Porphyry Indicator Minerals (PIMs): Targeting Mineralized Centres using Apatite Texture and Chemistry

Farhad Bouzari[1], Craig Hart[1], Shaun Barker[1] and Thomas Bissig[1, 2]
[1]Mineral Deposit Research Unit, University of British Columbia. [2]Geoscience BC, Vancouver

PIMs and Mineral Exploration

Resistate accessory minerals have successfully been utilized in diamond exploration by evaluating the mineralogy of their host kimberlites. Although easy to collect in heavy mineral concentrates, resistate minerals have only rarely been used as exploration tools for other deposit types, because the characteristics of these minerals in other ore systems have not been well characterized.

Porphyry indicator minerals (PIMs) are minerals, such as apatite, rutile, garnet and titanite, that are associated with porphyry copper deposits and are resistant to weathering. Thus, an improved understanding of these minerals could provide a key tool to increase exploration targeting success, especially in glacial, fluvial and regolith terrains.

Huckleberry mine, pit bench, showing weathered and leached jarositic-goethitic host-rock covered by glacial till.

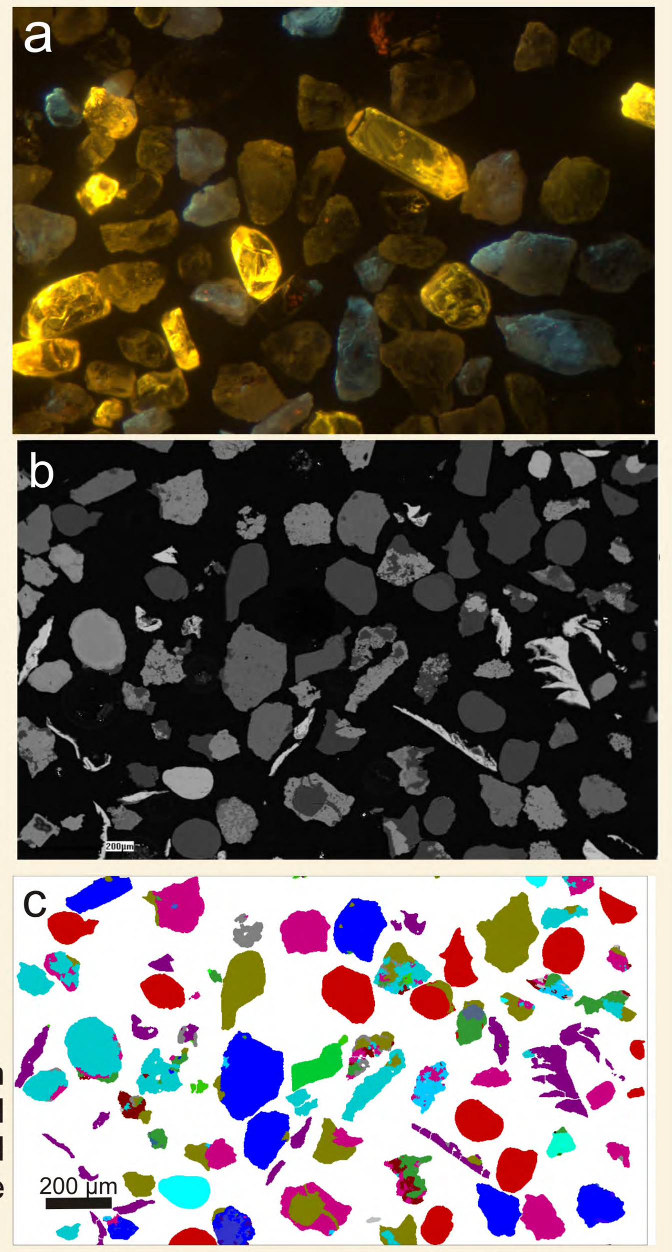
Apatite in Porphyry Copper Deposits

Apatite is a common accessory mineral in igneous rocks related to porphyry copper deposits and may also form during K-silicate alteration. Trace element composition of apatite has been used to recognize the host rock and degree of fractionation and oxidation state of the host magma. Apatite from porphyry deposits is Cl-rich, displays yellow luminescence under CL (cathodoluminescence) and shows complicated history of corrosion and redeposition with a characteristic zoning (liesegang rings).

Methods

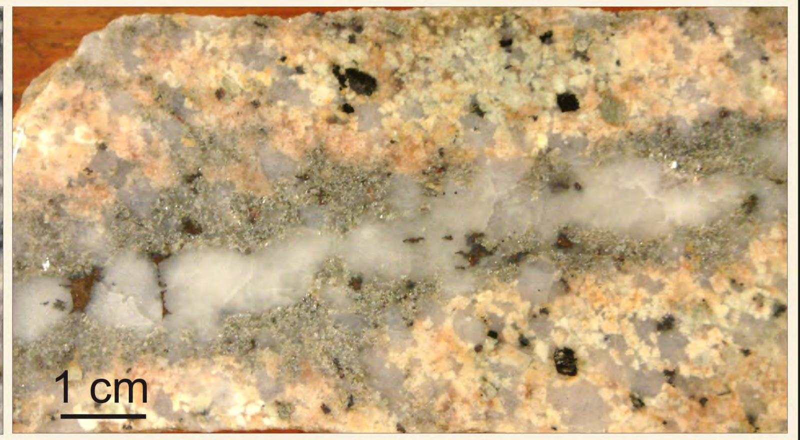
Samples were selected from different alteration assemblages at different vertical levels to determine and characterize the occurrence of apatite at various depths in a porphyry system. Samples were also collected from unmineralized host-rocks for direct comparison.

Analytical techniques included petrographic study employing optical and cathodoluminescence (CL) microscopy, scanning electron microscopy (SEM), electron microprobe analysis and MLA (Mineral Liberation Analysis) which is an automated scanning electron microscope.



a) CL image of heavy mineral separate from Mt Milligan moderately altered host rock showing transparent yellow and dull yellow apatite. **b** and **c)** Example of SEM and corresponding MLA image of heavy mineral separate showing apatite grains color coded dark blue.

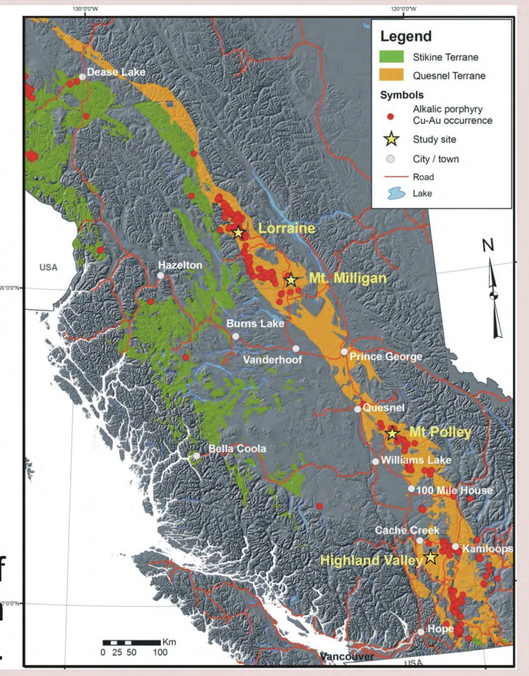
Fresh Bethsaida granodiorite, the main host-rock to mineralization at Highland Valley, with rounded quartz phenocrysts and biotite books.



Sample of Valley ore zone with pervasive K-silicate alteration cut by quartz-bornite-chalcopyrite vein with coarse green muscovite alteration.

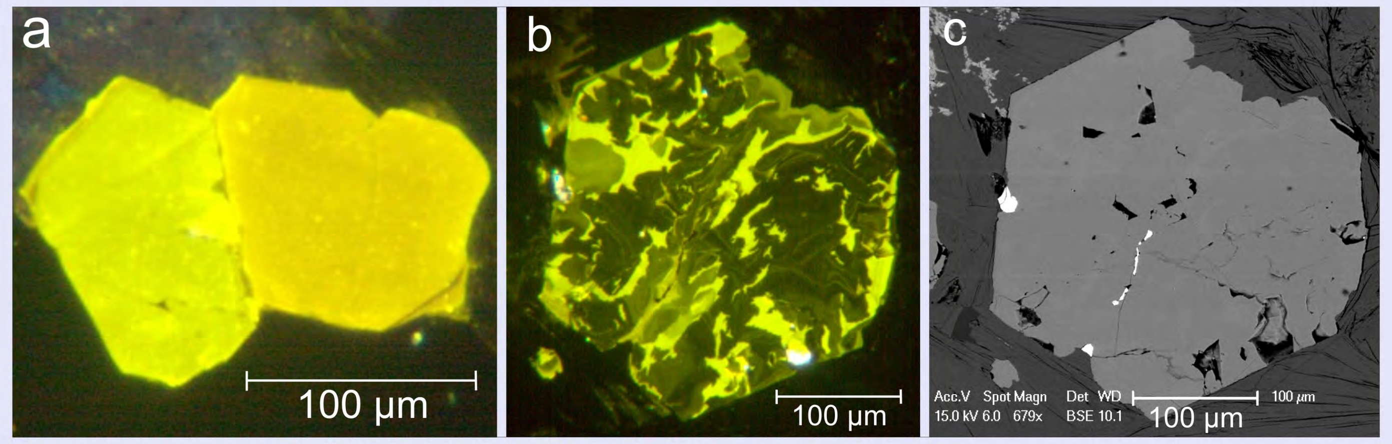
Research Sites

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.

Textural Characteristics



a) CL image showing two primary apatite grains in least altered rock with yellow to yellow-pale green luminescence and no obvious internal texture;
b) CL image of apatite in altered-mineralized host rock showing replacement of the green-luminescent apatite by a dark green- to grey- luminescent phase generating a 'messy' texture;
c) SEM image of the apatite in figure b showing chalcopyrite, as a very bright phase at the rim and inside the apatite formed within a micro-fracture, which in figure b shows an envelope of green to grey-luminescent apatite.

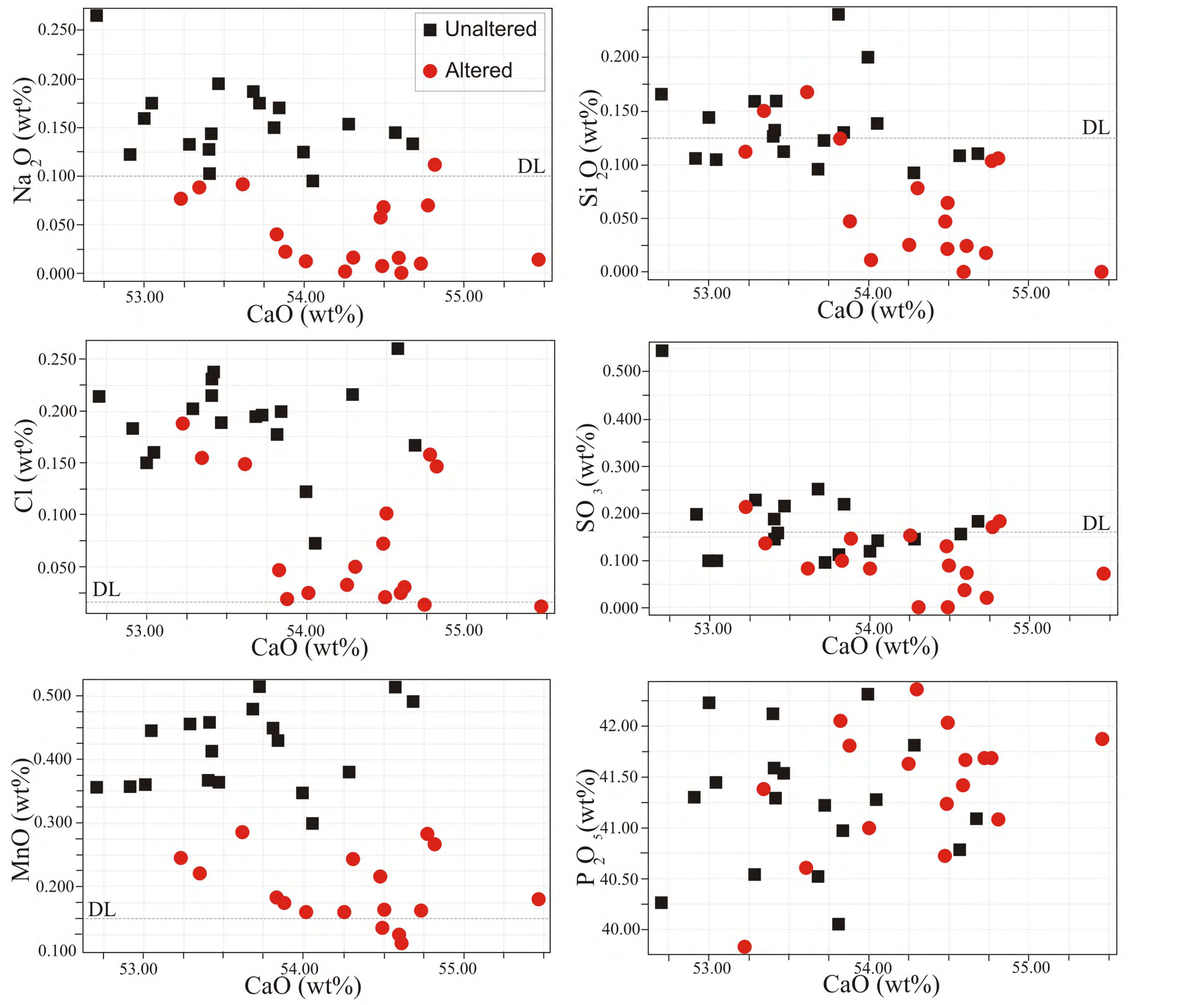
Apatite in fresh host-rock:

- Displays strong luminescence of yellow to yellow-green and sometimes yellow-brown.
- No major internal structures were observed using either CL, SEM or MLA.

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.
- Strongly altered apatite is overprinted by a complex network and bodies of dark-green to grey-luminescent domains producing a characteristic 'messy' texture contemporaneous with muscovite alteration and associated copper mineralization.

Chemical Characteristics



Microprobe analysis on apatite from fresh and altered host rocks indicate that:

- There is no major change in Ca and P content of the apatite in fresh and altered host rock.
- Mn is significantly depleted in the altered rock. Loss of Mn explains observed loss of luminescence in apatite during the hydrothermal alteration event.
- Chlorine was also lost during alteration. Similarly, depletion in F is also expected.
- Na has also been lost in apatite during alteration.
- Most of the reliably measured sulphur values were from fresh apatite. Therefore, sulphur may have also been lost from apatite during alteration event.

Conclusions

- Apatite from unmineralized host rock displays yellow luminescence and is enriched in Mn, Cl and S.
- Altered apatite displays yellow-green luminescence due to excitation by Fe^{2}. Strongly-altered apatite shows dark-green to grey luminescence, producing a complex texture with remnants of green-luminescent apatite, and is depleted in Mn^{2+}, Na, Cl and S.
- These results provide the first step towards application of resistate minerals as indicator for porphyry copper exploration.

Acknowledgments

We would like to thank Teck Corporation (Highland Valley deposit), Terrane Metals Corp (Mount Milligan deposit) and Imperial Metals (Huckleberry deposit) for allowing access and sampling at their properties. ALS Laboratory Group Vancouver provided access to the MLA instrument. Geoscience BC is thanked for its generous financial contribution in support of this project.