GLACIAL DISPERSAL OF REFRACTORY MINERALS FROM THE GIBRALTAR PORPHYRY COPPER DEPOSIT, SOUTH CENTRAL BRITISH COLUMBIA, CANADA

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Scientific Presentation 73

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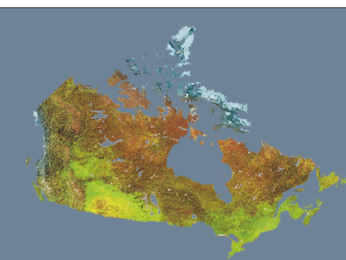
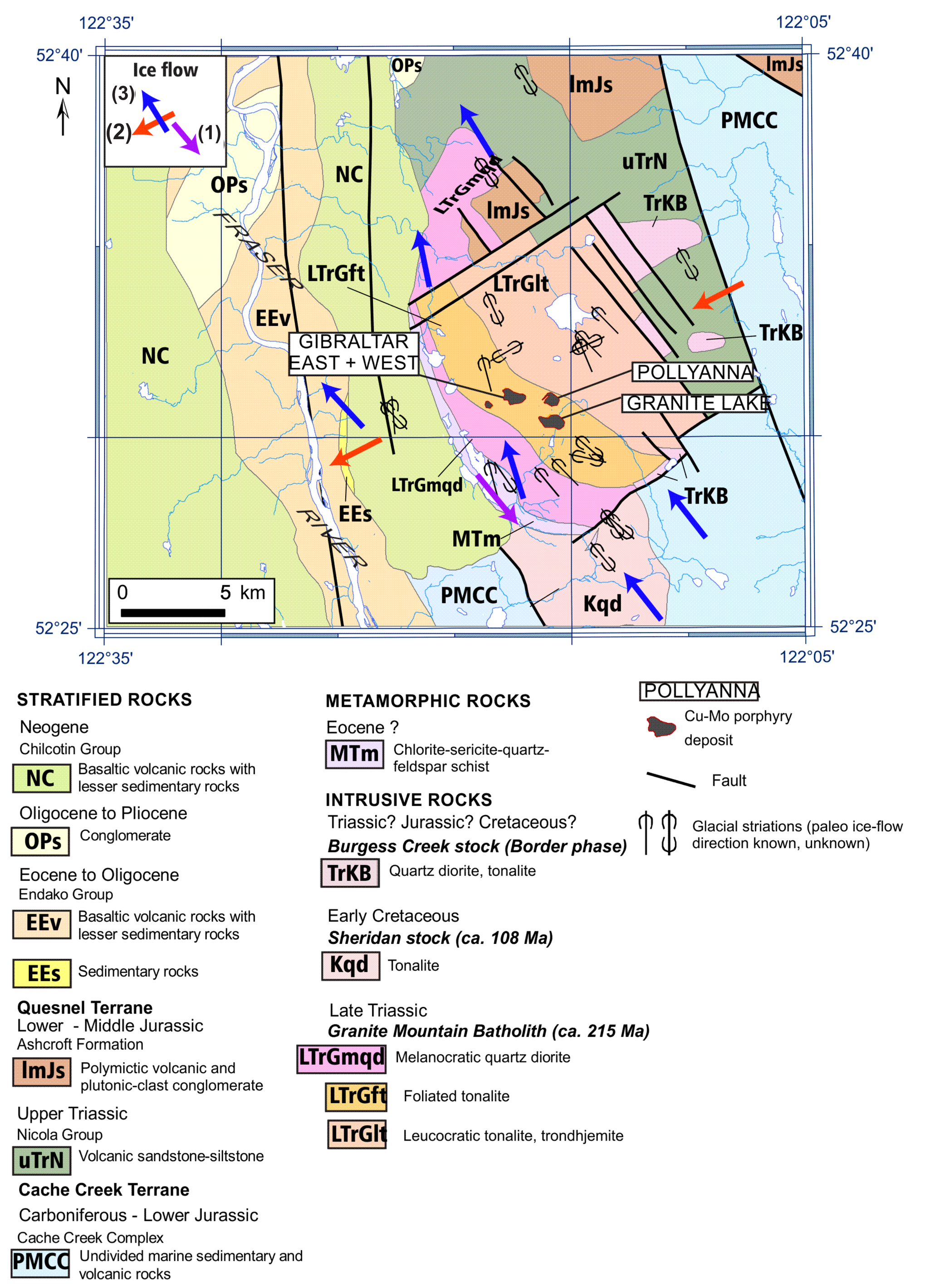


Introduction

Porphyry copper indicator minerals (PCIM) are defined as minerals indicative of porphyry mineralization. Identifying PCIM in surficial sediments (e.g. till and stream sediments) can serve to detect the presence of buried porphyry mineralization. This project was initiated to develop and test potential PCIM using zircon, epidote and rutile recovered from till in the region of the Gibraltar porphyry Cu-Mo deposit of south central British Columbia.

Study area

The Gibraltar porphyry Cu-Mo deposit is the second largest open pit mine in Canada with reserves of 1.79 Mt Cu (Reported from www.tasekomines.com/properties/gibraltar). The Gibraltar deposit is hosted by the Late Triassic Granite Mountain batholith, comprised primarily of tonalite and diorite with minor variations in abundance in minerals (Kobylinski et al., 2016). The mine has three pits central to our study area; Gibraltar, Pollyanna and Granite Lake (Fig. 1-A). The batholith intruded into Nicola Group volcanic rocks in the western limit of the Quesnel Terrane near the boundary with the Cache Creek terrane (Schiarizza, 2014). Nicola Group rocks are composed primarily of volcanic rocks that have been metamorphosed under greenschist facies conditions. Cache Creek terrane rocks are composed of chemical and siliciclastic sedimentary rocks (Schiarizza, 2014). The region is in large part covered by till deposited during three phases of ice flow which include in chronological order movements to the southeast, southwest and north to northwest (Fig. 1-A) (Plouffe et al., 2014).



Samples

Heavy minerals were separated from ca. 10 kg till samples. Details on the field and laboratory methodologies are provided in Plouffe and Ferbey (2016). A total of 440 mineral grains were analyzed including 64 rutile, 185 epidote, and 191 zircon grains. Till sample locations are provided in Figures 2-1, 3-1 and 4-1. Sample sites were selected with the objective of obtaining samples from near (<1 km) and at varying distances down-ice (>1 km) from mineralization. For comparison, samples were also collected from sites up-ice (east) from the main deposits because they unlikely contain mineral grains derived from mineralization.

Analytical methods

- Examination with a binocular and a petrographic microscopes
- Scanning electron microscope equipped with an energy dispersive X-ray spectroscopy (SEM-EDS) and cathodoluminescence detector (CL-SEM)
- Electron probe microanalyzer (EPMA)
- Laser ablation – inductively coupled plasma mass spectrometry (LA-ICP-MS)

Results - mineral chemistry

Rutile

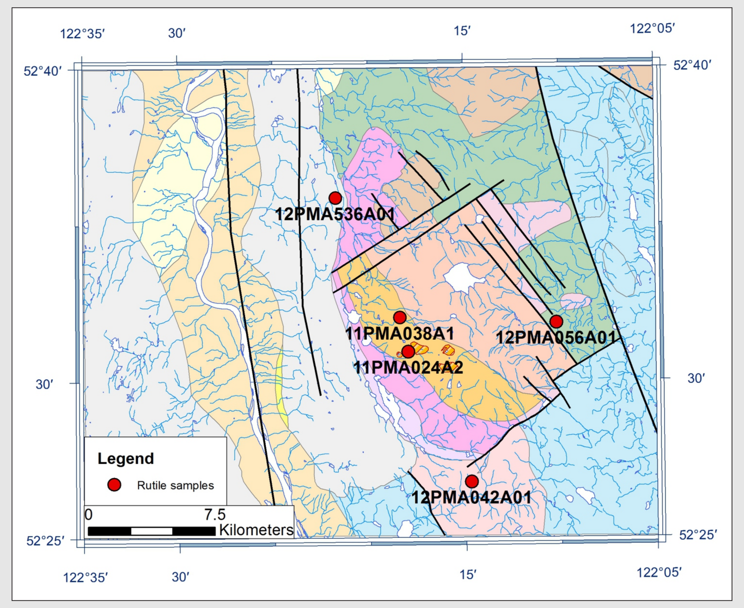


Fig. 2-1: Till sample location from which rutile grains were analyzed.

Rutile grains have a composition close to the end member with >99 wt.% TiO_2. Twenty-six rutile grains analyzed by LA-ICP-MS show large variations in Fe, Nb, and W concentrations. Average and median values are 3970 ± 2008 (1 sigma) and 3990 ppm for Fe, 2800 ± 2680 (1 sigma) and 1770 ppm for Nb, and 658 ± 2020 ppm (1 sigma) and 186 ppm for W, respectively. Inclusions of ilmenite occur in 16 out of 64 grains (Fig. 2-2). The ilmenite inclusions are composed of approximately 35-45 wt.% FeO(t) with up to 2 wt.% MnO.

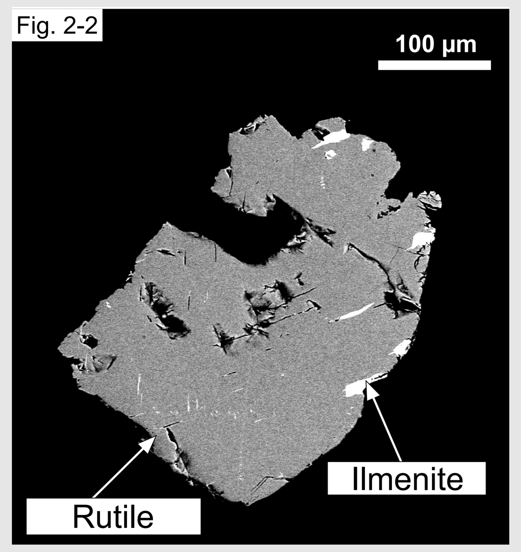


Fig. 2-2: SEM-back scattered electron (BSE) image of rutile grain #6 from sample site 12PMA-056-A01. This rutile grain displays ilmenite inclusions and homogeneous rutile composition. These characteristics are typical of rutile grains observed in all samples.

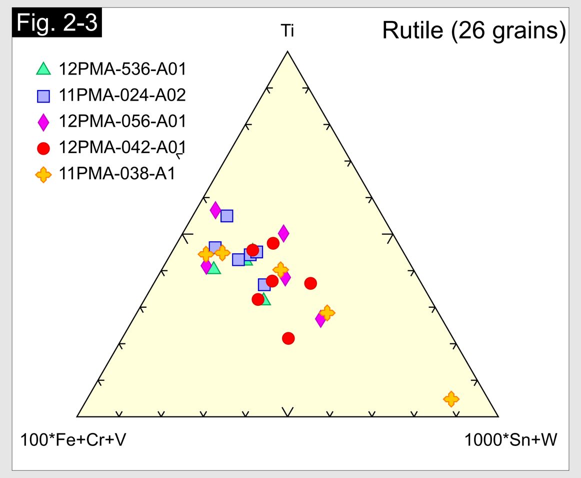


Fig. 2-3: Rutile contains up to 1 wt.% W averaging 658 ppm W.

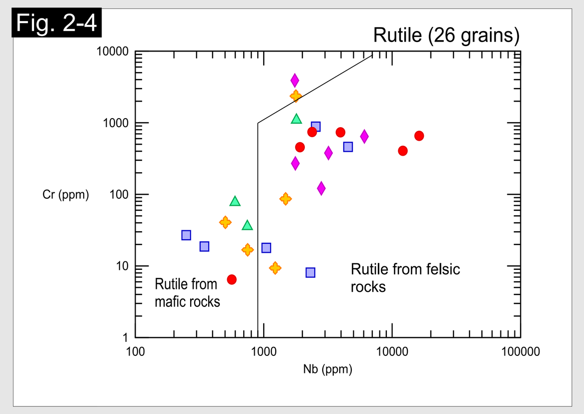


Fig. 2-4: Rutile samples are sourced from both felsic and mafic rocks according to the discrimination from Meinhold (2010).

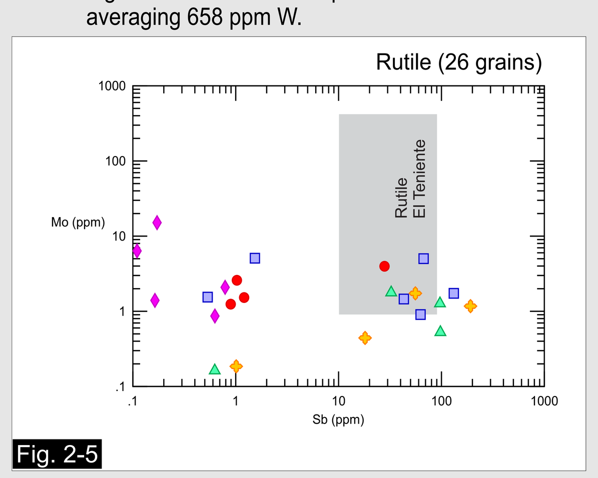


Fig. 2-5: The diagram shows the Mo and Sb content of rutile from the study area compared to the values from high- and low-grade ore at the El Teniente Cu deposit in Chile reported by Rabbia et al. (2009; their Fig. 5a) (grey box). Only sample 12-PMA-056-A01, located up-ice from mineralization, does not contain a grain within the El Teniente field. None of the rutile grains in till contain a high Mo content as observed in the mineralized felsic intrusive rocks at El Teniente (186 ± 20 ppm Mo) by Rabbia et al. (2009).

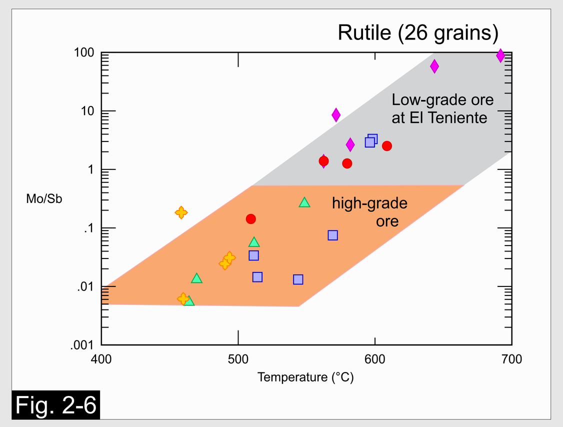


Fig. 2-6: Rabbia et al. (2009) showed a trend between Mo/Sb ratio and crystallization temperature in rutile from low- to high- grade ore at El Teniente (brown and grey shaded areas). Rutile grains in till yielded crystallization temperatures ranging from 460 to 700 °C, using the Zr-in-rutile geothermometry of Ferry and Watson (2007). Only samples 11PMA-024-A2, 11PMA-038-A1 and 12PMA-536-A01 located close and down-ice from mineralization contain mulitple grains that plot in the high-grade ore field of Rabbia et al. (2009).

Zircon

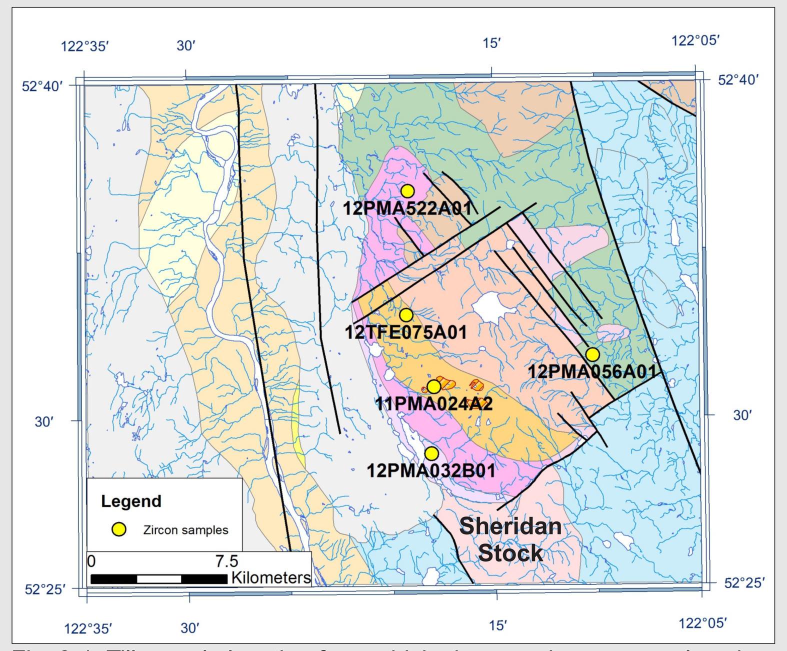


Fig. 3-1: Till sample location from which zircon grains were analyzed.

Zircon grains have subhedral to euhedral crystal habit with many inclusions (Fig. 3-2). Images of cathodoluminescence – scanning electron microscope (CL-SEM) show oscillatory zoning, indicating an igneous origin of the grains. Most grains (95%) display sector zoning (Fig. 3-2B). Chondrite-normalized rare earth element (REE) patterns are similar among all grains (Fig. 3-3). Together with the well-developed zoning patterns, the zircon grains are interpreted to be derived from felsic igneous rocks.

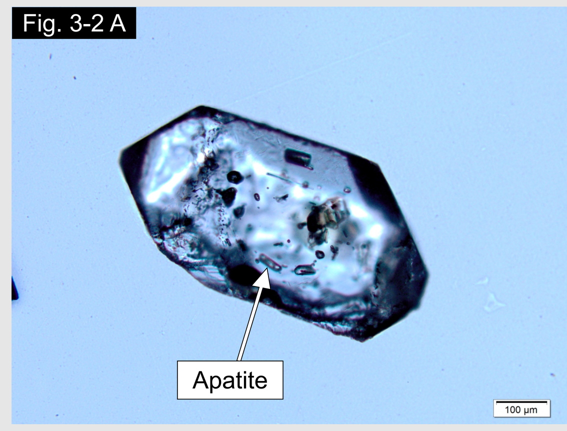


Fig. 3-2 A: Typical euhedral zircon grain recovered from till with apatite inclusions.

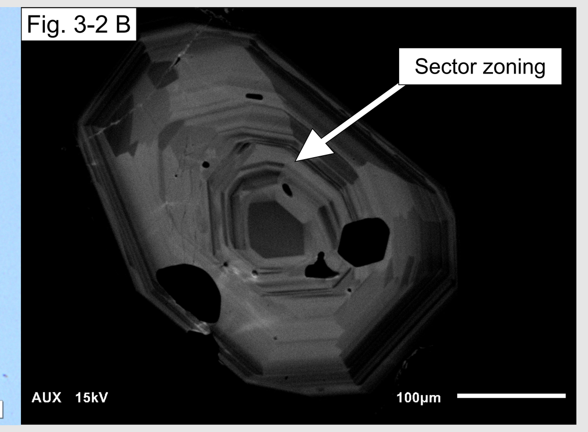


Fig. 3-2 B: CL-SEM image of zircon grain #32 from sample site 11PMA-024-A02.

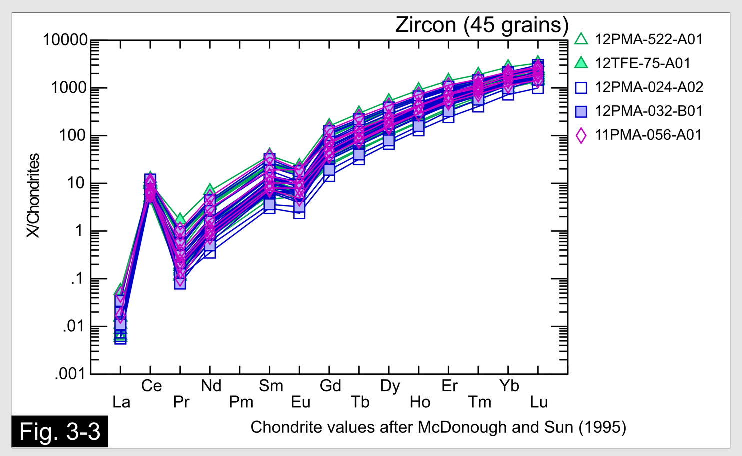


Fig. 3-3: Chondrite-normalized REE patterns are similar among all zircon grains from till. Along with their well developed oscillatory zoning (Fig. 3-2B) they are interpreted to be derived from felsic intrusive rocks.

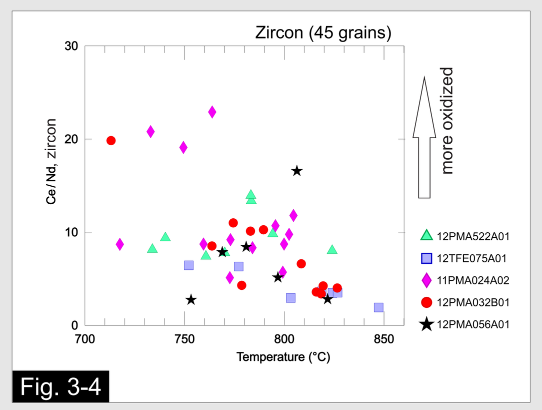


Fig. 3-4: Ti content in zircon ranges from 5 to 19 ppm. Crystallization temperatures range from 713 to 847 °C using Ti-in-zircon geothermometry by Ferry and Watson (2007) with an activity of 0.7 for TiO_2 and an activity of 1 for SiO_2. Cerium occurs as Ce^{4+} in oxidized magmas (potentially fertile for porphyry mineralization) and can subsitute for Zr^{4+} in zircon to produce positive Ce anomalies in chondrite-normalized REE patterns (Fig. 3-3). We use the ratio Ce/Nd to show the degree of the Ce anomaly in zircon and hence, the relative oxidation state of the magma. Some zircon grains from till plot in the oxidized magma field which is interpreted as an indicator of mineralization fertility (Ballard et al. 2002). Sample 11PMA-024-A02 with three zircon grains with an oxidized magma signature is located close (<1 km) to the main mineralization.

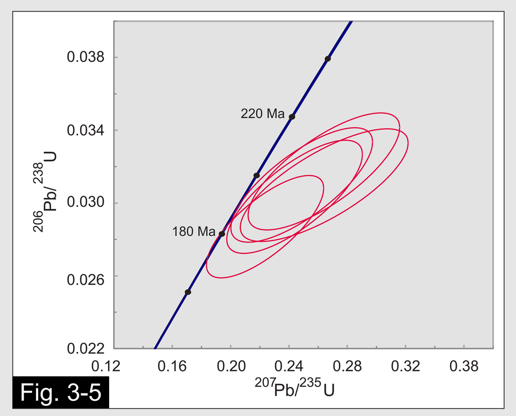


Fig. 3-5: To evaluate the provenance of zircon grains in till, ages of individual grains were calculated from their U and Pb isotope compositions determined with LA-ICP-MS. Most grains yielded Concordia ages around 210 Ma, which are similar to the ages of the Granite Mountain batholith: 210-215 Ma (Schiarrizza, 2014). Five out of seven zircon grains at 12TFE-075-A01 yielded young Concordia ages; 177±11, 186±11, 192±12, 185 ±12, and 189 ±12 Ma (shown above). The source of these grains is uncertain.

Epidote

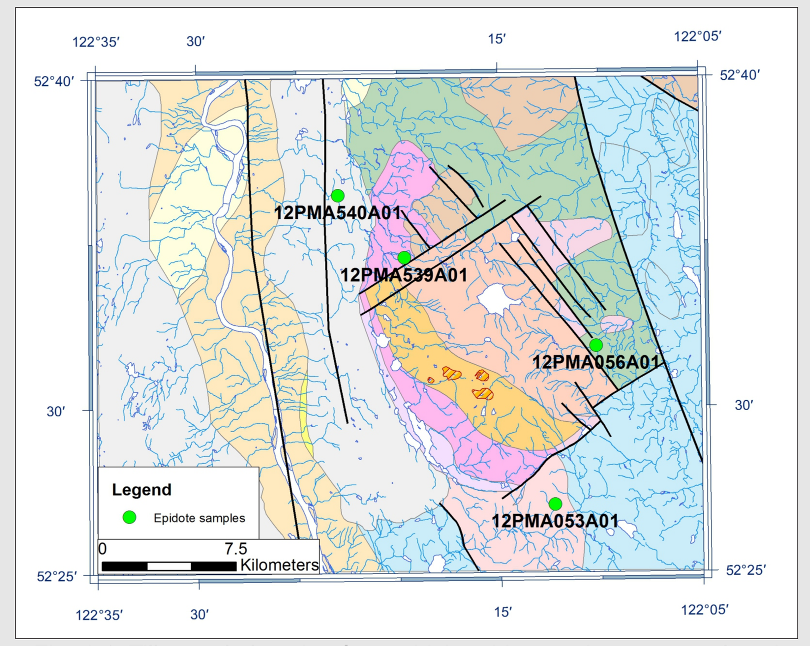


Fig. 4-1: Till sample location from which epidote grains were analyzed.

Grains of epidote in till are Ca-rich (ca. 23 wt.%) with varying Fe_2O_3(t) (12-20 wt.%). The 93 grains analyzed show total REE contents up to 0.1 wt.%. Approximately 40% of epidote grains contain mineral inclusions of titanite. Titanite contains a variance of Al_2O_3 between 1 and 5 wt.%, suggesting that they are mostly hydrothermal in origin (Kobylinski et al., 2016). Other mineral inclusions are zircon, quartz, apatite, magnetite and actinolite. Although Al-rich epidote in till is similar in composition to that associated with sulphide minerals at Gibraltar, epidote in till is distinctly different from that in the Granite Mountain batholith. Epidote in till contains abundant mineral inclusions with no compositional zoning, whereas epidoth in the batholith lacks mineral inclusions and shows compositional zoning with Fe-rich rims (Kobylinski et al., 2016).

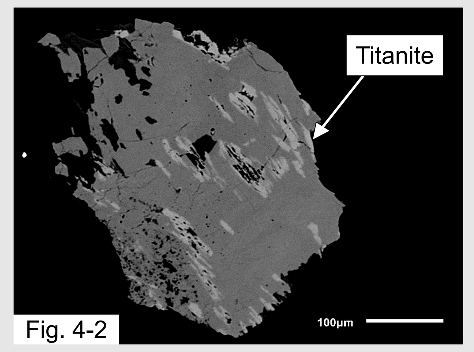


Fig. 4-2: SEM-BSE image of epidote grain #14 from sample site 12PMA-540-A01.

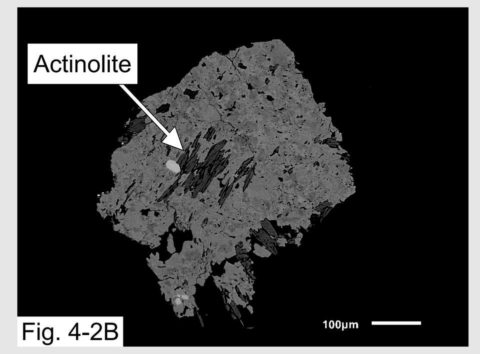


Fig. 4-2B: SEM-BSE image of epidote grain #1 from sample site 12PMA-053-A01.

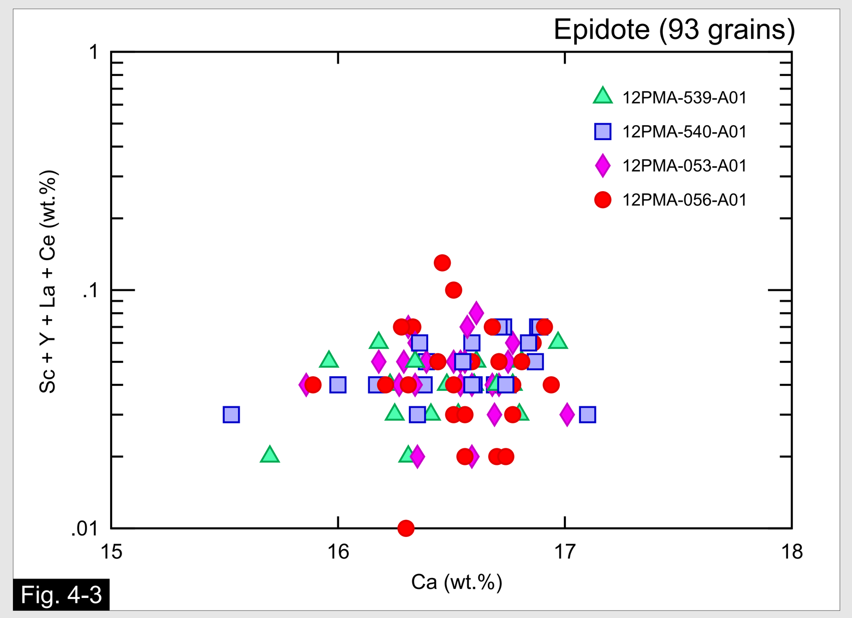


Fig. 4-3: Abundance of REE elements in epidote for 93 grains analyzed by EPMA.

Epidote group general formula: $A_2M_3[T_2O_7][TO_4](O,F)(OH,O)$

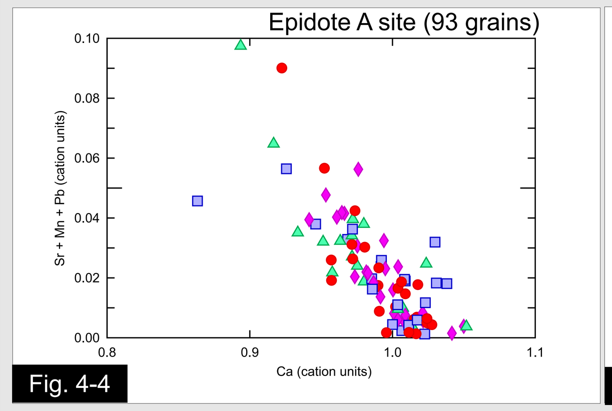


Fig. 4-4: Abundance (cation units) of elements allocated to the A site mineral formula of epidote based on 93 grains analyzed by EPMA.

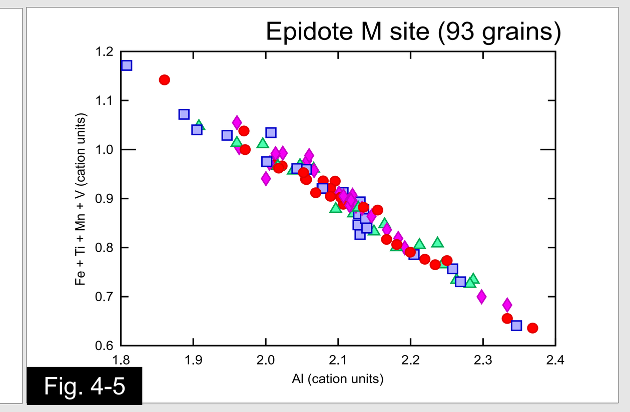


Fig. 4-5: Epidote grains in till show varying Al and Fe contents. Fractionation of Fe into the sulphide phases can form low-Fe, high-Al epidote.

Summary

- Some rutile grains in till at Gibraltar have a trace element composition (Mo and Sb) similar to rutile from the high- and low-grade ore zones at the El Teniente Cu-Mo porphyry deposit in Chile (Rabbia et al., 2009). Comparison between rutile composition in till and in ore at Gibraltar is in progress.
- Zircon grains display sector and oscillatory zoning indicating they are of igneous origin.
- Three zircon grains in one till sample located close (<1 km) from the main mineralization show high Ce/Nd ratios suggesting that they are derived from relatively oxidized magmas.
- Comparison of zircon grains in till and zircon from the Granite Mountain batholith is on-going.
- Epidote shows a compositional variation from Fe-rich epidote to Al-rich clinozoisite.
- Although Al-rich epidote is similar in composition to that from the mine site, epidote in tills is distinctly different from that in the Granite Mountain batholith because the former shows abundant mineral inclusions and no compositional zoning, whereas epidote in the batholith lacks mineral inclusions and shows distinct compositional zoning with Fe-rich rims (see Kobylinski et al., 2016).
- Grains of zircon and rutile with a composition indicative of a porphyry mineralized source have been identified in till samples located close and distal (ca. 12 km) from mineralization. These minerals were dispersed by detrital glacial processes and have survived post-glacial weathering. Our results demonstrate that zircon and rutile recovered from till can be indicative of mineralization but need to be further tested as PCIM.

Acknowledgements

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References

Ash, C.H. and Riveros, C.P., 2001. Geology of the Gibraltar copper-molybdenite deposit, east-central British Columbia (93B/9); in Geological Fieldwork 2000, British Columbia Ministry of Energy and Mines, Paper 2001-1, Victoria, p. 119-134.

Ballard, J.R., Palin, J.M., and Campbell, I.H., 2002. Relative oxidation states of magmas inferred from Ce(IV)/Ce(III) in zircon: application to porphyry copper deposits of northern Chile; Contributions to mineralogy and petrology, v. 144, p. 347-364. doi:10.1007/s00410-002-0402-5

Ferry, J.M. and Watson, E.B., 2007. New thermodynamic models and revised calibrations for the Ti-in-zircon and Zr-in-rutile thermometers; Contributions to mineralogy and petrology, v. 154, p. 429-437. doi:10.1007/s00410-007-0201-0

Kobylinski, C., Hattori, K., Smith, S., and Plouffe, A., 2016. Report on the composition and assemblage of minerals associated with the porphyry Cu-Mo mineralization at the Gibraltar deposit, south central British Columbia, Canada; Geological Survey of Canada, Open File 8025, 30 p. doi:10.4095/298804

McDonough, W.F. and Sun, S.S., 1995. The composition of the Earth; Chemical Geology, v. 120, p. 223-253. doi:10.1016/0009-2541(94)00140-4

Meinhold, G., 2010. Rutile and its applications in earth sciences; Earth-Science Reviews, v. 102, p. 1-28. http://dx.doi.org/10.1016/j.earscirev.2010.06.001

Plouffe, A. and Ferbey, T., 2016. Till geochemistry, mineralogy and textural data near four Cu porphyry deposits in British Columbia; Geological Survey of Canada, Open File 8038 and British Columbia Geological Survey Geofile 2016-10, 1 .zip file. doi:10.4095/298805

Plouffe, A., Ferbey, T., and Anderson, R.G., 2014. Till composition and ice-flow history in the region of the Gibraltar Mine: developing indicators for the search of buried mineralization; Geological Survey of Canada, Open File 7592, poster. doi:10.4095/293839

Rabbia, O.M., Hernández, L.B., French, D.H., King, R.W., and Ayers, J.C., 2009. The El Teniente porphyry Cu-Mo deposit from a hydrothermal rutile perspective; Mineralium Deposita, v. 44, p. 849-866. doi:10.1007/s00126-009-0252-4

Schiarizza, P., 2014. Geological setting of the Granite Mountain batholith, host to the Gibraltar porphyry Cu-Mo deposit, south-central British Columbia in Geological Fieldwork 2013, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey, Paper 2014-1, p. 95-110.

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