INTRODUCTION
The fundamental relationship of porphyry Cu (Au, Mo) deposits with intrusive rocks is well established (Mitchell, 1979), but distinguishing metal-lithophile from barren plutons remains a significant challenge for geologists. New information that contributes such a priori knowledge provides guidance early in the exploration process to make decisions more effectively and efficiently, focusing exploration resources on more prospective targets. This research project, therefore, provides tools and understanding that emphasize porphyry fertility in the British Columbia context.

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 composition of major intrusive rocks from three well-documented batholiths, the Granite Creek, Takomkane, and Granite Mountain batholiths, are studied to develop exploration tools that utilize such porphyry fertility indicators. The characterization of fertility 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.

METHODS
Field and laboratory work are focused on a series of intrusive rocks and associated accessory minerals, e.g., apatite, titanite, zircon, that show evidence of magmatic processes and porphyry-copper deposits. Apatite deposits will be characterized:

- Determine the mineralogical features of accessory minerals that characterize and distinguish porphyry fertility.
- 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.

Figure 1: Simplified geology map of south-central British Columbia showing location of major pluton intrusive bodies (from Schiarrizza, 2016).

Figure 2: Distribution of a porphyry complex showing relationship of fertility and porphyry deposits.

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, magmatic mixing, and the amount of saturation of water, metal, chlorine and sulphur. These features are variably recorded in crystallizing fertility indicator minerals of the parental magma.

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

Figure 4: Distribution of host-rocks and porphyry deposits.

Figure 5: Cathodoluminescence image of apatite grains: a) large apatite grains from the Highland Valley porphyry deposits with brownish CL colour have higher concentrations of CI and Sr relative to the more green-brown CL at the rim.

The mineralized Woodjam Creek unit of the Takomkane batholith and the Mineralized Granite Mountain batholith have lower CI and Sr concentrations than the unmineralized phases of the batholiths.

• The zoned apatite grains show a similar trend for Cl and Sr. The core of apatite with the most brownish CL colour has higher concentrations of CI and Sr relative to the less brownish luminescence at the rim.

Figure 6: Whole rock RREE chemistry.

Figure 7: Apatite textural fertility characteristics.

APATITE TEXTURAL FERTILITY CHARACTERISTICS
Apatite petrography was studied using 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 major phases of the Guichon Creek batholith.
- Yellow luminescence is common in the felsic Betchaasid phase of the Guichon Creek batholith.
- Apatite grains with yellow luminescence have higher (<0.2%) MnO concentrations.
- Apatite grains with brown luminescence have lower (<0.2%) MnO.
- Apatite texture varies from uniform to zoned. The zoned apatite grains have a brown CL core surrounded by a less brownish to yellow-green CL rim, and locally multiple zones occur.

Figure 8: Variation in trace element composition across rims of apatite grains.

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 Betchaasid phase, main host to the Highland Valley porphyry deposits, has less CI and S relative to the Chataway phase. The CI concentration of apatite in both phases is significantly less than CI concentrations in the Border phase apatite.
- The mineralized Woodjam Creek unit of the Takomkane batholith and the Mineralized Granite Mountain batholith have lower CI and Sr concentrations than the unmineralized phases of the batholiths.
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Figure 9: Variation in trace element composition across rims of apatite grains.

CONCLUSIONS AND FURTHER WORK
The preliminary results suggest that both geochemical and mineralogical characteristics of plutons can be used to distinguish fertile and barren rocks.

Porphyry-fertile plutons commonly display depleted HREE without significant negative Eu anomalies, consistent with hornblendes and garnet fractionation, which is favoured by high magmatic water content and oxidation state.

Porphyry-fertile plutons host apatite, which becomes progressively depleted in magmatic water (Cl and S) and Sr and Sr. Chlorine and sulphur were probably consumed during the orthopyroxene and hornblende 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 fluidized. Further geochemical and mineralogical studies on a complete suite of samples are underway.

Biochemical and mineralogical 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 composition of major intrusive rocks from three well-documented batholiths, the Guichon Creek, Takomkane, and Granite Mountain batholiths, are studied to develop exploration tools that utilize such porphyry fertility indicators.

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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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