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Petrography, Lithogeochemistry and Magma Fertility of the Guichon Creek Batholith, Southcentral British Columbia, Canada

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Abstract. The Guichon Creek Batholith (GCB) is a Late Triassic calc-alkaline intrusion within the Quesnel Terrane of the Intermontane Belt and hosts the Highland Valley Cu-Mo porphyry system in British Columbia, Canada. A single U-Pb zircon age of 210 ± 3 Ma has been reported for the batholith (Mortimer et al. 1990). The intrusion is composed of six petrographiclly and geochemically distinct phases. The geochemistry of the intrusive phases are consistent with the fractionation of hornblende and titanomagnetite from highly oxidized and hydrous magmas in the GCB relative to other, infertile granitoid plutons of the Intermontane Belt that host no significant porphyry style mineralization.

Keywords. Porphyry Copper, Highland Valley, petrography, geochemistry, magma fertility

1 Introduction

The Guichon Creek Batholith (GCB) is a Late Triassic calc-alkaline intrusion approximately 60km x 35km in size located approximately 54km southwest of Kamloops, British Columbia, Canada (Fig. 1). The GCB is part of the Quesnel Terrane, comprised of stacked volcanic-arc assemblages and associated sedimentary units, which in addition to the Stikine and Cache Creek terranes comprise the Intermontane Belt of central British Columbia. The GCB is host to the Highland Valley Cu-Mo porphyry system comprised of at least five known economic porphyry style deposits (Valley, Lornex, Highmont, Bethlehem and J.A.) which as of December 31, 2013, collectively contain proven and probable reserves of 663, 353, 000 tonnes at 0.294% Cu and 0.008% Mo (Teck Resources Limited 2014). It is also one of two mineralized calcalkaline batholiths that form a Late Triassic belt parallel to younger mineralized alkaline and calcalkaline belts to the east. Most of this belt is buried under a thin veneer of Jurassic and younger cover. Understanding the petrogenesis and composition of the GCB is important in developing exploration techniques to locate similar buried porphyry deposits along this belt.

2 Petrography

The GCB consists of six concentrically zoned intrusive facies ranging from diorite to granodiorite from the margin to the core. Field relationships indicate that the facies young towards the centre of the batholith although observable contacts are rare in outcrop. The six intrusive facies are from the margin inward: 1) Border facies, 2)

Guichon facies, 3) Chataway facies, 4) Bethlehem facies, 5) Skeena facies, and 6) Bethsaida facies.
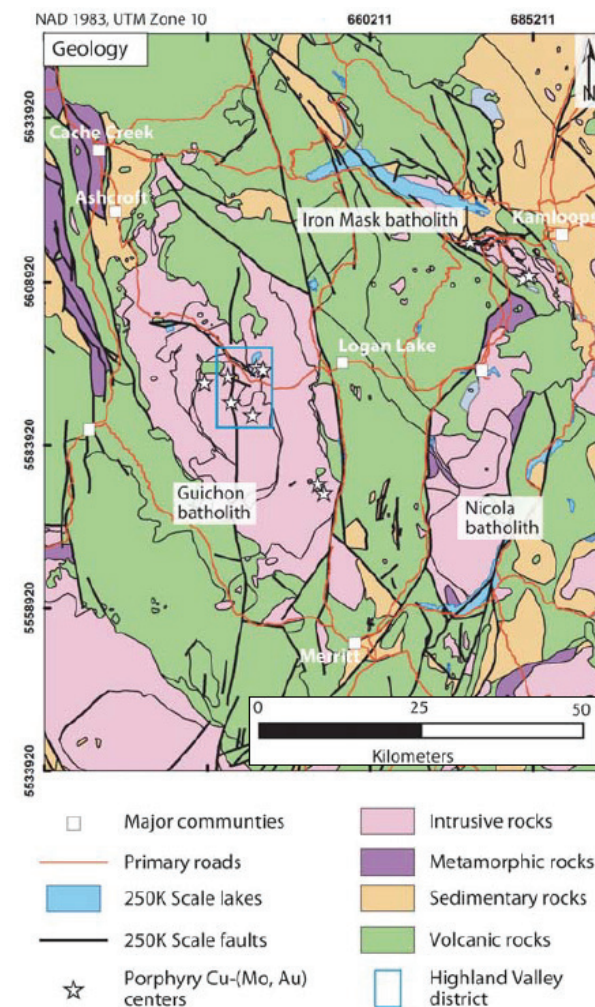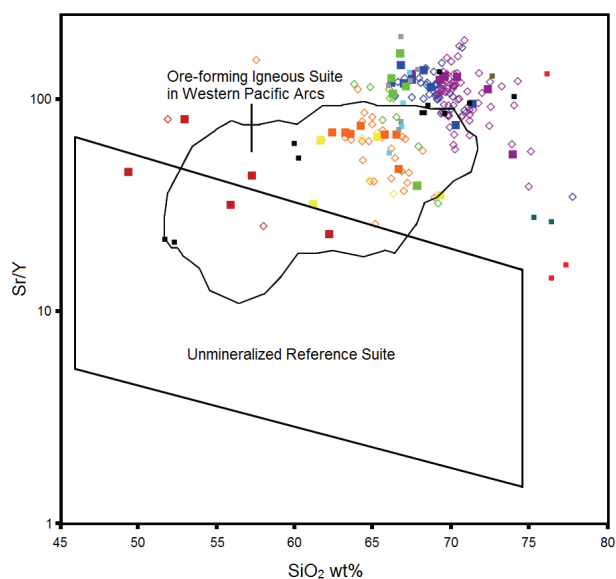

Figure 1. Regional map showing the location of the Guichon Creek Batholith study area within the Intermontane Belt of central British Columbia (modified after Massey et al. 2005).

The Bethsaida facies is comprised of quartz monzonite to granodiorite (1 to 5% biotite ± hornblende) with biotite/hornblende ratios of 2.0 to 3.0 and contains numerous coarse-grained amoeboid quartz and stacked biotite phenocrysts in a feldspar groundmass. The Bethlehem facies varies from tonalite to granodiorite (7 to 12% hornblende ± biotite) with biotite/hornblende ratios ~0.3, lacks amoeboid quartz phenocrysts and has coarse-grained hornblende phenocrysts that poikilitically enclose fine-grained euhedral plagioclase chadacrysts.

The Skeena facies is a granodiorite (5 to 10% hornblende ± biotite) and displays textures and mineralogy intermediate to the adjacent Bethsaida and Bethlehem facies. Skeena rocks are characterised by a seriate texture with finer-grained amoeboid quartz and hornblende phenocrysts than those observed in the Bethsaida and Bethlehem facies and biotite/hornblende ratios of 0.4 to 0.8. The Chataway facies is a quartz diorite to tonalite (13 to 15% hornblende ± biotite) with evenly distributed mafic minerals and an equigranular texture. The Guichon facies is an equigranular quartz diorite to granodiorite (~15% hornblende + biotite) with evenly distributed sub- to euhedral mafic minerals, biotite/hornblende ratios of ~1 and up to 10% conspicuous potassium feldspar. The Border facies is strongly heterogeneous ranging from gabbro to quartz diorite with localized xenoliths of Nicola Group country rocks and autoliths near the batholith's margins. Most hornblendes in the Border facies characteristically contain multiple inclusions of anhedral pyroxene. Common accessory minerals include primary igneous apatite, titanite, zircon, magnetite and secondary ilmenite, hematite and rutile after magnetite. Rare barite is observed associated with magnetite and apatite in the Bethsaida facies. Hornblendes from all facies are typically unzoned.

3 Geochemistry

Bivariate diagrams suggest that fractional crystallization may account for the geochemical differences between the facies. Samples can be divided into two groups (pre- and post-Bethlehem) on plots of Al_2O_3 wt%, Al_2O_3/TiO_2 and Sr/Y vs. SiO_2 wt% (Fig. 2). This subdivision coincides with a simultaneous transition from a metaluminous margin to a weakly peraluminous core. Samples display a medium- to high-K calc-alkalic affinity. Trace element geochemistry indicates enrichment in light rare earth elements and strong negative Nb and Ti anomalies consistent with magmas derived from a mantle wedge source typical of continental arcs. The magma fertility (based on oxidation and hydration state) of the GCB has been assessed and compared to that of the Upper Triassic Nicola Batholith (NB) located approximately 20km to the east and other arc-related plutons of the Intermontane Terrane. The relative fractionation of hornblende and titanomagnetite versus plagioclase was used as a proxy for the oxidation and hydration state of the magmas. Plots of Sr/Y (Fig. 2), Al_2O_3/TiO_2 and V/Sc versus SiO_2 wt% (Fig. 3) are consistent with the fractionation of hornblende and titanomagnetite from highly oxidized and hydrous magmas in both the GCB and NB relative to other, infertile granitoid plutons of the Intermontane Terrane that host no significant known porphyry style mineralization. La/Sm_{cn} ratios gradually increase with decreasing relative age peaking with the emplacement of the Bethsaida facies and aplite dykes possibly representing continuous fractionation or possibly contamination of the source region. Gd/Yb_{cn} ratios are unchanged prior to the first mineralizing event and then show a gradual decrease through the emplacement of the crowded quartz feldspar porphyry to aplite dykes.

Figure 2. A plot of Sr/Y vs. SiO_2 wt% for the Guichon Creek and Nicola Batholiths. An increase in the Sr/Y ratio indicates the depletion of Y and concentration of Sr in the residual melt during crystallisation. The majority of samples plot within or well above the ore-forming igneous suite defined by Loucks (2014). Solid circles represent samples collected as part of the CMIC footprints project. Hollow circles represent unpublished data
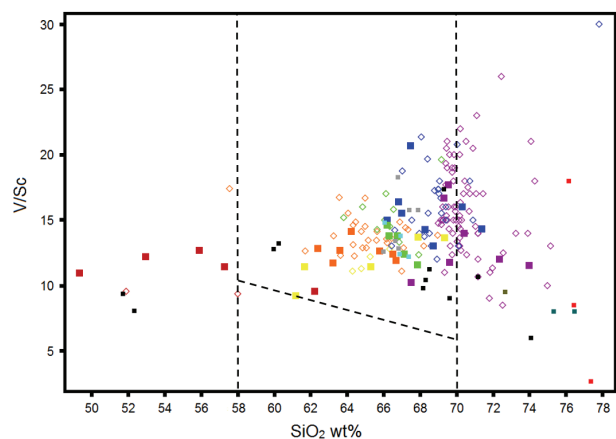
LEGEND

- ■ Aplite Dyke, CMIC
- ■ Bethlehem, CMIC
- ◇ Bethlehem, Teck
- ■ Bethsaida, CMIC
- ◇ Bethsaida, Teck
- ■ Border, CMIC
- ◇ Border, Teck
- ■ Chataway, CMIC
- ◇ Chataway, Teck
- ■ FPC, CMIC
- ■ FPM, CMIC
- ■ FQPC, CMIC
- ■ Guichon, CMIC
- ◇ Guichon, Teck
- ■ Nicola Batholith, CMIC
- ■ Skeena, CMIC
- ◇ Skeena, Teck
- ■ Tan Porphyry, CMIC

Figure 3. A plot of Sr/Y vs. SiO_2 wt% for the Guichon Creek and Nicola Batholiths. An increase in the Sr/Y ratio indicates the depletion of Y and concentration of Sr in the residual melt during crystallisation. The majority of samples plot within or well above the ore-forming igneous suite defined by Loucks (2014). Solid circles represent samples collected as part of the CMIC footprints project. Hollow circles represent unpublished data provided by Teck.

This differs from the increasing Gd/Yb_{cn} ratios observed for Chilean and Philippine porphyry systems where it has been suggested to be linked to ridge subduction and crustal thickening, possibly triggering mineralization (Hollings et al. 2005; 2011). This change cannot be linked to a concurrent change in La/Sm_{cn} ratios

and is likely due to fractionation of the MREEs into hornblende and/or garnet at deep crustal levels.

The presence of barite and high V/Sc ratios indicate a highly oxidized magma which reached sulfate saturation and contained abundant V^{5+} which behaves incompatibly relative to V^{4+}. The absence of pyroxene cores in hornblende throughout the batholith with the exception of the Border facies suggests that the GCB magmas had high water contents upward of 5-6 wt% allowing hornblende to be a stable liquidus phase through most of it's crystallization history. The absence of any discernable zoning in hornblende suggests a long residence time for hornblendes within the magma chamber allowing for re-equilibration of hornblende core with solidus rim compositions. Further work is needed to determine whether the change in geochemical signature between the pre- and post-Bethlehem facies represents a change in fractionating phases, replenishment of the parent magma chamber from a second source or progressive contamination and fractionation of the source magmas during a hiatus in magmatic activity and what role, if any, this played in the generation of the mineralized porphyries.

Acknowledgements

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