Zircon geochemistry (U-Pb, ƐHf$_t$, δ^{18}O, TE) of northern Hogem batholith, Quesnel terrane, north-central BC

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Summary

Hogem batholith was emplaced in multiple phases into Nicola Group supracrustal host rocks over ~80 m.y. (ca. 207 to 128 Ma).

Hogem hosts numerous alkaline and calc-alkaline Cu-Au porphyry prospects, including the Lorraine and Kwanika deposits and Mount Milligan mine.

Geochronological and geochemical data are limited in the area, which inhibits understanding of the relationship between intrusions and mineralization.

The British Columbia Geological Survey (BCGS) updated the bedrock geology of northern Hogem batholith and surrounding areas in 2018 and 2019.

Representative samples from four intrusive suites were collected for zircon chemistry analyses, which provides a modern geochronology and tracer isotope dataset for the Hogem batholith.

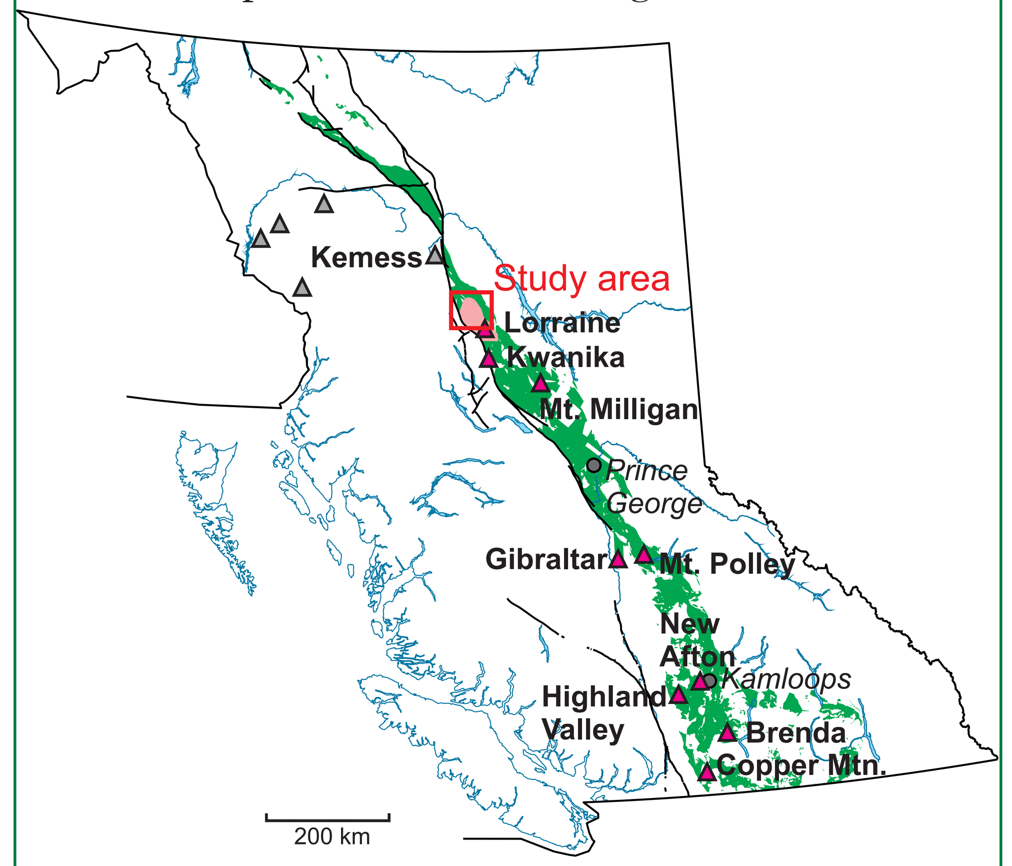


Figure 1. Distribution of Quesnel terrane and selected major Late Triassic-Early Jurassic Cu-(Au, Mo) porphyry deposits within British Columbia. Northern Hogem batholith is shown in pink, the location of this study is outlined in red.

Geology and Geochronology

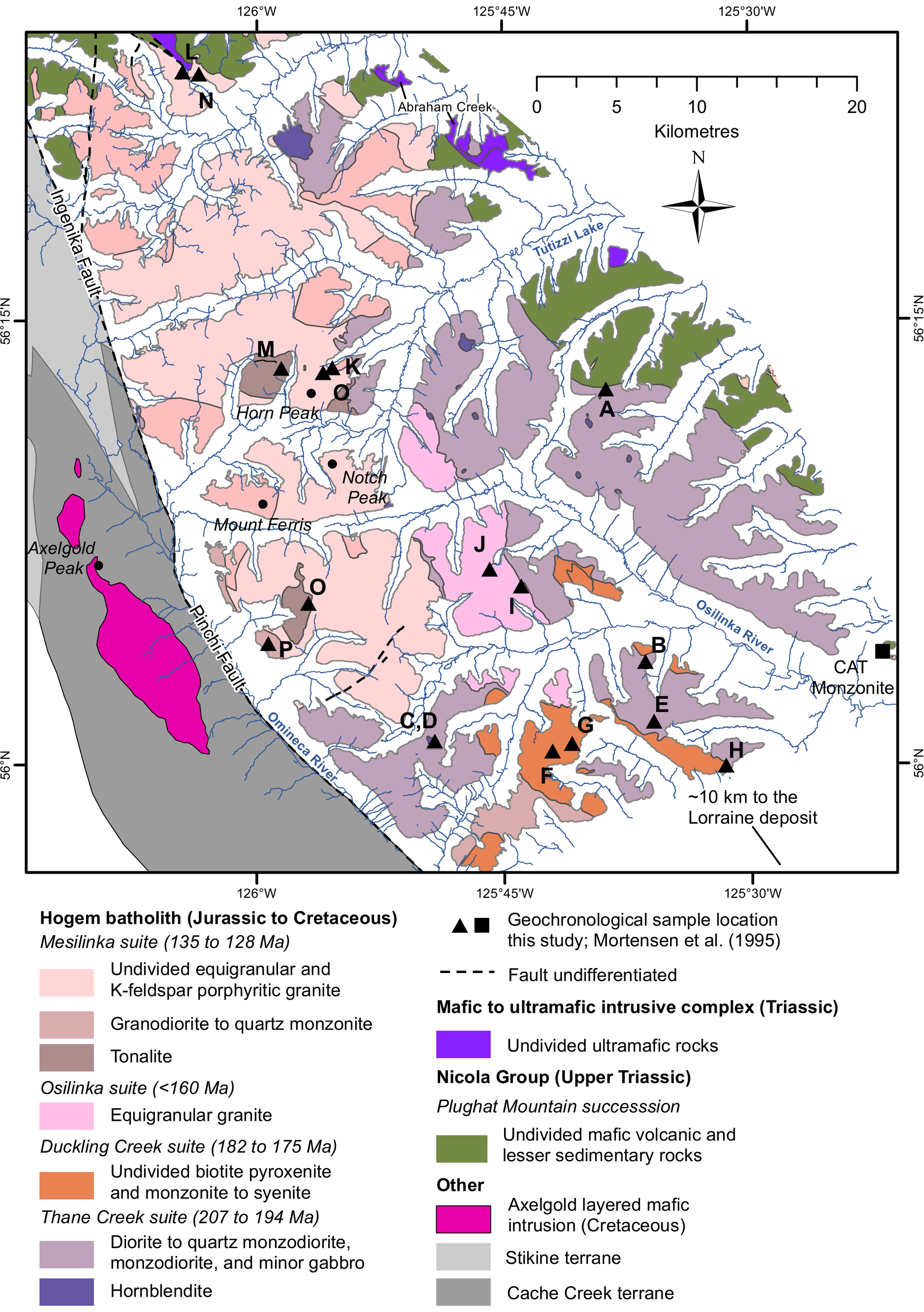


Figure 2. Bedrock geology map of northern Hogem batholith (modified after Ootes et al., BCGS Open File 2020-02). Triangles indicate geochronological sample locations (Jones et al., BCGS Paper 2021-1). The letters of sample locations correspond to the results in Figures 4-7.

The Hogem batholith is subdivided into four distinct intrusive suites with varying lithologies, geochemical signatures, and crystallization age ranges:

a) Thane Creek suite (207-194 Ma): predominantly calc-alkaline medium-grained diorite to quartz monzodiorite that intruded and co-mingled with coarse-grained hornblendite.

b) Duckling Creek suite (182-175 Ma): includes older biotite clinopyroxenite that is intruded by alkaline two-feldspar syenites to monzonites. The Lorraine Cu-Au deposit is hosted in Duckling Creek suite rocks to the south of this study area.

c) Osilinka suite (< 160 Ma): includes leucocratic, medium-grained equigranular granite and feldspar porphyry sheets.

d) Mesilinka suite (135-128 Ma): older tonalite and granodiorite phases that are intruded by equigranular granite and K-feldspar porphyritic granite.

Figure 3 (right). Field outcrop photographs of: **a)** Co-mingled Thane Creek suite diorite and hornblendite. **b)** Rhythmic magmatic layering of Duckling Creek suite felsic syenites with biotite and amphibole-rich mafic syenites. **c)** Osilinka suite leucocratic granite. **d)** Mesilinka suite K-feldspar porphyritic granite cut by a pegmatite dyke.

Geochronology results from this study include:

Zircon chemical abrasion-thermal ionization mass spectrometry (CA-TIMS), TIMS, and titanite TIMS U-Pb analyses, University of British Columbia.

Zircon laser ablation-inductively couple plasma (LA-ICP)-MS U-Pb analyses, University of Alberta.

Biotite, hornblende, and muscovite Ar-Ar analyses, University of Manitoba.

Previously published geochronology results from CAT monzonite and Lorraine Cu-Au deposit (Mortensen et al., 1995; Devine et al., 2014; Bath et al., 2014).

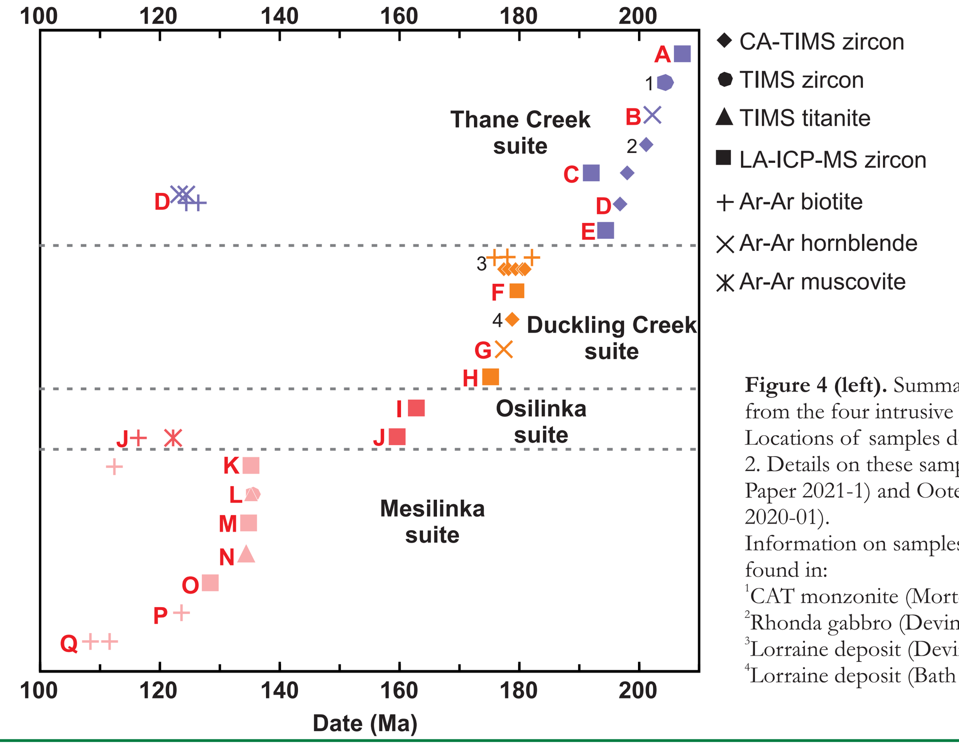


Figure 4 (left). Summary of geochronology results from the four intrusive suites in the Hogem batholith. Locations of samples denoted by letters are in Figure 2. Details on these samples are in Jones et al. (BCGS Paper 2021-1) and Ootes et al. (BCGS Geofile 2020-01).
Information on samples denoted by numbers can be found in:
[1]CAT monzonite (Mortensen et al., 1995)
[2]Rhonda gabbro (Devine et al., 2014)
[3]Lorraine deposit (Devine et al., 2014)
[4]Lorraine deposit (Bath et al., 2014)

Zircon Oxygen-isotopes

Zircon oxygen-isotopes (δ^{18}O) were analyzed using secondary ion mass spectrometry (SIMS) at the Canadian Centre for Microanalysis at University of Alberta.

δ^{18}O signatures are used to determine the relative contributions of recycled crustal and mantle sources to magmatism.

δ^{18}O values above the mantle range (5.3±0.6‰; Valley et al., 2005) indicate magma sources with a component that interacted with the low temperature hydrosphere, while values below the mantle range indicate a high temperature hydrothermal component in the source.

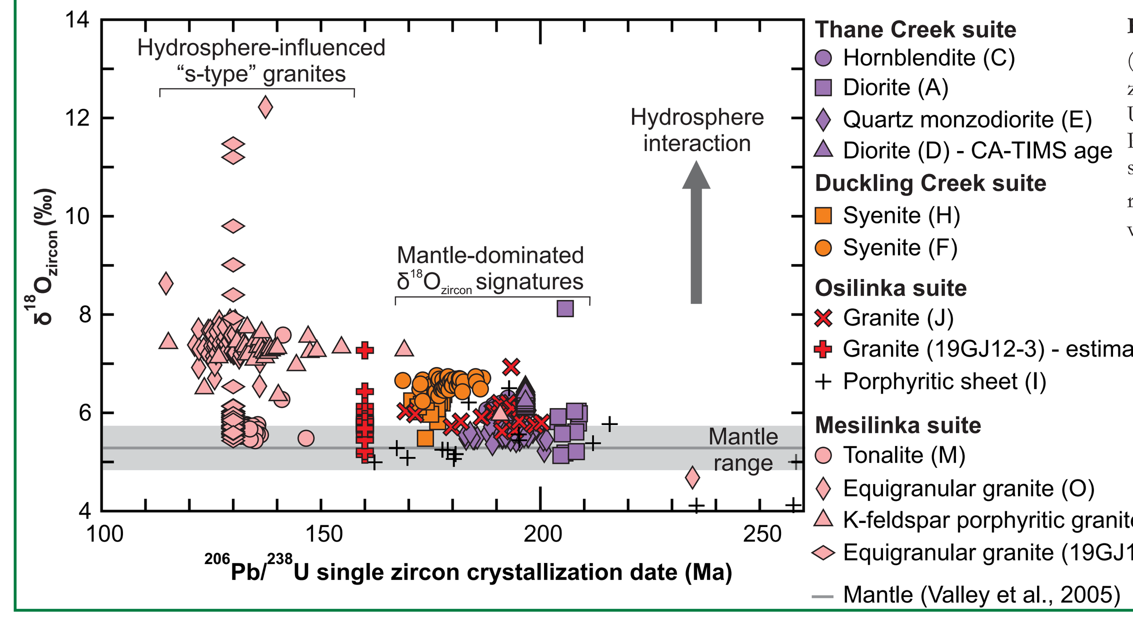


Figure 5. Zircon oxygen-isotope (δ^{18}O$_{zircon}$) results versus single zircon ^{206}Pb/^{238}U dates. Zircon U-Pb data is from Jones et al. (BCGS Paper 2021-1). Sample locations are shown in Figure 2. The grey bar represents the range of mantle δ^{18}O$_{zircon}$ values (5.3±0.6‰; Valley et al., 2005).

Zircon Lu-Hf

Zircon Lu-Hf isotope analyses were conducted using LA-ICP-MS at the Arctic Resources Laboratory at University of Alberta.

Hf data is presented as ƐHf(t), which is the ^{176}Hf/^{177}Hf ratio relative to the chondritic uniform reservoir (CHUR) at the time of zircon crystallization (t). These Hf values are also shown relative to the range of Pacific mid-ocean ridge basalts (MORB), which represents the ƐHf of the underlying depleted mantle.

Hf values below the MORB range indicates samples that are more evolved than the depleted mantle.
Hf values above CHUR indicates samples that are less evolved (more juvenile) than CHUR.

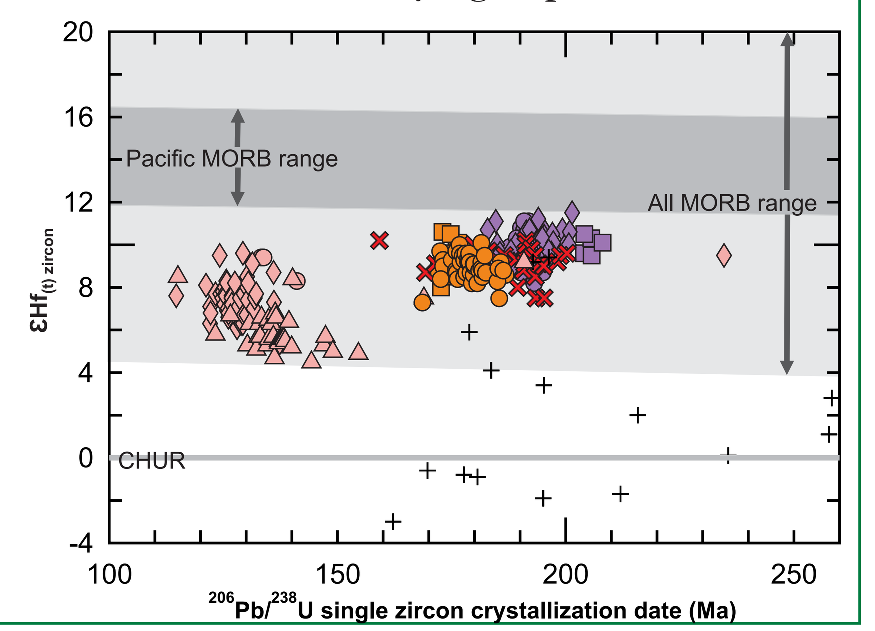
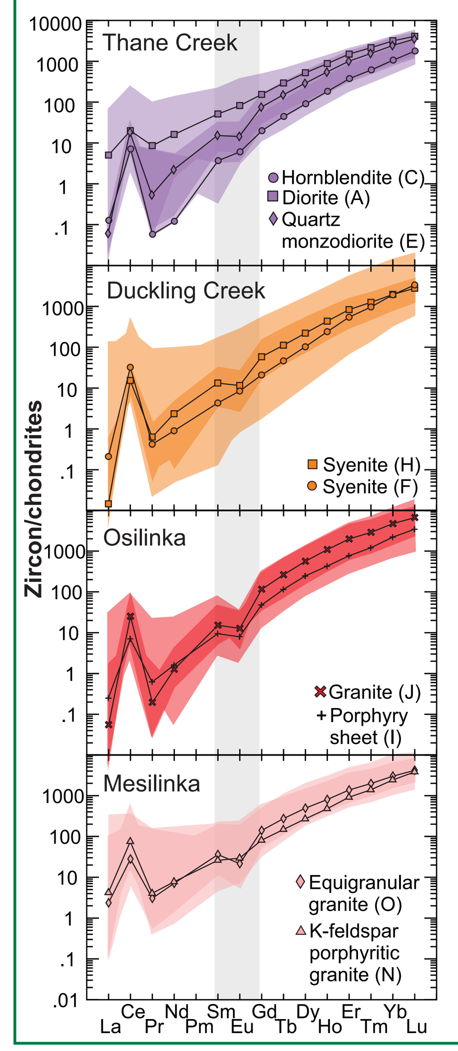


Figure 6. Zircon Lu-Hf isotope (εHf(t)) results versus single zircon ^{206}Pb/^{238}U dates. Symbols are as in Figure 5. Mid-ocean ridge basalt (MORB) data is from Chauvel and Blichert-Toft (2001). Chondritic uniform reservoir (CHUR) data is from Bouvier et al. (2008).

$$\varepsilon Hf_t = [(^{176}Hf/^{177}Hf)_{SAMPLE(t)}/(^{176}Hf/^{177}Hf)_{CHUR(t)})-1] \times 10000$$

Zircon Trace Elements



Zircon trace elements (TE) were analyzed using LA-ICP-MS at the Arctic Resources Laboratory at University of Alberta.

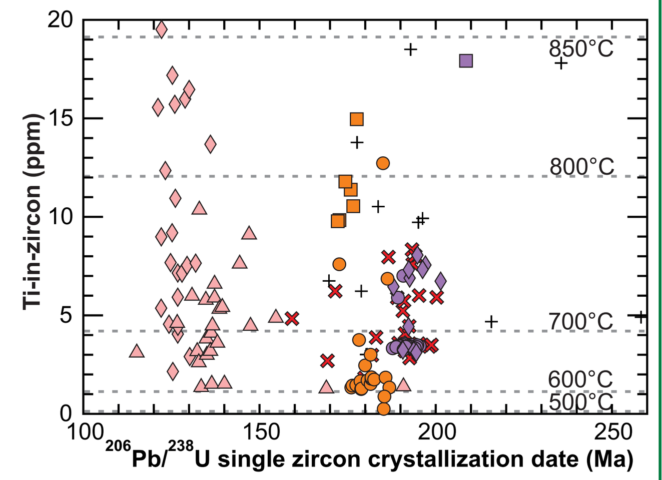
Chondrite-normalized REE patterns of zircon are indicative of different rock types, e.g. TE concentrations tend to increase from ultramafic to felsic rocks.

TE concentrations may also be used to estimate relative magma conditions during crystallization, e.g. zircon Eu anomalies are suggested proxies for magma oxidation state.

Ti concentrations in zircon are used to calculate estimated temperatures during crystallization.

Figure 7 (left). Chondrite-normalized zircon REE patterns. Coloured regions indicate the range of values for each intrusive suite. Individual sample patterns represent the median results of several single grain analyses. The grey bar highlights the Eu anomaly. Chondrite data from Sun and McDonough (1989).

Figure 8 (right). Ti-in-zircon concentration (ppm) versus single zircon ^{206}Pb/^{238}U dates. Symbols are as in Figure 5. Zircon U-Pb data is from Jones et al. (BCGS Paper 2021-1). Dashed lines represent estimated Ti-in-zircon temperatures (°C) using the thermometer of Ferry and Watson (2007), with aSiO_2=1.0 and aTiO_2=0.7.



Conclusions

Hogem batholith geochronology results indicate prolonged and punctuated magmatism from ca. 207 to 128 Ma.

Zircon δ^{18}O results record an increase in crustal input in Hogem batholith magmas from Thane Creek suite (mantle-dominated) to Mesilinka suite (hydrosphere influenced "s-type" granites).

Zircon Lu-Hf data indicate the most juvenile Hogem batholith samples overlap with the Pacific MORB range. Future work includes modelling possible sources to Hogem batholith magmatism.

Zircon TE results show dominantly negative Eu anomalies (less oxidized?), with two samples in Thane and Duckling Creek suites showing less negative/no Eu anomalies (more oxidized?=more favourable for porphyry mineralization). Ti-in-zircon temperature estimates indicate an increase in the range of crystallization temperatures from Thane Creek to Mesilinka suite. Further work will constrain activities of SiO_2 and TiO_2 of individual samples to better estimate Ti-in-zircon temperatures.

Acknowledgments

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