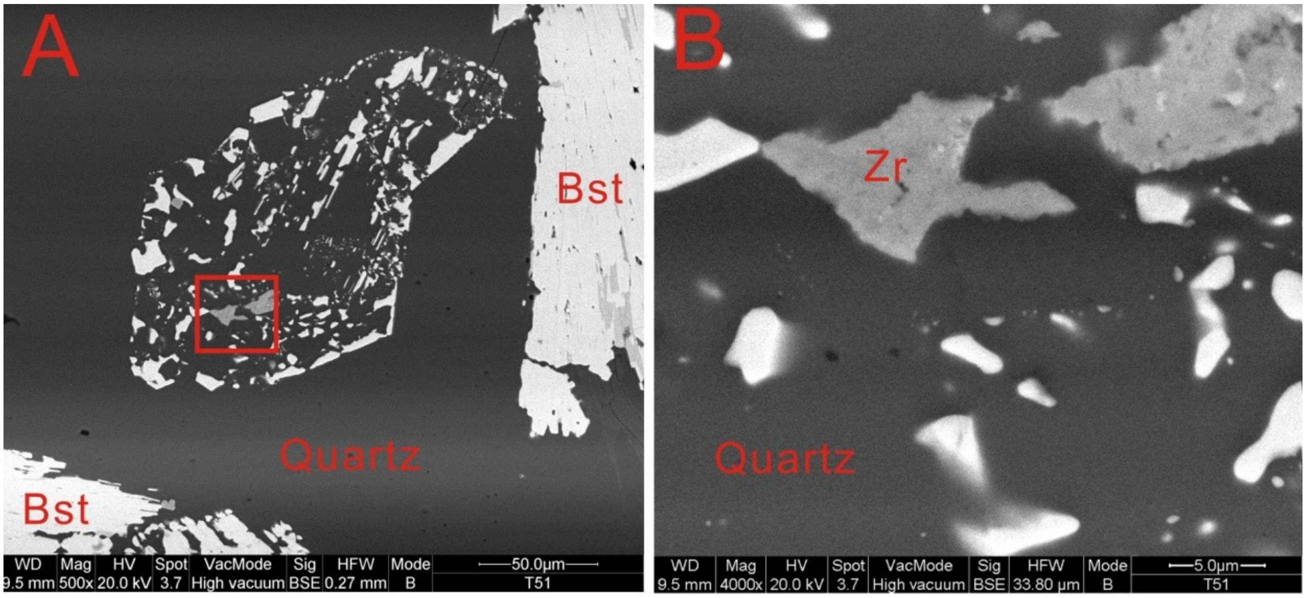

Fig.2 Backscatter electron images of a zircon-monazite-bearing pseudomorph in a quartz matrix. (B) is an enlarged image of the area marked by the red square in (A). The grey minerals and bright minerals in (B) are zircon and monazite, respectively. Bst-bastnäsite, and Zr-zircon.

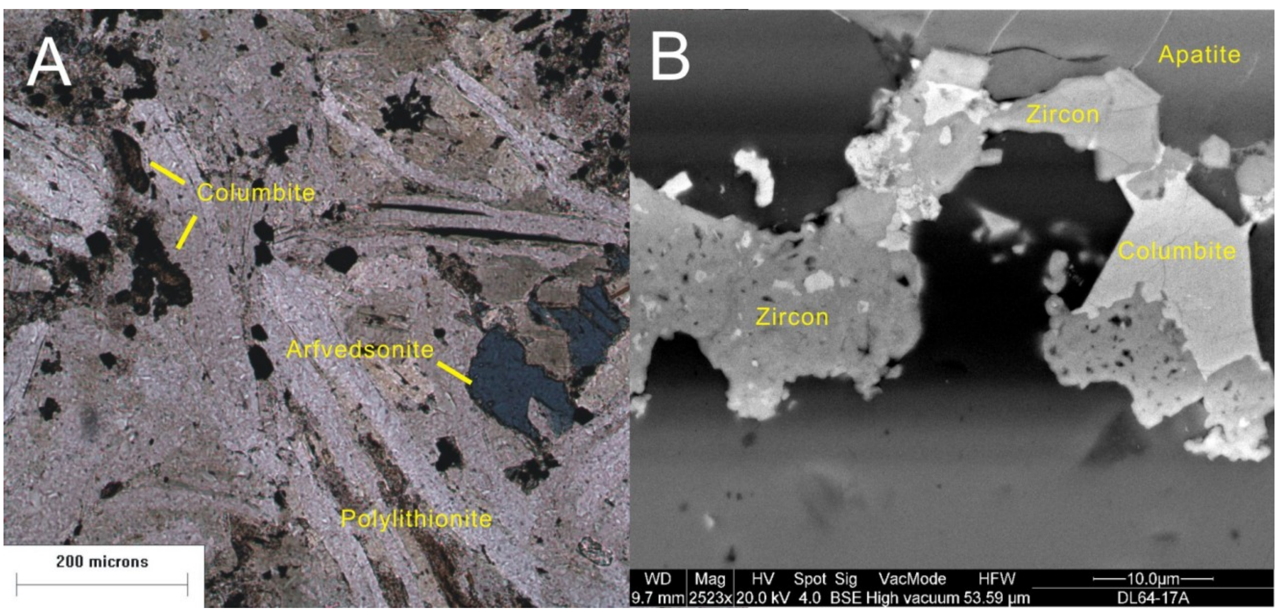

Fig. 3 (A) Photomicrograph of medium-grained subhedral columbite in a mineral assemblage of polylithionite + arfvedsonite + columbite. (B) BSE image of zircon and columbite illustrating that columbite postdates zircon. Bright minerals in the image are columbite.