Deconvolution of complex spatial-temporal records of porphyry fertility recorded in till minerals

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Introduction

The objective of this study of porphyry copper indicator minerals (PCIM) in till and bedrock is to aide development of innovative mineral exploration methods in glaciated areas using minerals in till to quantify fertile porphyry mineralization. This activity builds on TGI-4 results that shows igneous, alteration and porphyry ore minerals in till in the vicinity of the Gibraltar, Mount Polley and Highland Valley Copper mines and the Woodjam prospect (Fig. 1; Hashmi et al., 2015; Plouffe et al., in press). Some of these minerals, solely based on their abundance and regional distribution in till, reflect the presence of mineralization. Specifically, they are more abundant in till near and down-ice (5-10 km and even farther in some cases) of mineralization compared to background regions (Plouffe and Ferbey, 2015; Plouffe et al., in press). This new activity is targeting minerals that survive glacial transport and post glacial weathering to assess what their composition and physical attributes tell us about ore forming processes.

Research on PCIM in till in the Canadian Cordillera conducted as part of the TGI-4 program has generated great interest by industry and academia given its direct applicability to mineral exploration. Consequently, a number of detailed studies on PCIM composition have already been conducted as derivative research of the TGI-4 program. For instance, Rukhlov et al. (2016) has completed a study on apatite composition in till and bedrock in the region of four porphyry mineralized zones. A study on magnetite composition from till and bedrock at the Mount Polley Cu-Au porphyry deposit has demonstrated that hydrothermal magnetite reflecting porphyry mineralization can be detected in till up to 6 km down-ice from mineralization (Grondahl, 2014; Piziak et al., 2015; Canil et al., 2016). At the Woodjam porphyry prospect, tourmaline is generally more abundant in till near the mineralized zones compared to background regions (Fig. 2; Chapman et al., 2015). By comparing the composition of tourmaline in till and bedrock, Chapman et al. (2015) showed that only the till close to mineralization (sample 11PMA012 in Fig. 2) contains tourmaline grains with an ore-forming fluid "fingerprint".

Activity highlights

Processing of mostly legacy bedrock and unconsolidated sediment samples for the recovery of indicator minerals is being undertaken in commercial laboratories with quality assurance and quality control procedures in place(QA/QC) (e.g., Plouffe et al., 2013). The QA/QC protocol includes the usage of spiked, blank, and duplicate samples. Given the current research on the development of indicator minerals for mineral exploration, new QA/QC protocols need to be developed and tested. A number of blank, spiked and naturally enriched samples were submitted for indicator mineral processing in two independent commercial laboratories. Results demonstrate that the current procedures utilized in commercial laboratories is efficient at discriminating samples from background (devoid of mineralization), slightly anomalous (low indicator mineral content), and highly anomalous (samples from near mineralized zones) regions. This testing also served to identify required improvements to the QA/QC protocol, including the homogenizing method for QA/QC samples and that the spiking grains need to be chemically and physically characterized prior to their artificial introduction into the base material.

Following the interest generated by the study of indicator minerals in glacial sediments in the Canadian Cordillera, A.S. Hickin, T. Ferbey and A. Plouffe co-organized a two-day workshop on indicator minerals in till and stream sediments at the 2016 Geological Association of Canada – Mineralogical Association of Canada (GAC-MAC) conference in Whitehorse. The workshop included one day with classroom presentations and a field trip on the second day. On the first day, attendees learned about basic glacial processes and recent research on indicator minerals in the Canadian Cordillera, with the second day dedicated to hands-on glacial sediment identification and ice-flow indicator measurements required in a till sampling survey. The workshop was followed by a one day special session on indicator minerals which included eleven presentations on various case studies from Canada and two from abroad plus six posters. Indicator mineral studies conducted on massive sulphides, copper porphyry, and orogenic gold deposits, and kimberlites were part of the session. A joint GAC-MAC special publication on indicator minerals in till and stream sediments is currently in progress.

A master's level study at the University of Ottawa investigating Gibraltar deposit mineralogy has been instigated. For the first phase of this study, petrographic analyzes of thin sections from selected bedrock samples of the Granite Mountain

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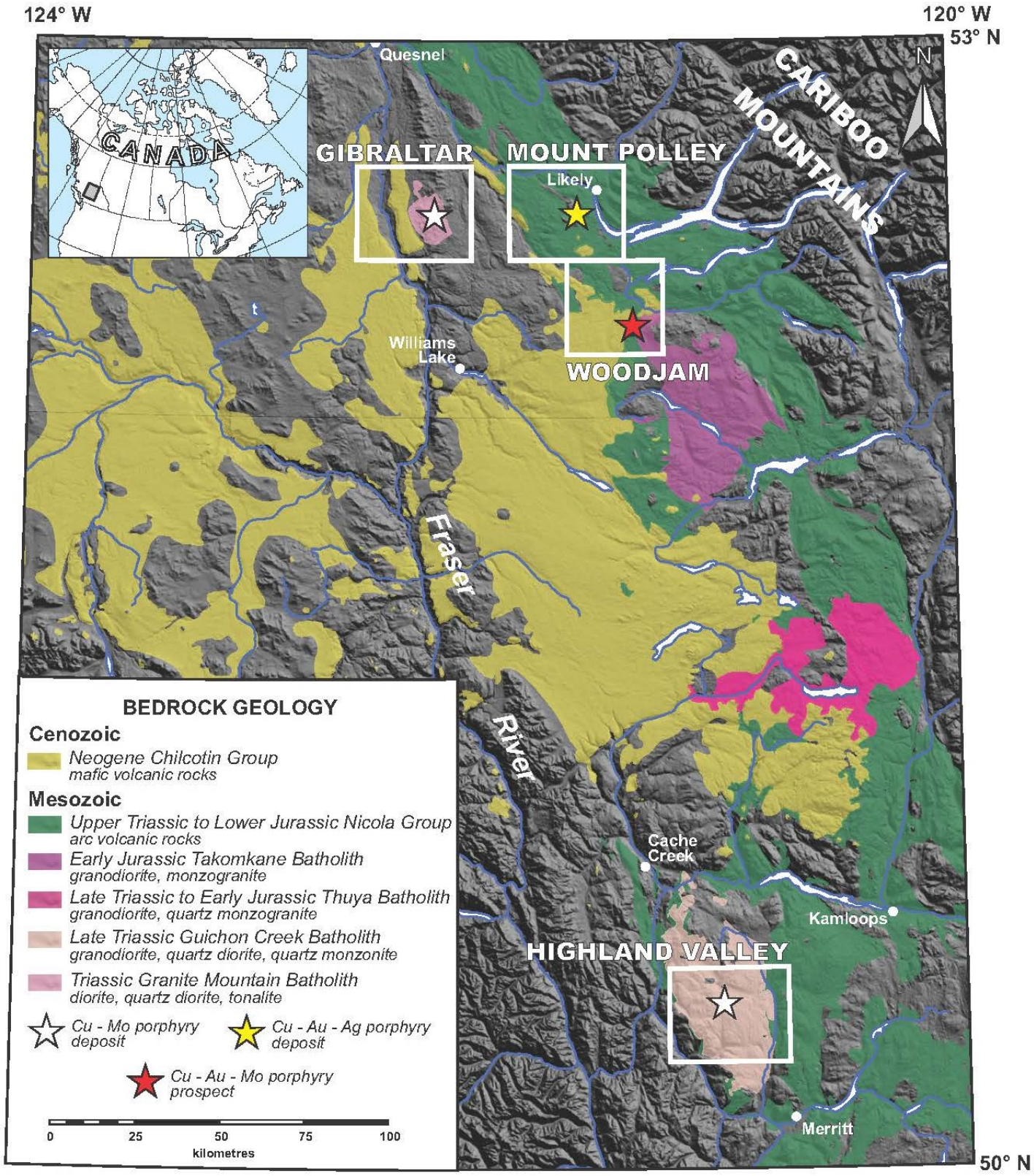

Figure 1 – Location map of the TGI-4 study sites: Gibraltar, Mount Polley and Highland Valley Copper mines and the Woodjam prospect .

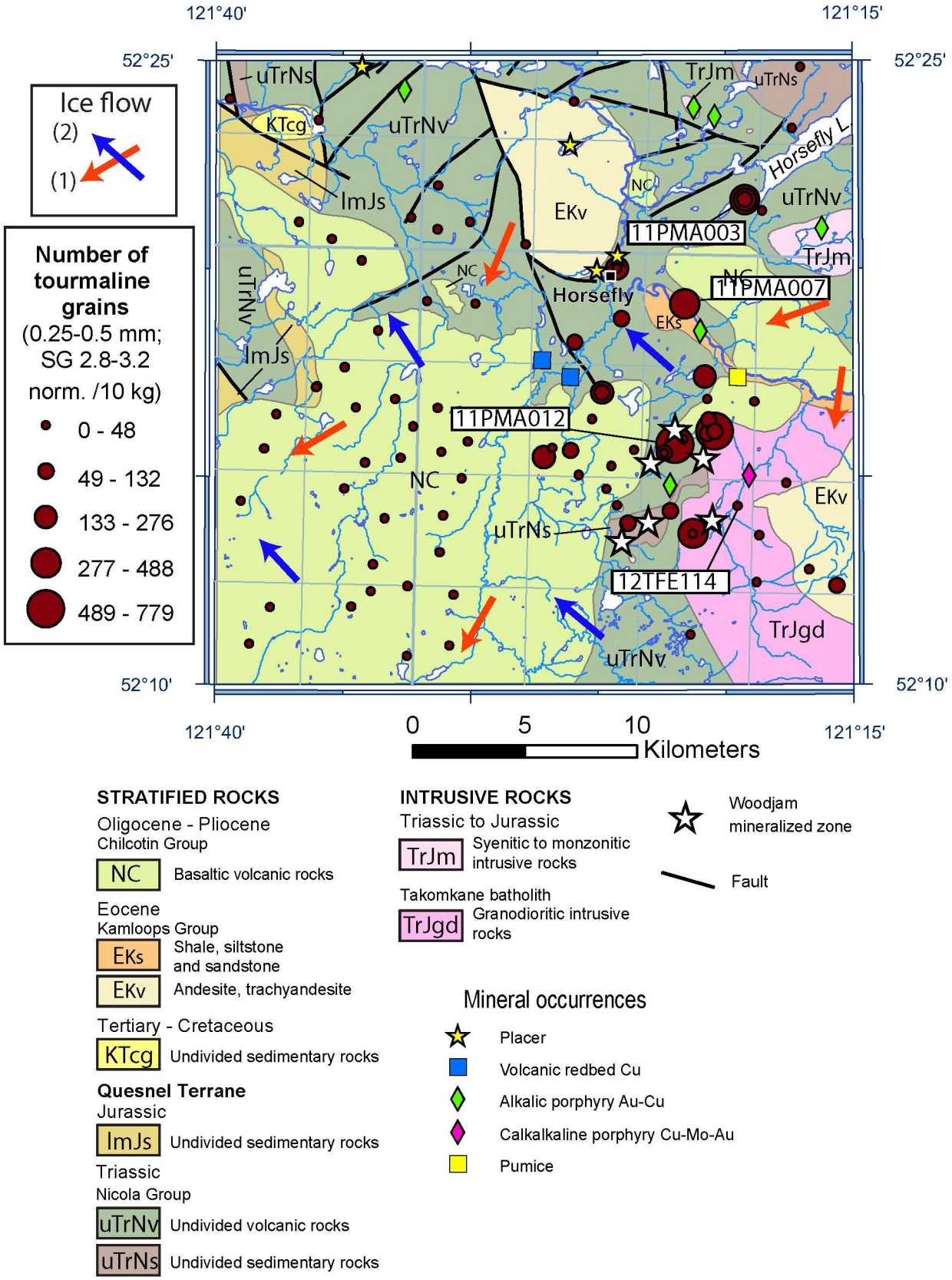

Figure 2 – Distibution of tourmaline in till at the Woodjam prospect (modified from Chapman et al., 2015). Geology from Massey et al. (2005), Logan et al. (2010) and unpublished data from P. Schiarizza (2012).

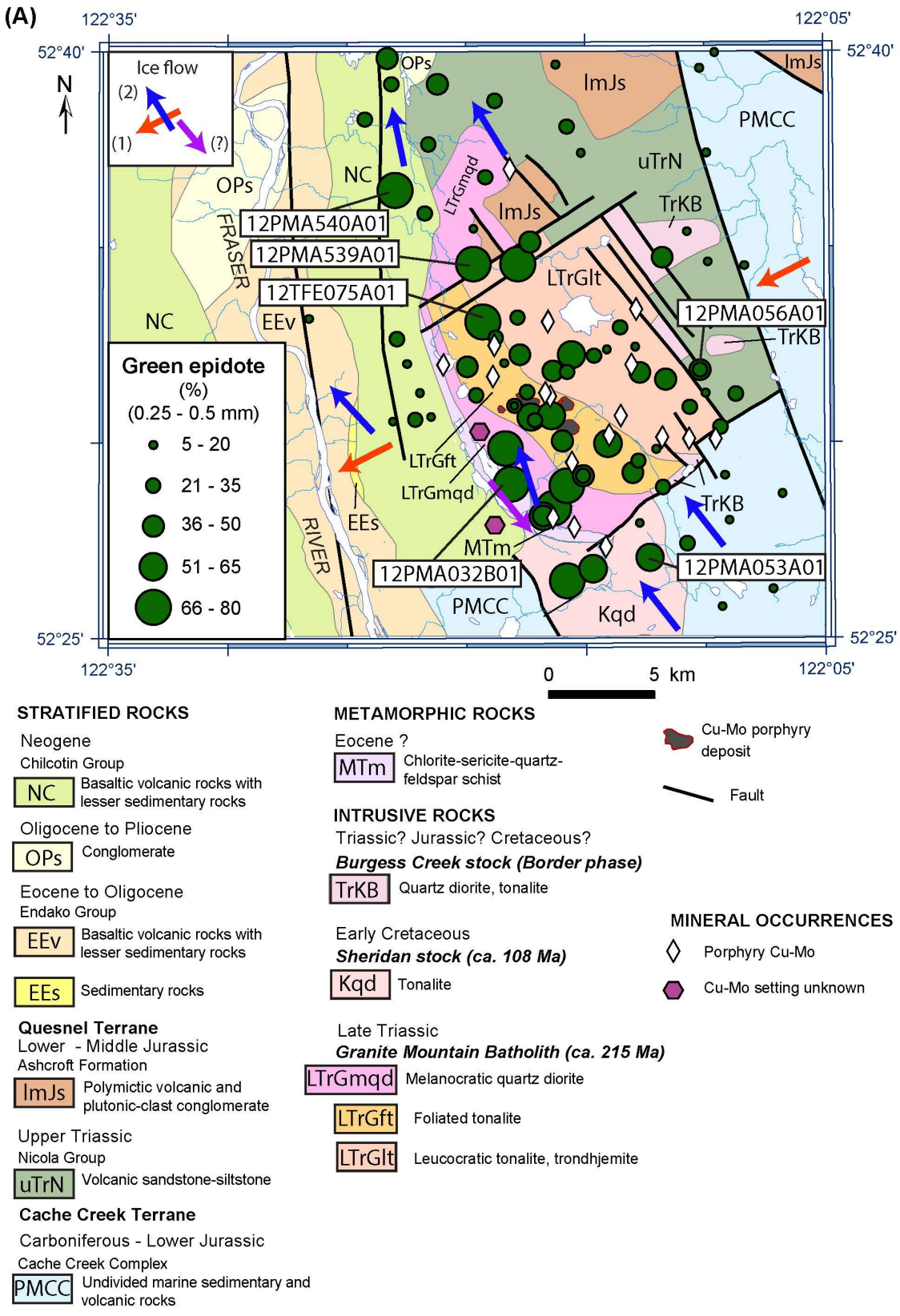

Figure 3 – (A) Epidote, (B) rutile and (C) zircon in till in the region of the Gibraltar deposit. The composition of mineral grains from the labelled samples will be analyzed as part of an honours thesis project. Geology from Ash et al. (1999), Massey et al. (2005), and Schiarizza (2014).

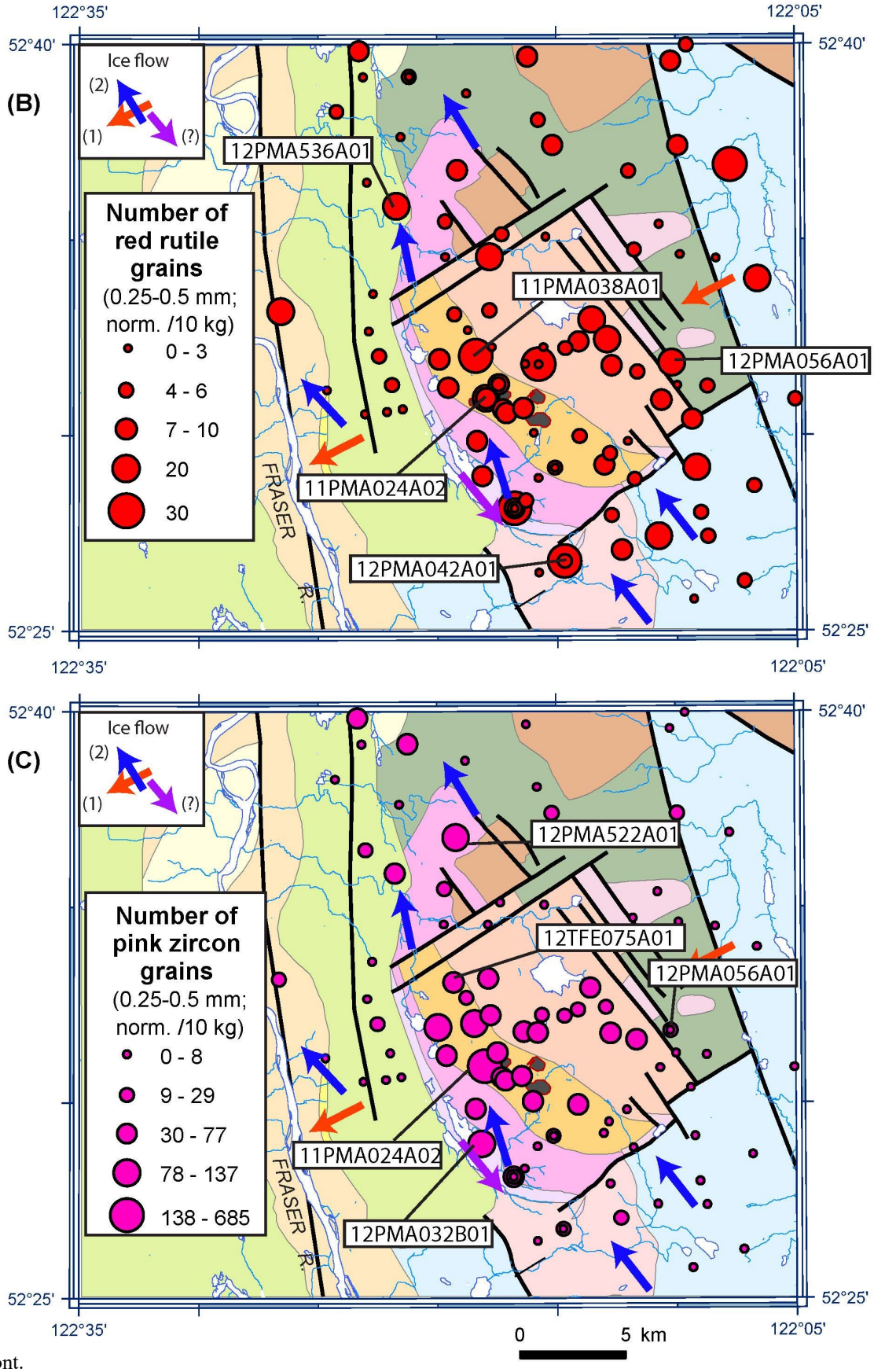

Figure 3 – Cont.

batholith, which hosts the porphyry mineralization, along with composition analyzes of titanite, epidote and rutile by scanning electron microscope equipped with an energy dispersive spectrometer (SEM-EDS) have been completed (Kobylinski et al., 2016). One key highlight of the preliminary results is the identification of hydrothermal epidote that is enriched in Ce and La reaching concentrations of 14.7 wt % Ce2O3 and 9.5 wt % La2O3. Elevated concentrations of light rare earth elements (LREE) was also reported by Cooke et al. (2014) outside pyrite halos in the Baguio porphyry district, Philippines, where it was interpreted as representing lateral outflow of fluids from the main mineralized zones and possibly the roof of an underlying pluton. During 2016 fieldwork, Kobylinski collected additional bedrock samples of the Granite Mountain batholith and regional, and has made a potentially key observation that epidote veins strike towards the mine pits. Petrographic evaluation and chemical composition analyzes of minerals is in progress.

An honours thesis project is in development for the study of the composition of epidote, rutile and zircon from till samples in the region of the Gibraltar deposit (Fig. 3). The objective is to test the detectability in till of PCIM identified in bedrock by Kobylinski, and thus evaluate if the PCIM identified in bedrock are abundant enough to be routinely detected in till and if so how far from mineralization.

Discussion

The study of PCIM, as their composition relates to ore formation processes and their use in mineral exploration in glaciated landscape, has generated interest from academia and industry. Fundamental questions that will be addressed during the evolution of this activity include:

- Are there other potential PCIMs present in till that warrant study?
- What is the diagnostic physical and chemical characteristics of these minerals and how are these related to the porphyry ore formation processes?
- Can these minerals be identified effectively and routinely as part of a mineral exploration program in glaciated landscape and serve for the detection of buried mineralization?
- How large is the PCIM footprint in till or how far can these PCIM be efficiently detected in till?

Results from this activity will serve to develop more efficient mineral exploration methods that will make a link between ore formation processes recorded in PCIMs and the detection and recovery of these minerals in the near surface environment.

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