Mineralogical and Geochemical Characteristics of Porphyry-Fertile Plutons: Guichon Creek, Takomkane and Granite Mountain Batholiths, South-Central British Columbia: Evidence From Apatite

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Introduction

The fundamental relationship of porphyry Cu (Au, Mo) deposits with bodies of intrusive rocks is well established (e.g., Sillitoe, 1973), but distinguishing metal-fertile from barren plutons remains a significant challenge for exploration. Information that contributes such a priori knowledge provides guidance early in the exploration process to make decisions more effectively and efficiently on focusing exploration resources on more prospective targets. This research project, therefore, provides tools and strategies that emphasize porphyry fertility in the British Columbia context.

The characterization of fertility features is of particular importance for BC porphyry exploration. In BC, many porphyry systems occur within or around the edges of large batholiths. These combined features make BC an exceptional locality to test and utilize such porphyry fertility indicators.

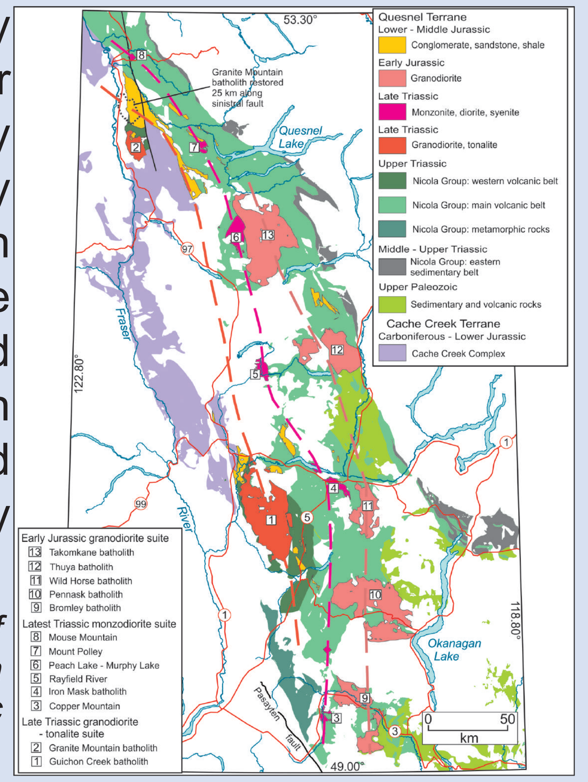

Figure 1: Simplified geology map of south-central British Columbia showing location of major plutonic bodies (from Schiarriza, 2014)

Objectives

This project identifies field, mineralogical and geochemical characteristics of known porphyry-fertile plutons and develops exploration tools for the subsequent identification of new fertile plutonic terrains of British Columbia. Physical and chemical features in common accessory minerals, e.g., apatite, titanite, zircon, that show evidence of magmatic processes favourable for generating porphyry copper deposits will be characterized:

- Determine the mineralogical features of accessory minerals that characterize and distinguish porphyry fertile intrusions.
- Document fertility evidence over time and space in an evolving composite zoned pluton.
- Assess the utilization of rapid mineralogical characterization tools.
- Construct a toolkit to provide a predictive decision-making framework to assess fertility in rocks, stream sediment and till heavy mineral concentrates.

Porphyry Deposits and Fertile Plutons

Porphyry deposits are commonly associated with batholiths composed of several plutonic bodies. However, specific pluton phases are linked to porphyry mineralization (Figure 2). The fertility of these plutons depends on the composition of the parental magma and its evolution. These are influenced by features or processes such as oxidation state, fractionation, magma mixing, and the amount and saturation of water, metal, chlorine and sulphur. These features are variably recorded in crystallizing fertility indicator minerals of the parent pluton commonly as characteristics such as zoning or chemical composition.

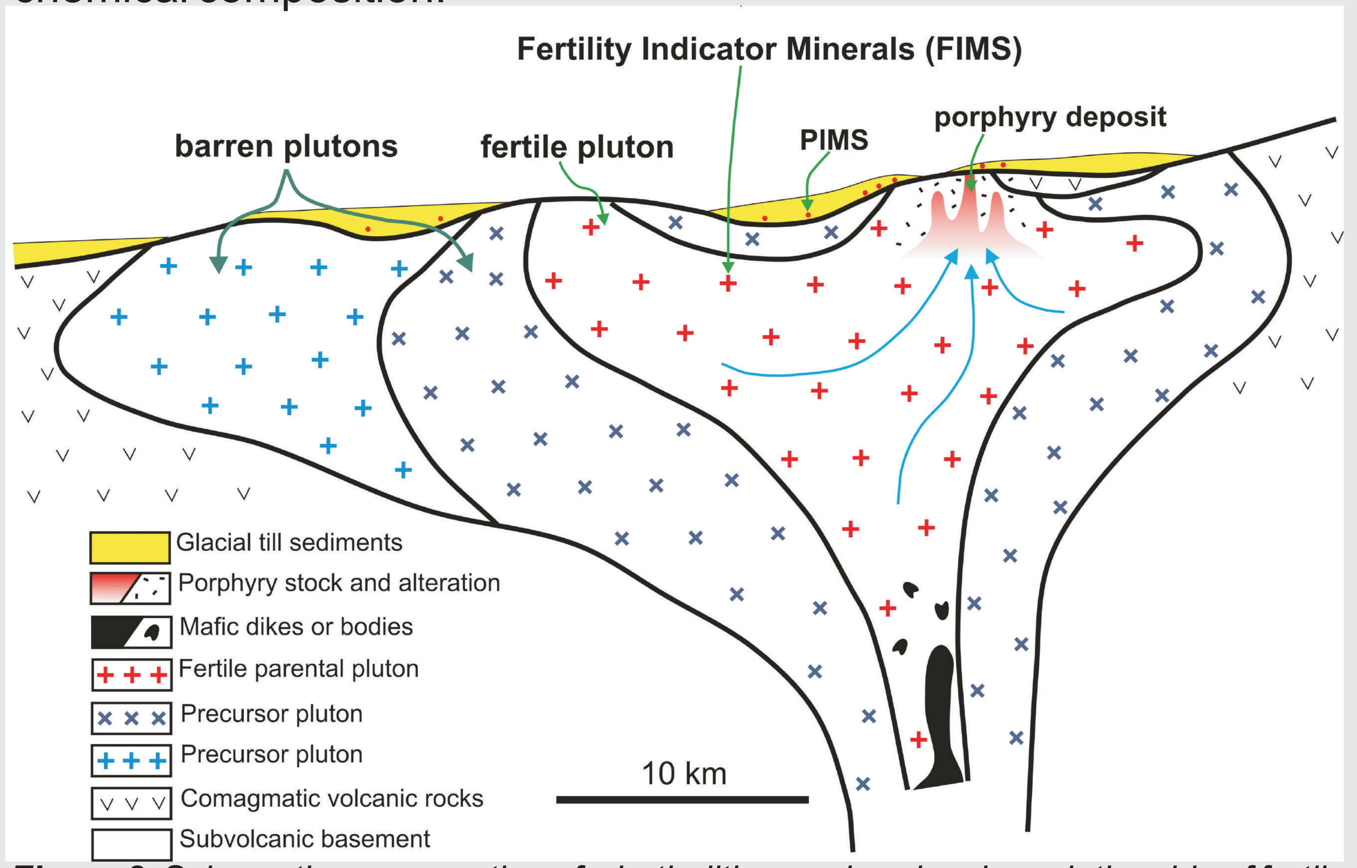

Figure 2: Schematic cross-section of a batholith complex showing relationship of fertile pluton and porphyry deposits.

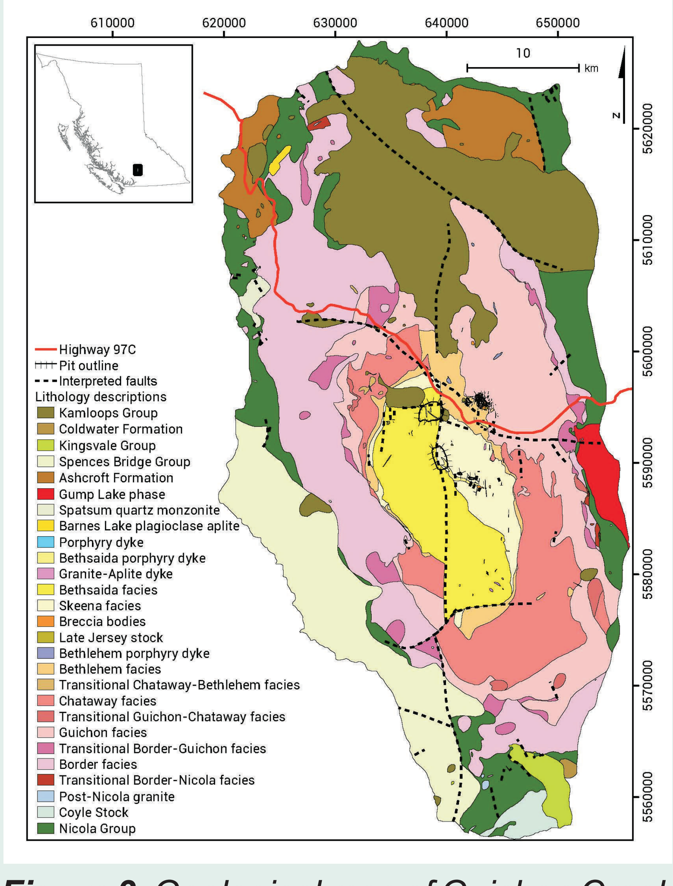

Figure 3: Geological map of Guichon Creek batholith (from McMillan et al., 2009)

Methods

Field and laboratory work are focused on various intrusive bodies of three well-documented batholiths, the Guichon Creek, Takomkane, and the Granite Mountain batholith, located in BC.

Laboratory techniques include petrography, cathodoluminescence, SEM and ICP-MS.

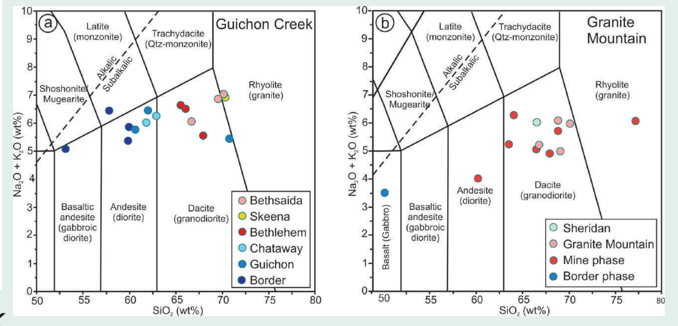

Figure 4: TAS composition of host-rocks

Apatite Textural Fertility Characteristics

Apatite petrography was studied using a cathodoluminescence (CL) microscope. Apatite grains display brown, pale brown, brownish-green and yellow luminescence.

- The brown luminescence is more common in the Granite Mountain and Takomkane batholiths and mafic phases of the Guichon Creek batholith.
- Yellow luminescence is common in the felsic Bethsaida phase of the Guichon Creek batholith.
- Apatite grains with yellow luminescence have higher (>0.2%) MnO concentrations.
- Apatite grains with brown luminescence have lower Mn concentration (<0.2% MnO).
- Apatite texture varies from uniform to zoned. The zoned apatite grains have a brownish CL core surrounded by a less brownish to yellow-green CL rim, and locally multiple zones occur.

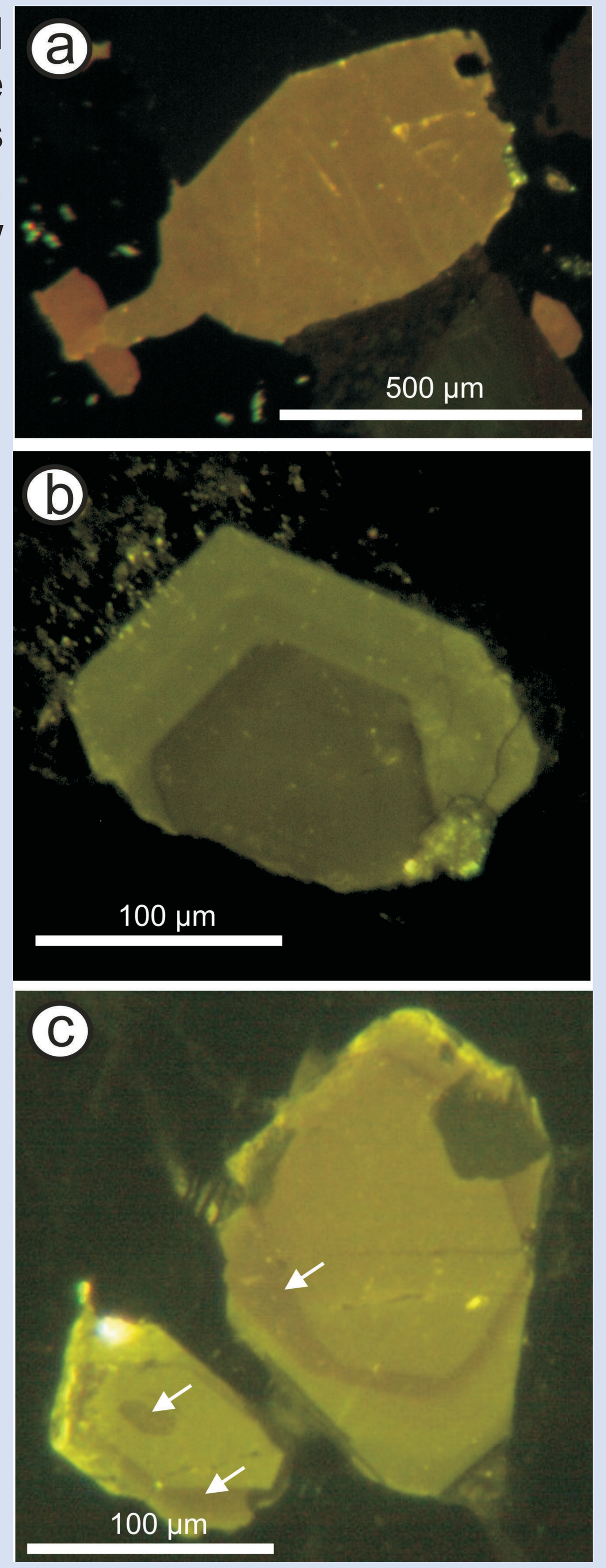

*Figure 5: Cathodoluminescence image of apatite grains: **a)** large apatite grains from the Woodjam Creek unit of the Takomkane batholith with pale brown luminescence; **b)** zoned apatite grain from the Bethsaida phase with brown luminescence at the core and pale brown-green luminescence at the rim; **c)** apatite grains in Bethlehem granodiorite with a light brown core, a distinct dark brown zone and a more green-brown CL at the rim.*

Apatite Chemical Fertility Characteristics

Chemical analysis of apatite grains by electron microprobe analysis shows distinct variations between mineralized and barren phases of the batholiths.

- At the Guichon Creek batholith, the Bethsaida phase, main host to the Highland Valley porphyry deposits, has less Cl and S relative to the Chataway phase. The Cl concentration of apatite in both phases is significantly less than Cl concentrations in the Border phase apatite.
- The mineralized Woodjam Creek unit of the Takomkane batholith and the Mine phase of the Granite Mountain batholith have lower Cl and S concentrations than the unmineralized phases of the batholiths.
- The zoned apatite grains show a similar trend for Cl and S. The core of apatite with the more brownish CL colour has higher concentrations of Cl and S relative to the less brownish luminescence at the rim.

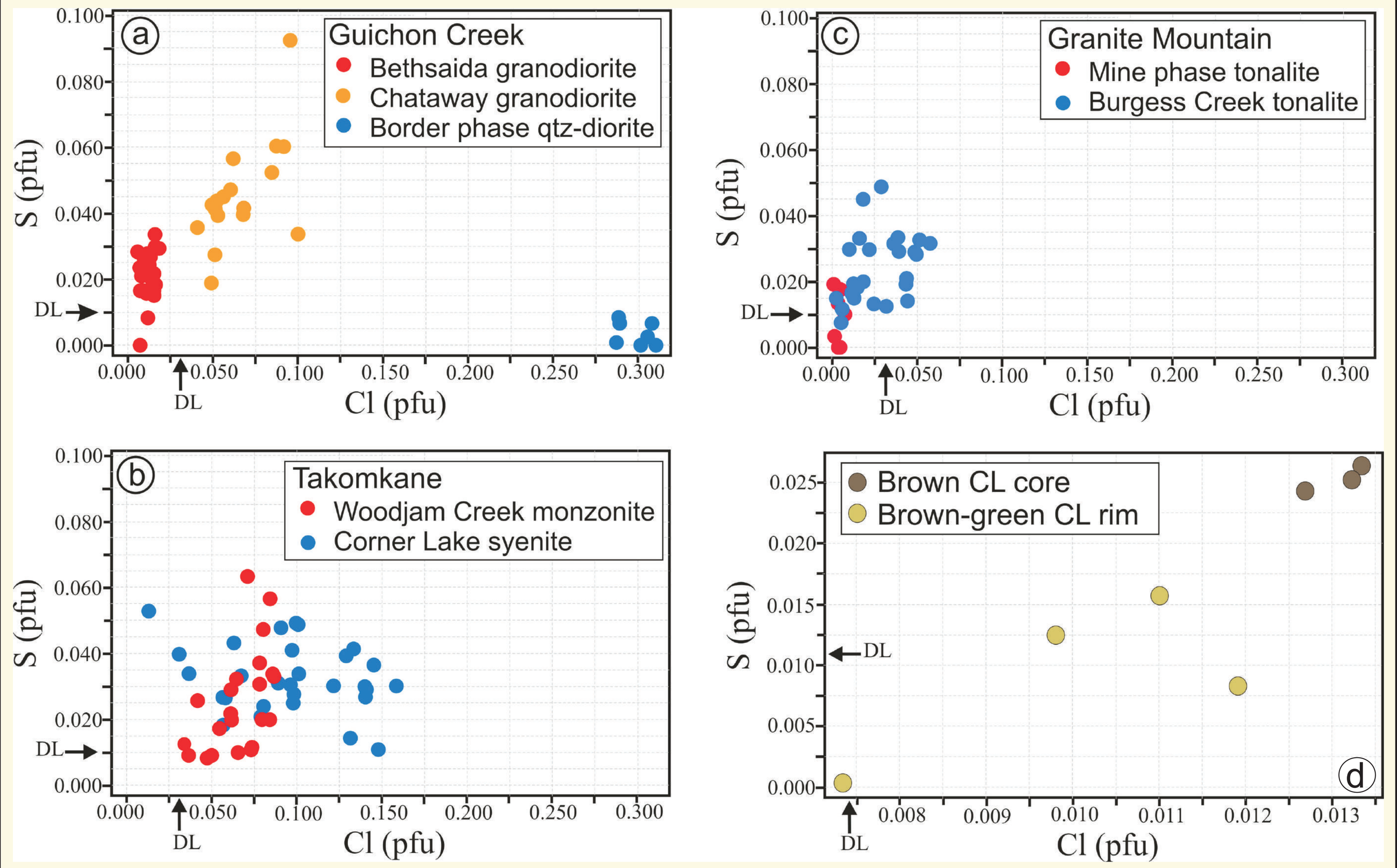

Figure 7: Apatite composition of various pluton phases (a, b, c) and single apatite grain (d).

Conclusions and Further Work

These preliminary results suggest that both geochemical and mineralogical characteristics of plutons can be used to distinguish fertile phases.

- Porphyry-fertile plutons commonly display depleted HREE without significant negative Eu anomalies, consistent with hornblende and garnet fractionation, which is favoured by high magmatic water content and oxidation state.
- Porphyry-fertile plutons host apatite, which become progressively depleted in Cl and S. Chlorine and sulphur were probably consumed during the orthomagmatic processes which could potentially generate hydrothermal fluids rich in chlorine, sulphur and copper, capable of producing porphyry copper ores.
- Compositional and CL zoning in apatite suggest that the parent magma was periodically fertilized.

Further geochemical and mineralogical studies on a complete suite of samples are underway.

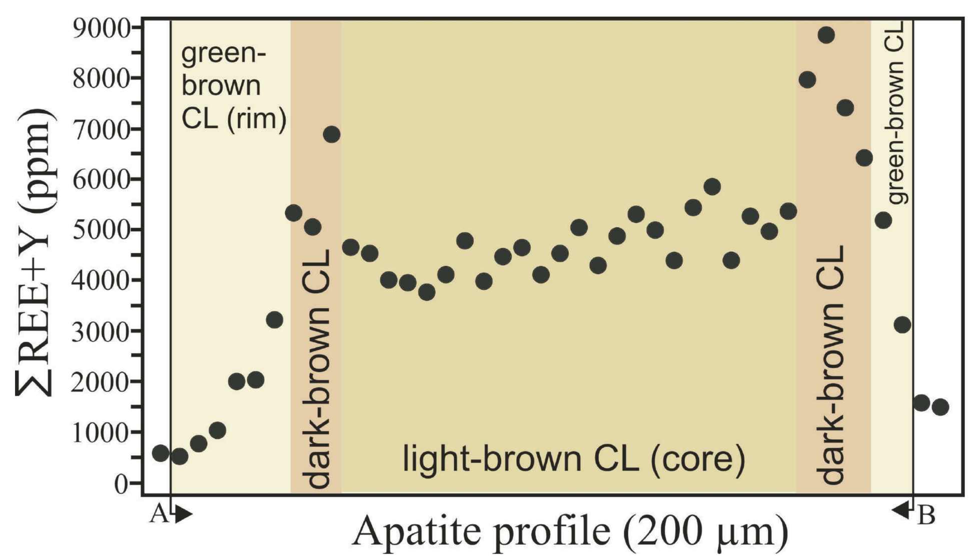

Figure 8: Variation in trace element composition across of a zoned apatite grain (see Fig. 5c)

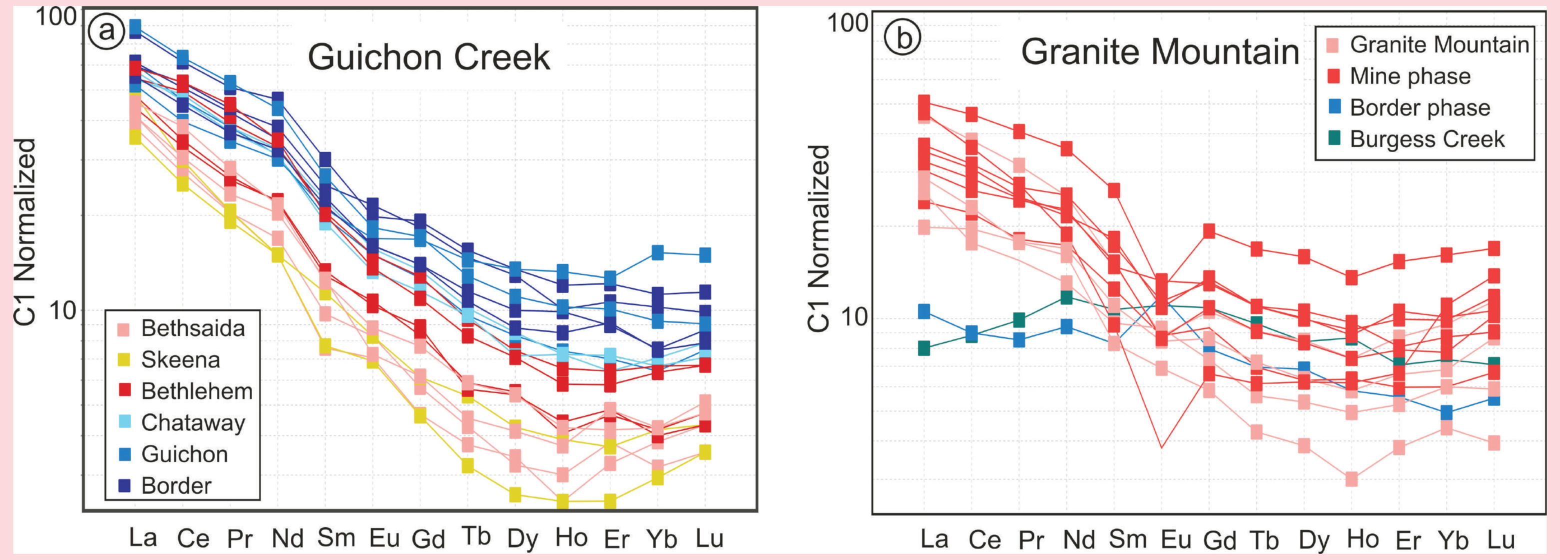

Figure 6: Whole rock REE composition.

Whole Rock REE Chemistry

- All Guichon Creek rocks lack Eu anomalies. Late, more felsic phases have listric-shaped patterns suggesting hornblende and garnet fractionation characteristics of porphyry-fertile suites and indicate high magmatic water content and high oxidation state.
- Granite Mountain show an Eu anomaly that ranges from minimal to negative. This indicates variable degrees of plagioclase fractionation which incorporates Eu^{2+}, and probably influenced by fluctuation in magmatic water content and/or oxidation state.

Acknowledgements

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Selected References

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