Porphyry Indicator Minerals (PIMs): Exploration for Concealed Deposits in British Columbia

Mineral Deposit Research Unit
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Geoscience BC

Statement of the Question

Resistate minerals have successfully been applied to diamond exploration but have only rarely been used as exploration tools for porphyry copper deposits. The common occurrence of resistate minerals as alteration products in British Columbia porphyry copper deposits suggests that these porphyry indicator minerals (PIMs) could provide a key tool to the increase of exploration targeting success, especially in terrains covered by glacial till.

The key objectives of the project are:

- Determine the occurrence and types of resistate minerals in various styles of alteration and mineralization in several BC porphyry copper-gold deposits to establish a PIMs signature.
- Determine the diagnostic physical parameters and chemical compositions of resistate minerals.
- Identify important indicator minerals and establish physical properties to distinguish those resistate minerals that are directly associated with porphyry copper-gold deposits.
- Establish criteria for use of resistate minerals as an exploration tool in BC.

Common resistate minerals in BC porphyry deposits*:

Rutile (4.2)	Monazite (~5.1)
Apatite (3.2)	Titanite (~3.5)
Garnet (~3.9)	Tourmaline (~3)
Zircon (4.6)	Jarosite (~3)

*numbers in the bracket are specific gravity.

Acknowledgments

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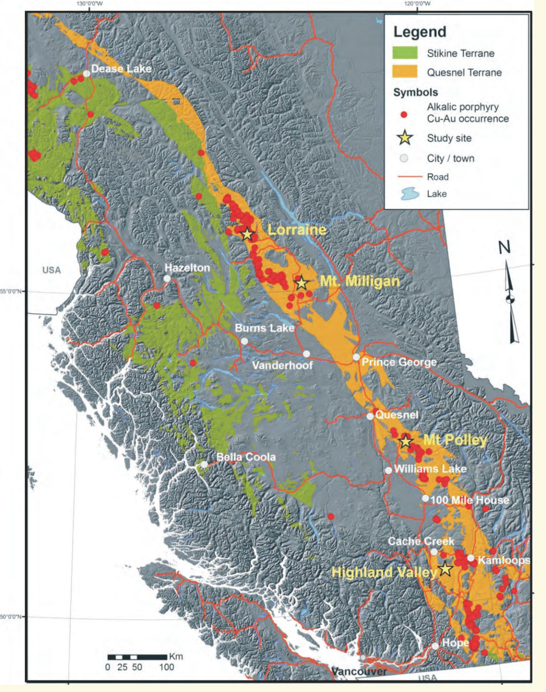
Materials and Methods

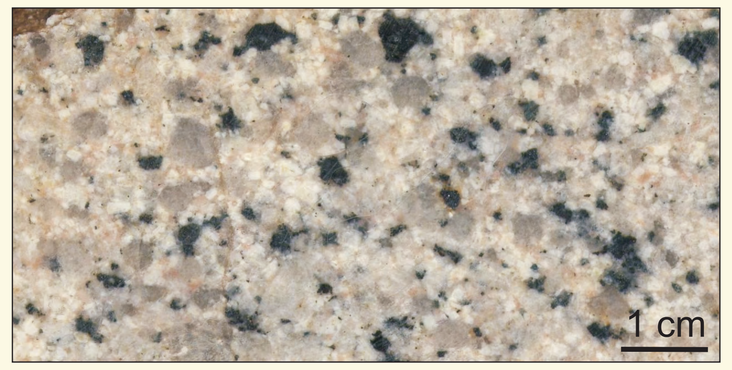
Quesnel and Stikine terranes host most of BC's known porphyry copper deposits. The Highland Valley, Mount Polley, Mount Milligan and Lorraine deposits represent examples of the typical styles and assemblages of porphyry deposits in the Quesnel terrain and were therefore selected for this project.



Digital elevation map of south-central BC with location of selected deposits.

Sampling

- Samples were selected from different alteration assemblages at different vertical levels to determine and characterize the occurrence of resistate minerals at various depths in a porphyry system.
- Samples were also collected from unmineralized host-rocks for direct comparison.



Fresh Bethsaida granodiorite, the main host-rock to mineralization at Highland Valley, with rounded quartz phenocrysts and biotite books.

Intense green mica alteration and associated chalcopyrite mineralization overprinting the Bethsaida granodiorite.

Methods

- Petrographic study employing optical and cathodoluminescence (CL) microscopy and scanning electron microscopy (SEM).
- Electron microprobe analysis of selected grains.
- Resistate minerals have also been separated to different size fractions for mineral liberation analyzer (MLA), which is an automated scanning electron microscope.

Results

Apatite, zircon and, to a lesser extent, rutile and titanite are common resistate minerals in the studied deposits. Apatite is by far the most common resistate mineral occurring in a wide range of host-rocks and alteration assemblages. More critically, physical and chemical properties of apatite are significantly different in altered-mineralized rock.

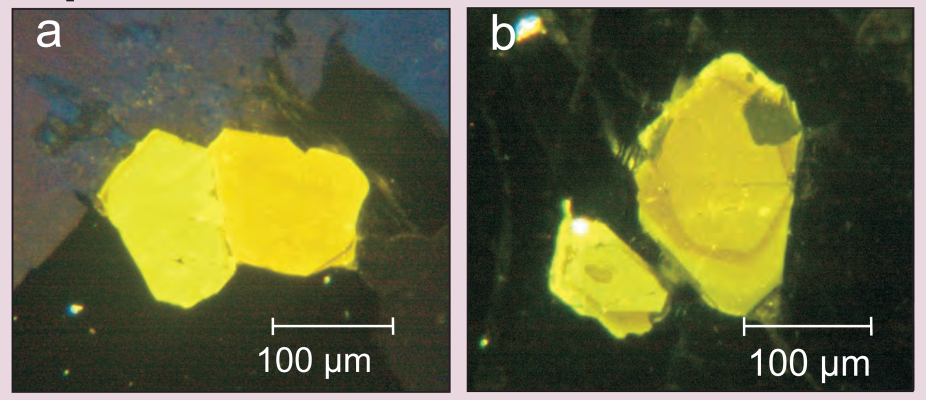
Apatite in fresh host-rock:

- Displays strong luminescence of yellow to yellow-green and sometimes yellow-brown.
- The yellow luminescence is attributed to excitation by Mn^{2+}.
- No major internal structures were observed using either CL or SEM.
- Some grains show a distinctive narrow brownish luminescence zone near the crystal rim.

Apatite in altered host-rock:

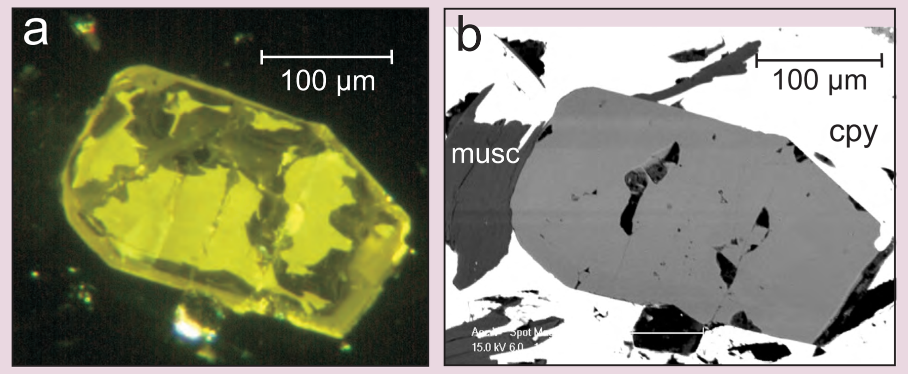
- Looks very similar to that associated with unaltered host-rock when examined using a polarizing microscope and SEM.
- However, CL microscopy reveals that apatite associated with altered host-rocks displays a unique green luminescence, probably reflecting Fe^{2+} excitation.
- It is also overprinted by a dark complex network and bodies of dark-green to grey-luminescent domains producing a characteristic 'messy' texture contemporaneous with muscovite alteration and associated copper mineralization.

Apatite in fresh host-rock

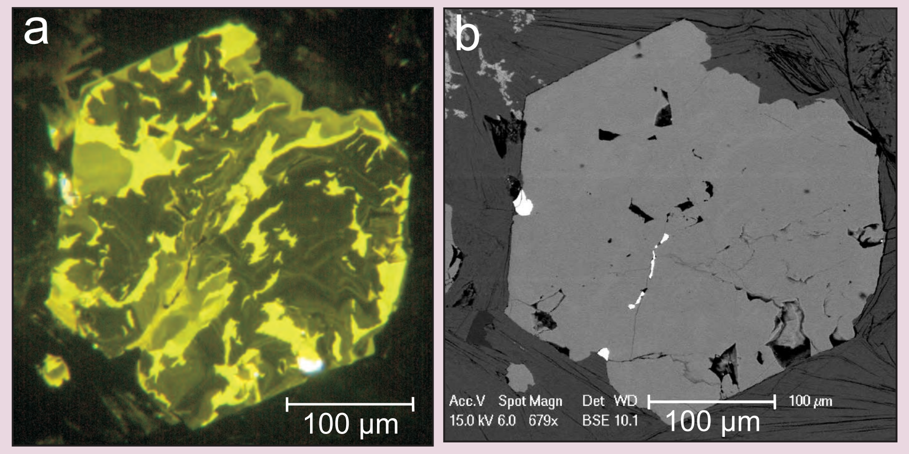


a) CL image showing two primary apatite grains with yellow to yellow-pale green luminescence and no obvious internal texture; b) apatite with a brown luminescence zone near rim.

Apatite in altered host-rock



a) CL image of apatite in altered granodiorite showing green-luminescent phase replaced by dark green- to grey-luminescent phase; b) SEM image showing no internal texture.



a) CL image showing replacement of the green-luminescent apatite by a dark green- to grey-luminescent phase generating a 'messy' texture; b) SEM showing chalcopyrite, very bright phase at the rim and inside the apatite, which has formed within a micro-fracture that has an envelope of green to grey-luminescent apatite.

Conclusions

- Altered apatite displays yellow-green luminescence due to excitation by Fe^{2+}.
- Strongly-altered apatite shows dark-green to grey luminescence, due to the loss of Mn^{2+}, producing a complex texture with remnants of green-luminescent apatite.
- Preliminary microprobe data suggest that apatite in altered host-rock has lost several trace components such as Mn^{2+}, Cl and S.