Mineralogy and chemistry of tourmaline in the Woodjam porphyry deposits, British Columbia

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Abstract: Tourmaline is a common accessory and gangue mineral in a diverse range of hydrothermal ore-forming systems covering a broad spectrum of pressure, temperature and chemical conditions, reflecting tourmaline's wide stability range. Previous studies, dating back into the 1960s, have shown that tourmaline can very closely track changes in physicochemical conditions within the fluid from which it is precipitated. Tourmaline's refractory and resistant physical properties mean that the mineral is able to preserve this information through numerous subsequent phases of metamorphism, alteration and weathering; in many cases tourmaline may be the only robust remaining record of original hydrothermal processes. Although tourmaline's utility in mineral exploration has been demonstrated, very few studies have attempted to measure concentrations of the ore metals themselves. In general, these limitations have been imposed by the common use of EPMA alone to interrogate mineral chemistry at high spatial resolution.

In many porphyry-related deposits of the South American Cordillera, tourmaline occurrences are abundant and extensive, and have attracted much interest for use during mineral deposit exploration. However, owing to various factors including differences in their tectonic settings and magma chemistries, porphyry-related deposits of the Canadian Cordillera rarely report significant tourmaline among their mineral inventory. Consequently, studies of tourmaline associated with Canadian deposits are limited, and almost no data exist on tourmaline occurrences associated with alkalic or hybrid alkalic - calc-alkalic systems. In this study we report mineralogical and LA-ICP-MS trace element analyses of tourmaline minerals from within the hybrid alkalic and calc-alkalic Woodjam porphyry Cu-Au deposits of central British Columbia. These minerals display significant variation in both their major and trace element compositions, reflecting both temporal and spatial evolution of the magmatic- hydrothermal fluids from which the deposit formed. Tourmaline associated with high-temperature potassic alteration has greater schorl (i.e., Fe-rich) component and trace element abundances characteristic of the core of a porphyry hydrothermal system, while tourmaline recovered in association with distal, lower-temperature, albite-rich alteration has an increased dravitic (i.e., Mg-rich) component and a distinct trace element suite. Tourmaline recovered in intimate association with chalcopyrite mineralization has a pronounced blue colour and increased copper content. Hence, within the Woodjam and other similar deposits it may be possible to use tourmaline mineralogy and chemistry as a vector to mineralization. In addition, careful analysis of tourmaline recovered from surficial samples (till, soil, etc.) may provide detailed information on the type and abundance of any concealed mineralized body.

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GAC-MAC 2014
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May 21, 2014
Tourmaline in the Woodjam porphyry deposits, British Columbia
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Geological Survey of Canada
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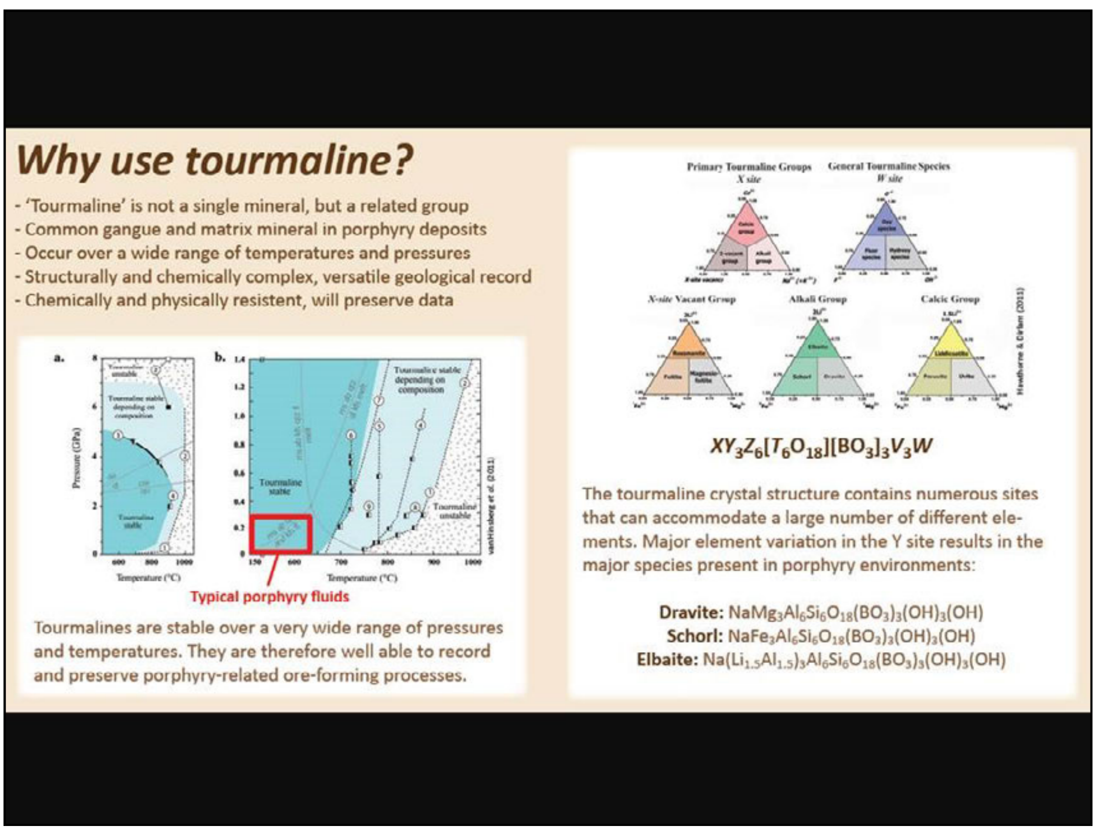
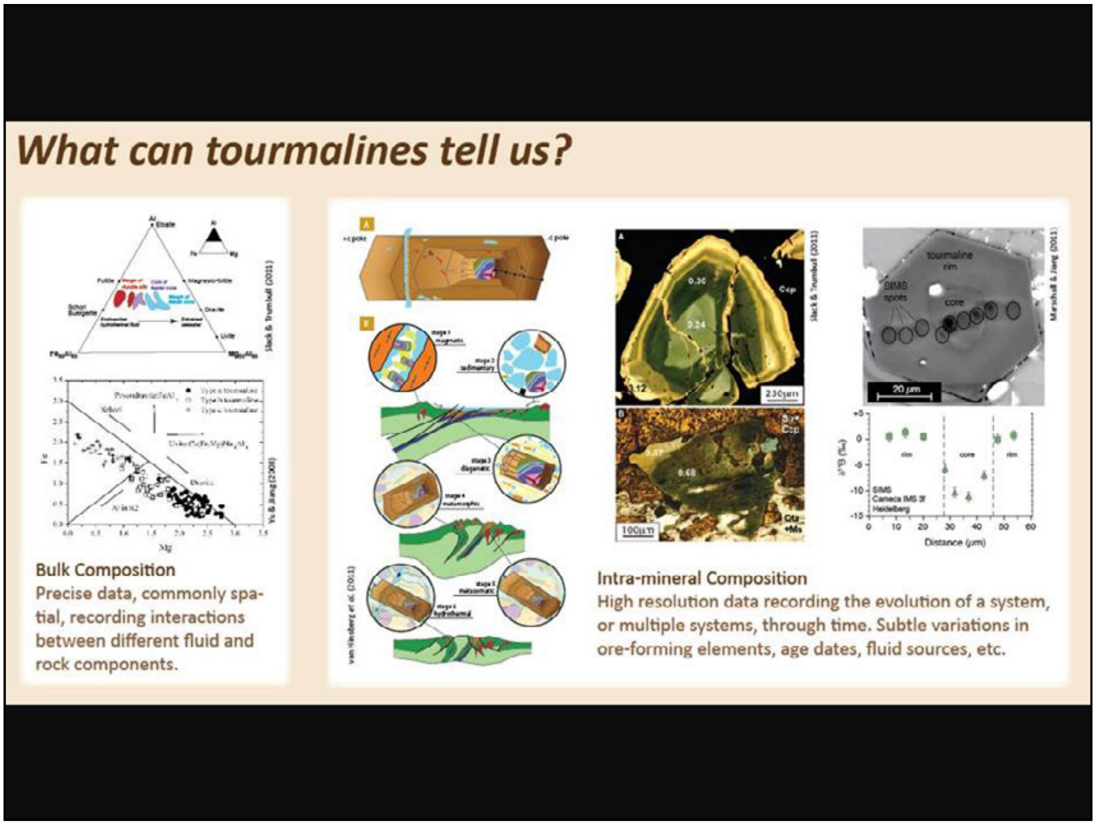
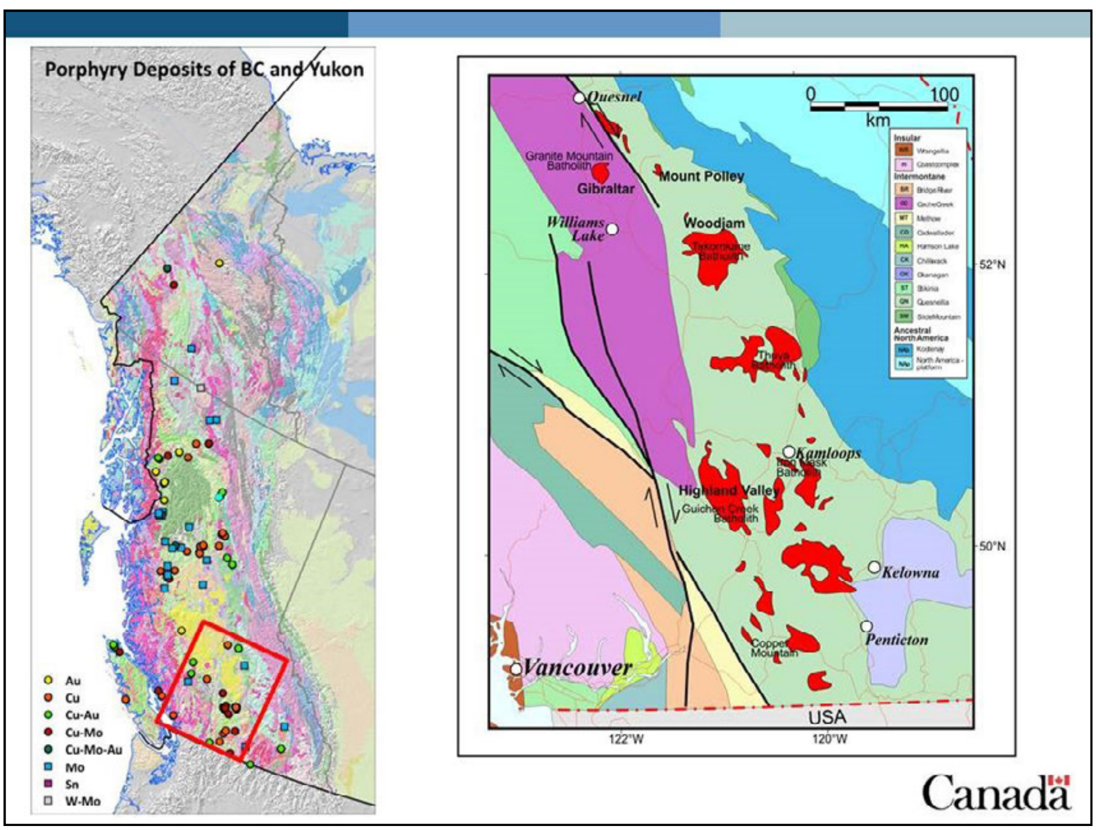
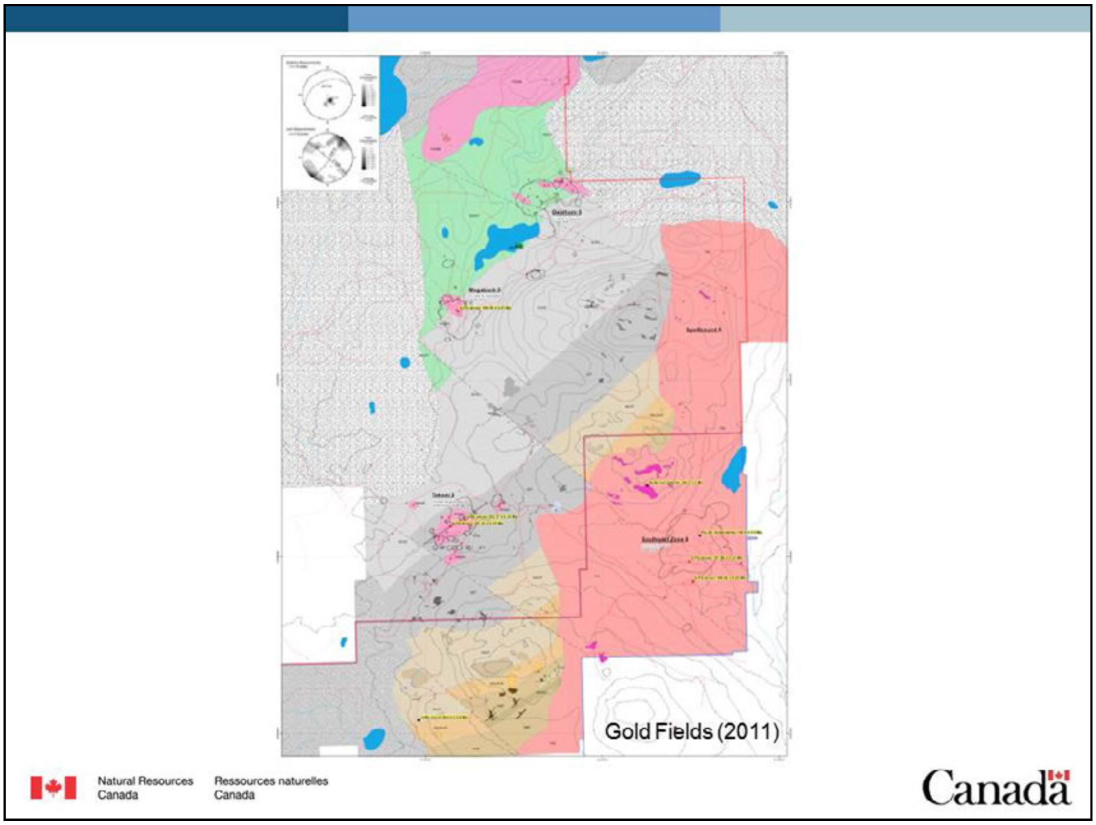

Why use tourmaline?
- 'Tourmaline' is not a single mineral, but a related group
- Common gangue and matrix mineral in porphyry deposits
- Occur over a wide range of temperatures and pressures
- Structurally and chemically complex, versatile geological record
- Chemically and physically resistent, will preserve data
a.
b.
Pressure (GPa)
Temperature (°C)
Tourmaline stable
Tourmaline unstable
Tourmaline stable depending on composition
van Hinsberg et al. (2011)
Typical porphyry fluids
Tourmalines are stable over a very wide range of pressures and temperatures. They are therefore well able to record and preserve porphyry-related ore-forming processes.
Primary Tourmaline Groups X site
General Tourmaline Species W site
X-site Vacant Group
Alkali Group
Calcic Group
Hawthorne & Dirlam (2011)
$XY_3Z_6[T_6O_{18}][BO_3]_3V_3W$
The tourmaline crystal structure contains numerous sites that can accommodate a large number of different elements. Major element variation in the Y site results in the major species present in porphyry environments:
Dravite: $NaMg_3Al_6Si_6O_{18}(BO_3)_3(OH)_3(OH)$
Schorl: $NaFe_3Al_6Si_6O_{18}(BO_3)_3(OH)_3(OH)$
Elbaite: $Na(Li_{1.5}Al_{1.5})_3Al_6Si_6O_{18}(BO_3)_3(OH)_3(OH)$


What can tourmalines tell us?
Slack & Trumbull (2011)
Yu & Jiang (2003)
Bulk Composition
Precise data, commonly spatial, recording interactions between different fluid and rock components.
van Hinsberg et al. (2011)
Slack & Trumbull (2011)
Marschall & Jiang (2011)
tourmaline rim
SIMS spots
core
20 µm
rim
core
rim
Distance (µm)
Intra-mineral Composition
High resolution data recording the evolution of a system, or multiple systems, through time. Subtle variations in ore-forming elements, age dates, fluid sources, etc.


Porphyry Deposits of BC and Yukon
Au
Cu
Cu-Au
Cu-Mo
Cu-Mo-Au
Mo
Sn
W-Mo
Quesnel
0
100
km
Granite Mountain Batholith
Gibraltar
Mount Polley
Williams Lake
Woodjam
Takomkane Batholith
Thuya Batholith
Kamloops
Iron Mask Batholith
Highland Valley
Guichon Creek Batholith
Kelowna
Penticton
Copper Mountain
Vancouver
USA
122°W
120°W
52°N
50°N
Insular
Intermontane
Ancestral North America
Canada


Gold Fields (2011)
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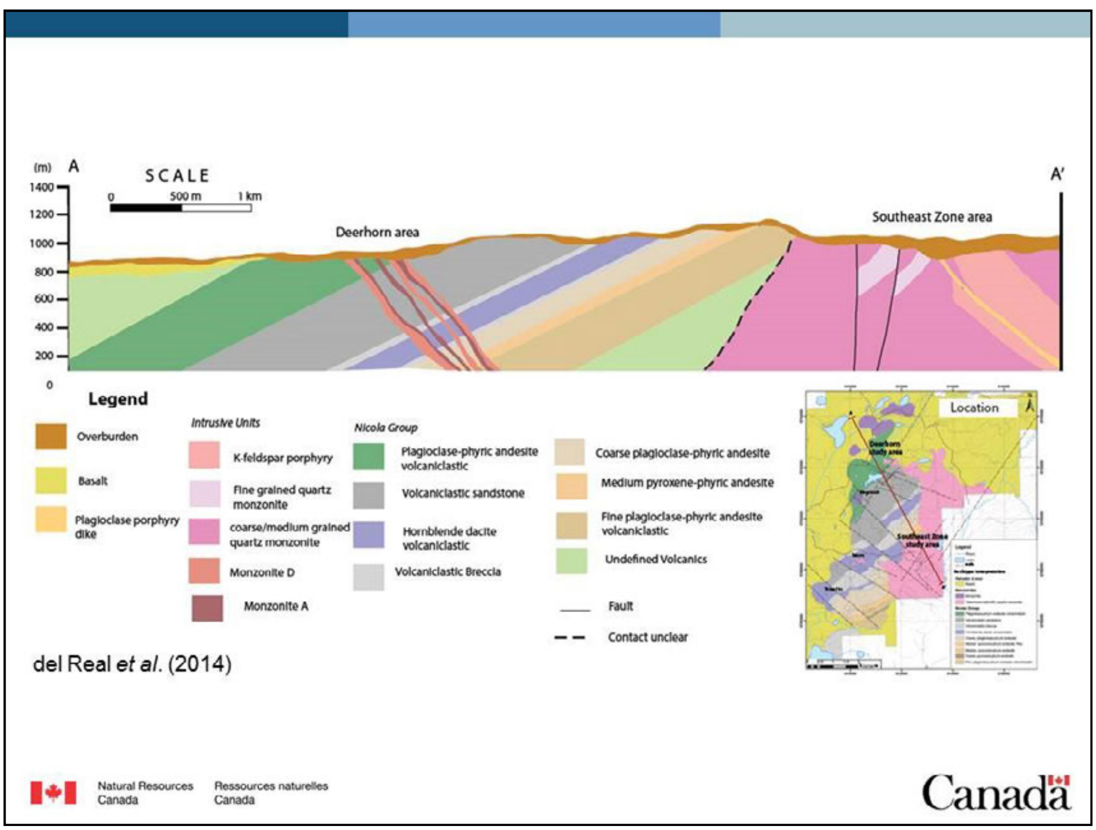
(m)
A
A'
SCALE
0
500 m
1 km
1400
1200
1000
800
600
400
200
0
Deerhorn area
Southeast Zone area
Legend
Overburden
Basalt
Plagioclase porphyry dike
Intrusive Units
K-feldspar porphyry
Fine grained quartz monzonite
coarse/medium grained quartz monzonite
Monzonite D
Monzonite A
Nicola Group
Plagioclase-phyric andesite volcaniclastic
Volcaniclastic sandstone
Hornblende dacite volcaniclastic
Volcaniclastic Breccia
Coarse plagioclase-phyric andesite
Medium pyroxene-phyric andesite
Fine plagioclase-phyric andesite volcaniclastic
Undefined Volcanics
Fault
Contact unclear
Location
Deerhorn study area
Southeast Zone study area
del Real et al. (2014)
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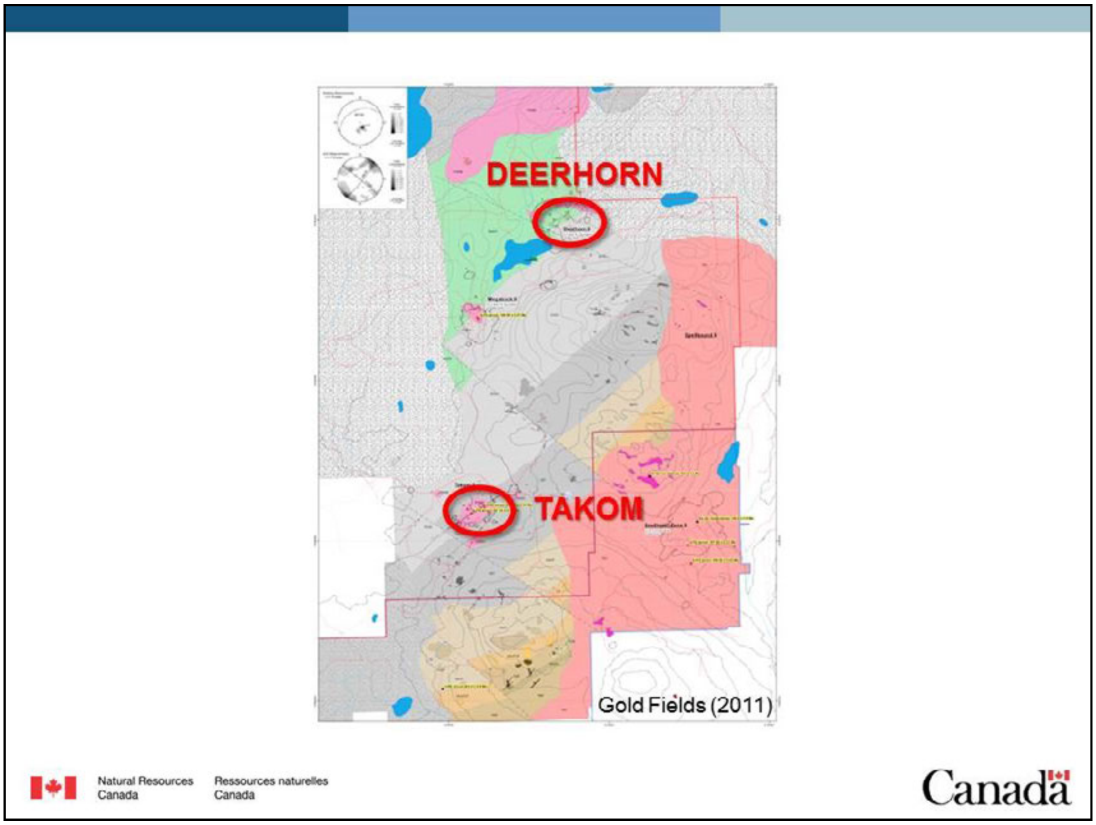
DEERHORN
TAKOM
Gold Fields (2011)
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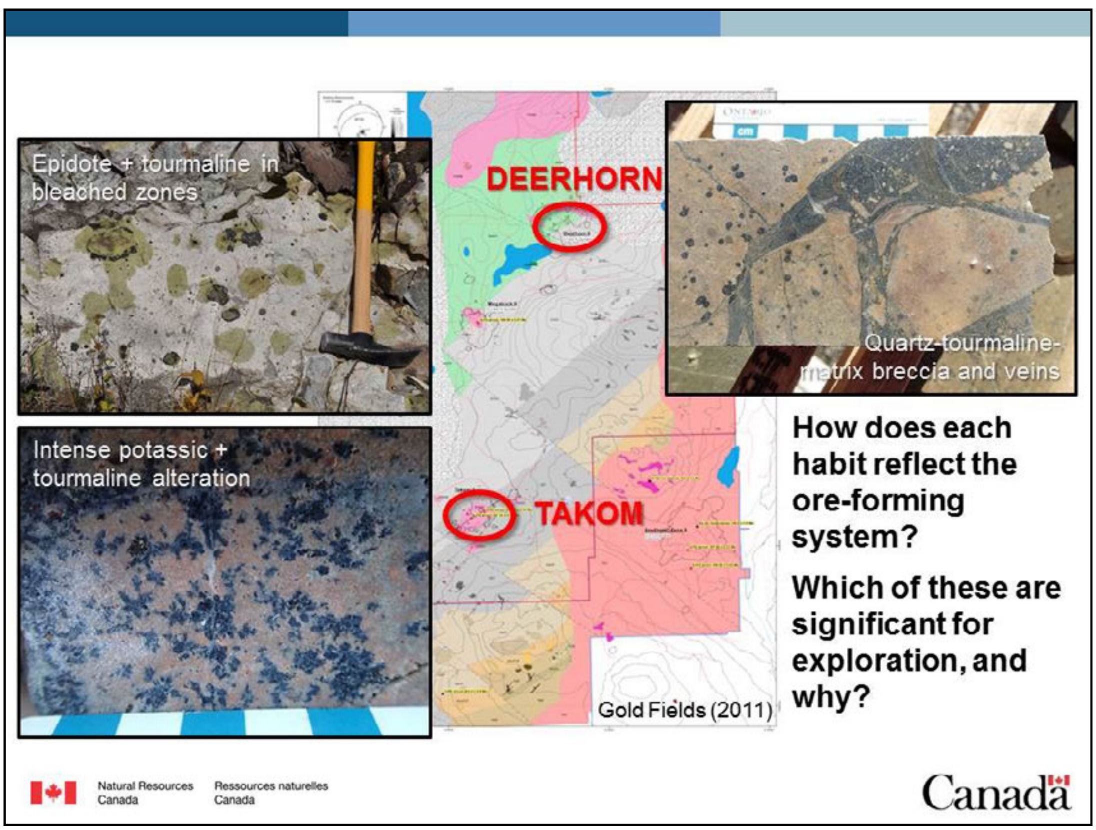
Epidote + tourmaline in bleached zones
Intense potassic + tourmaline alteration
DEERHORN
TAKOM
Gold Fields (2011)
Quartz-tourmaline-matrix breccia and veins
How does each habit reflect the ore-forming system?
Which of these are significant for exploration, and why?
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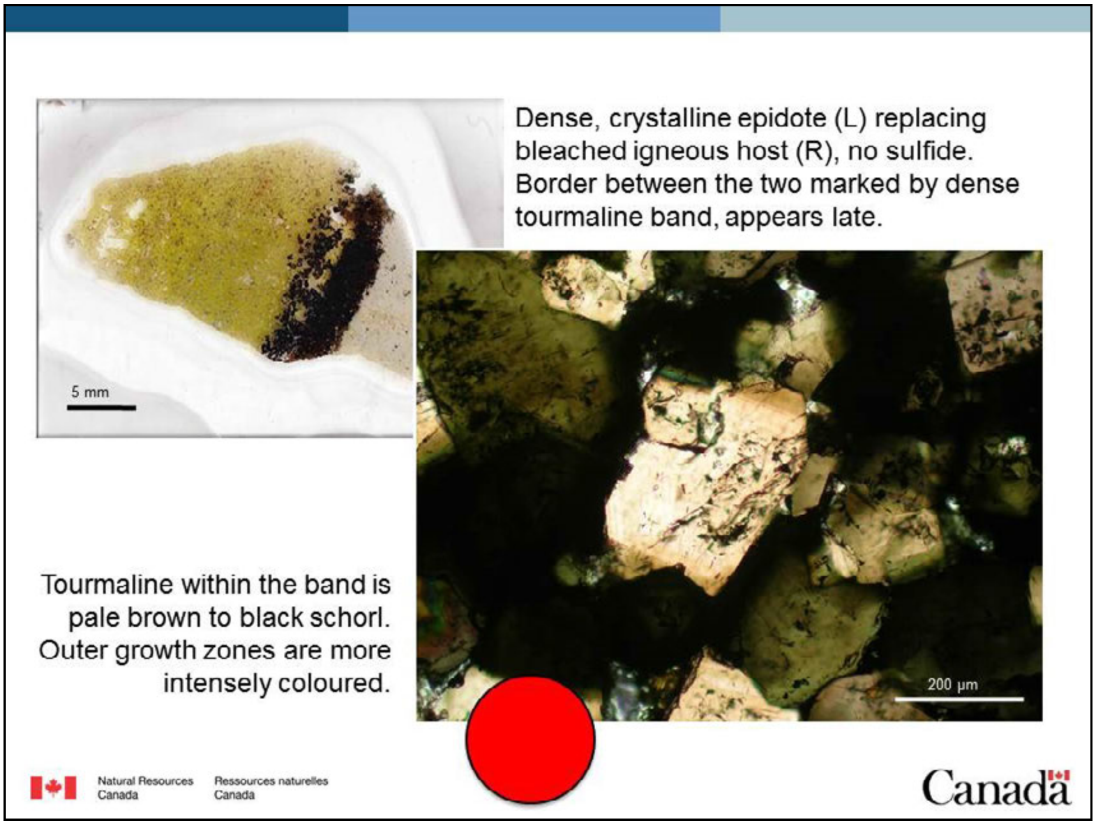
Dense, crystalline epidote (L) replacing bleached igneous host (R), no sulfide. Border between the two marked by dense tourmaline band, appears late.
5 mm
Tourmaline within the band is pale brown to black schorl. Outer growth zones are more intensely coloured.
200 µm
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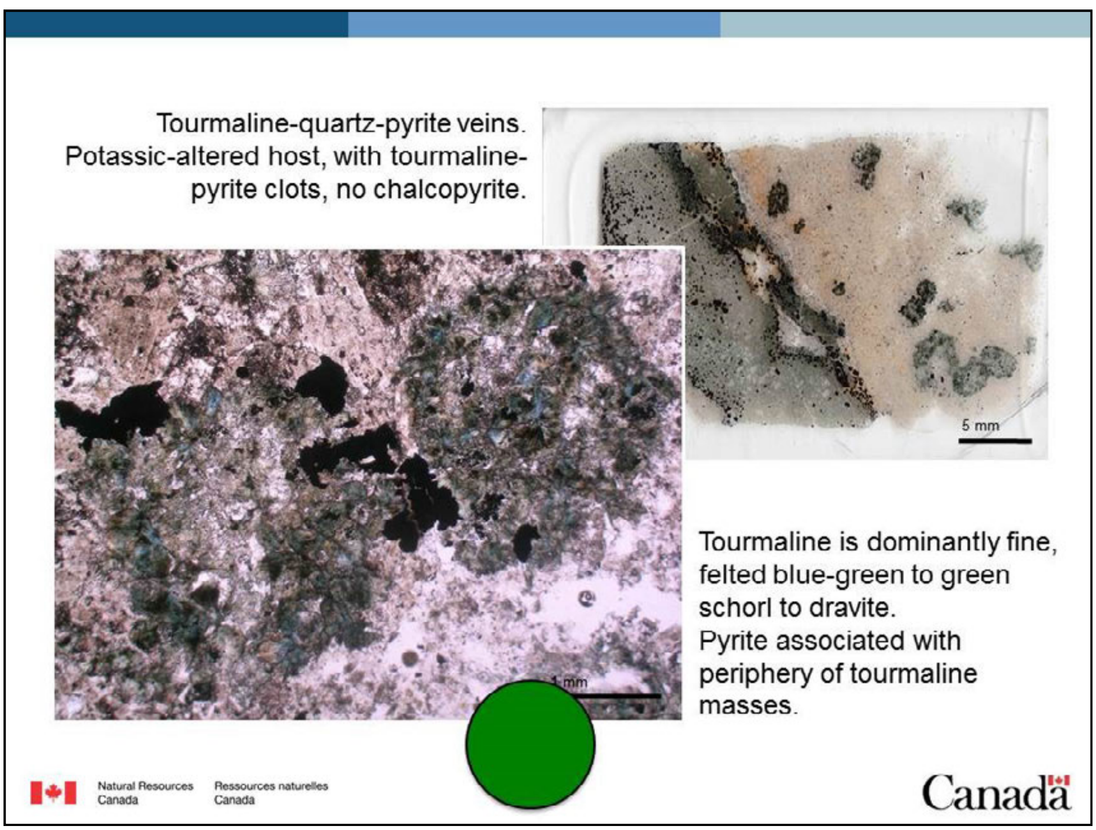
Tourmaline-quartz-pyrite veins. Potassic-altered host, with tourmaline-pyrite clots, no chalcopyrite.
5 mm
1 mm
Tourmaline is dominantly fine, felted blue-green to green schorl to dravite.
Pyrite associated with periphery of tourmaline masses.
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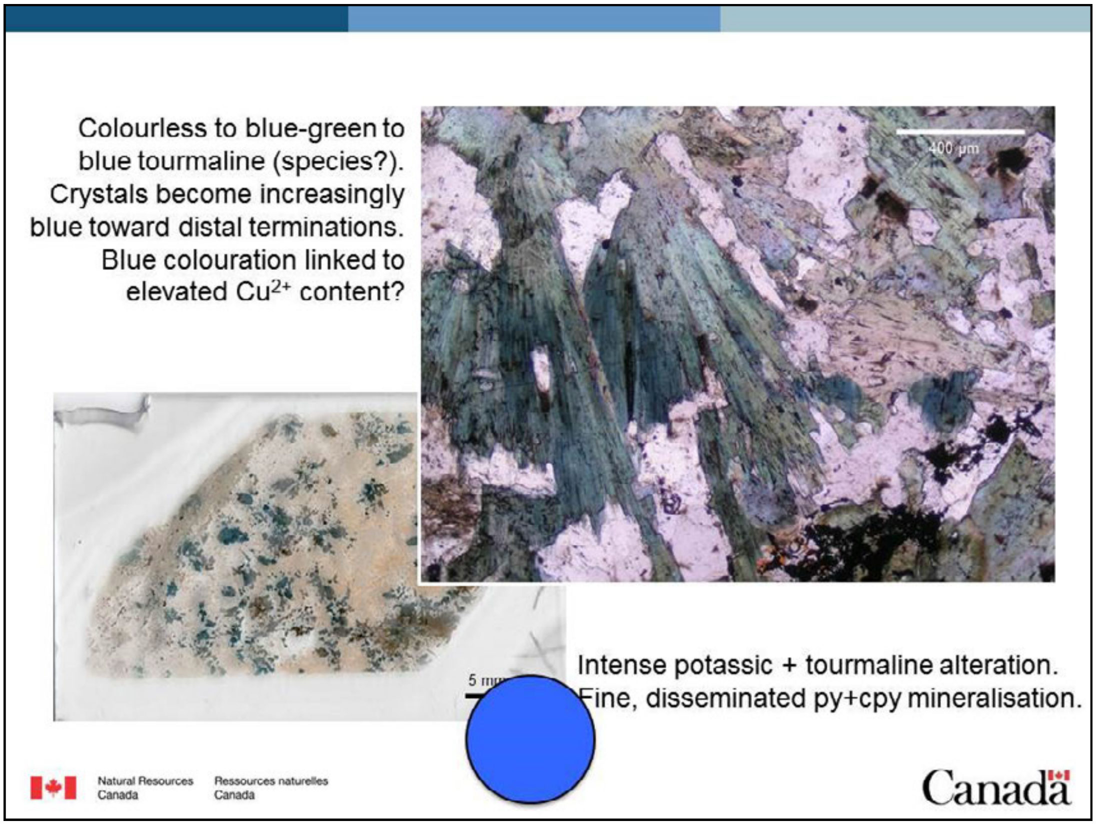
Colourless to blue-green to blue tourmaline (species?). Crystals become increasingly blue toward distal terminations. Blue colouration linked to elevated Cu^{2+} content?
400 µm
Intense potassic + tourmaline alteration. Fine, disseminated py+cpy mineralisation.
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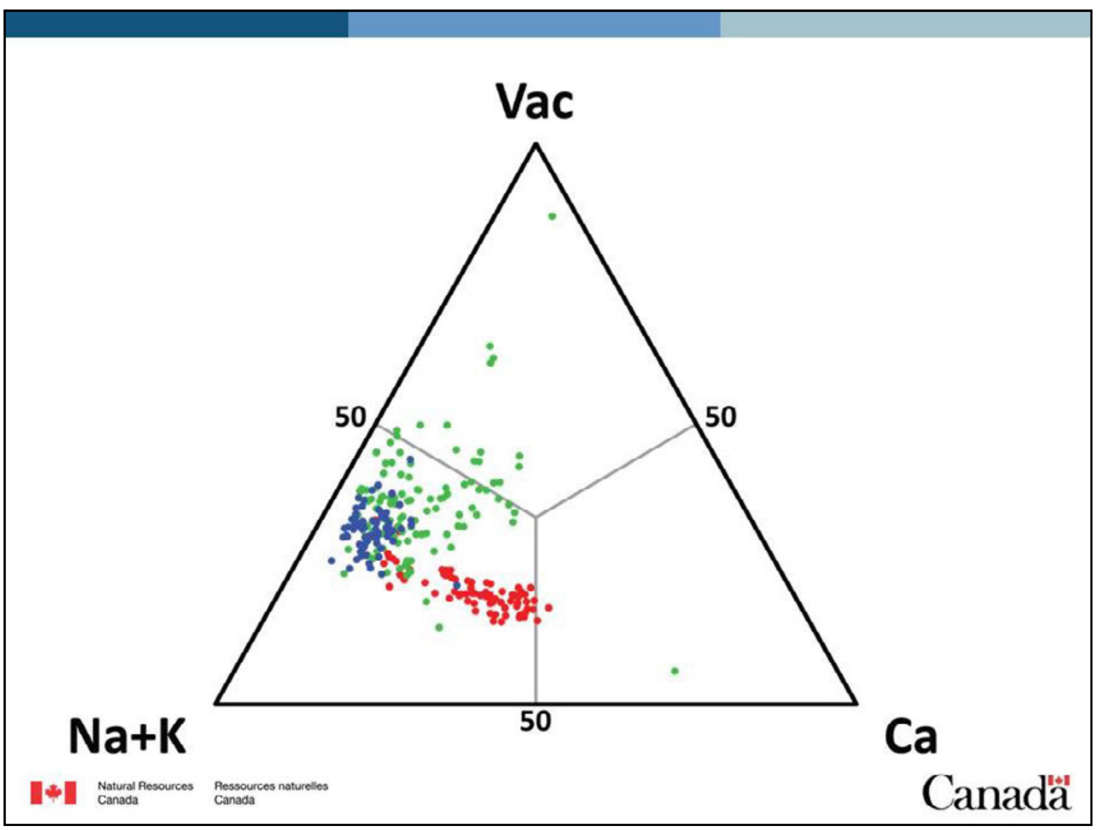
Vac
50
50
50
Na+K
Ca
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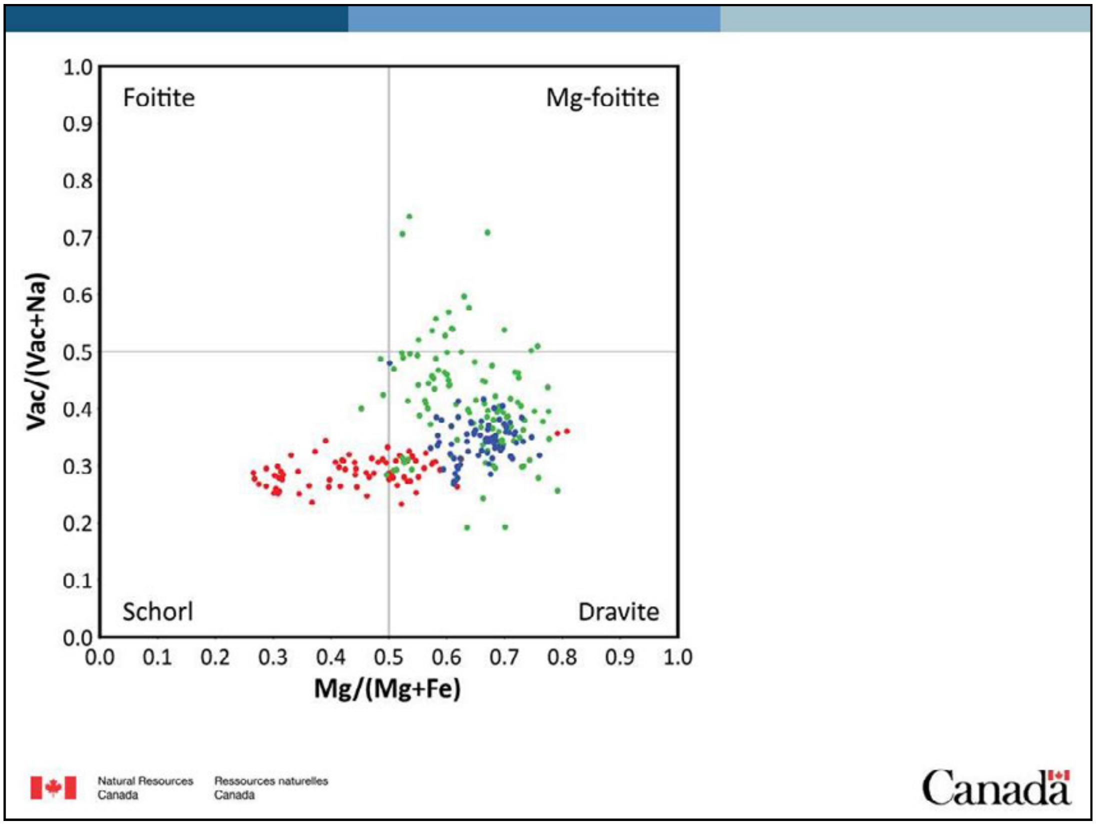
Foitite
Mg-foitite
Schorl
Dravite
Vac/(Vac+Na)
Mg/(Mg+Fe)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
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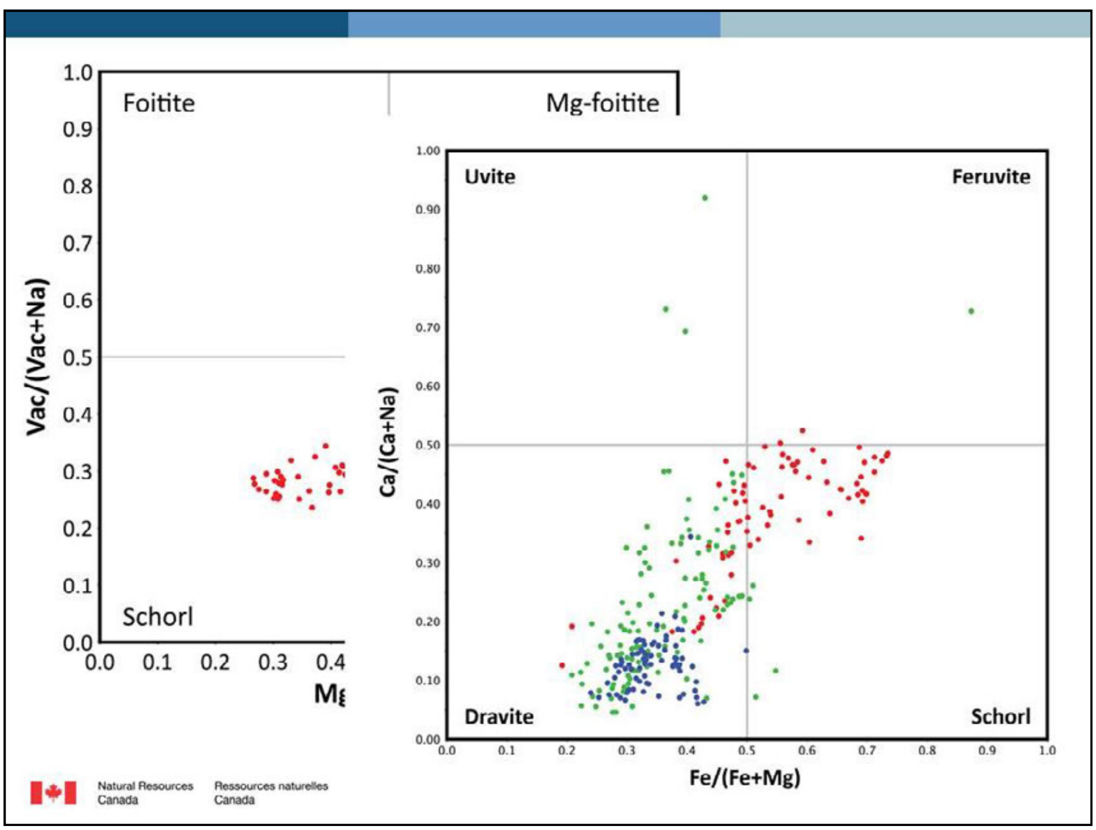
Foitite
Mg-foitite
Schorl
Vac/(Vac+Na)
Uvite
Feruvite
Dravite
Schorl
Ca/(Ca+Na)
Fe/(Fe+Mg)
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
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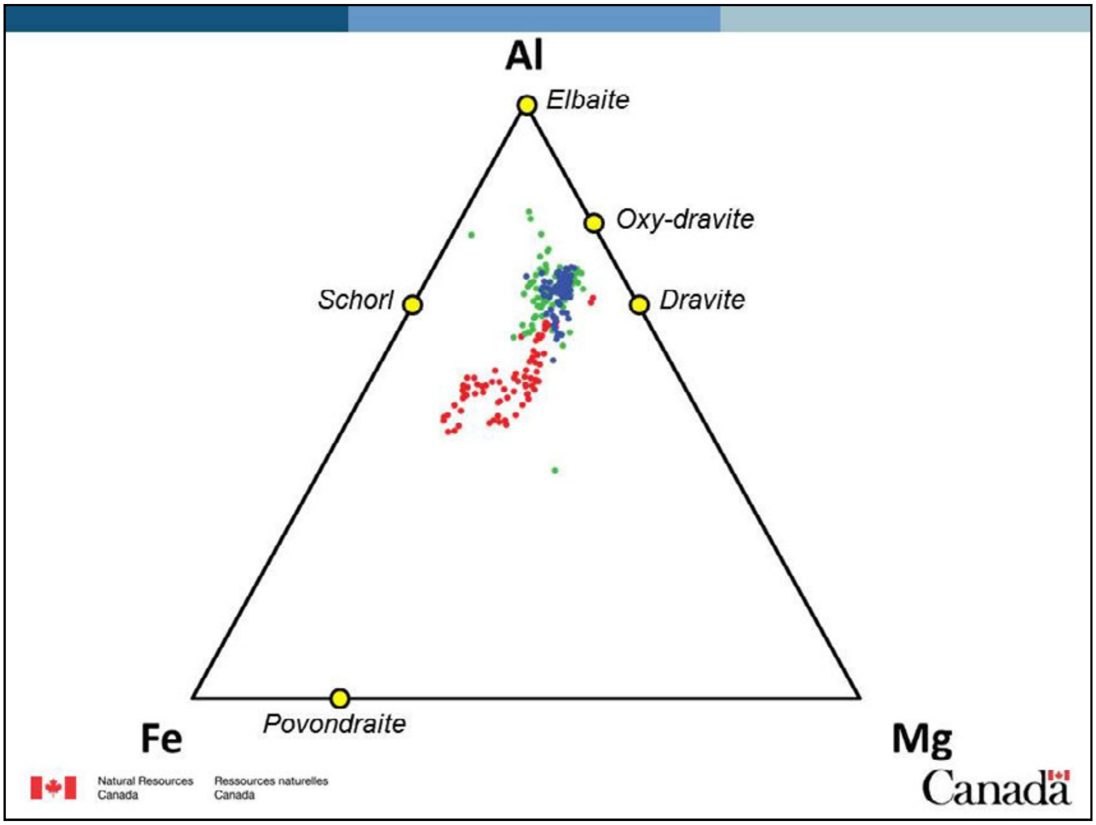
Al
Elbaite
Oxy-dravite
Schorl
Dravite
Fe
Povondraite
Mg
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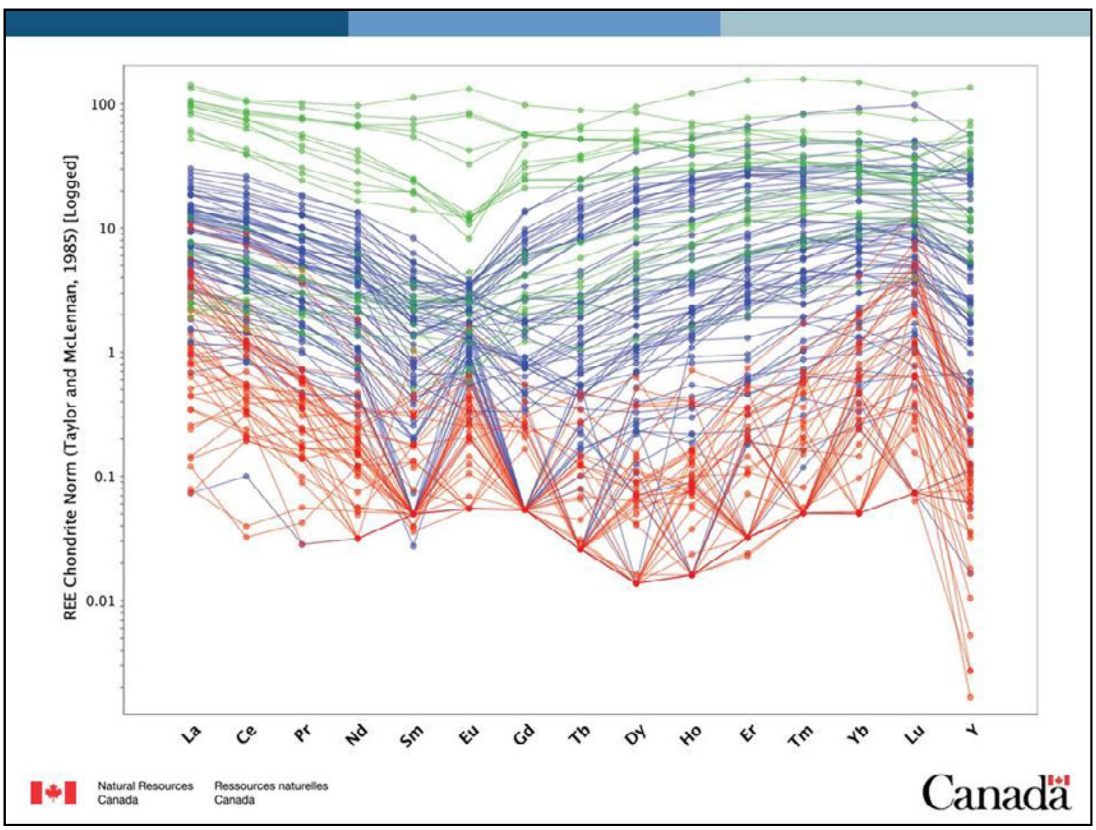
REE Chondrite Norm (Taylor and McLennan, 1985) [Logged]
100
10
1
0.1
0.01
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
Y
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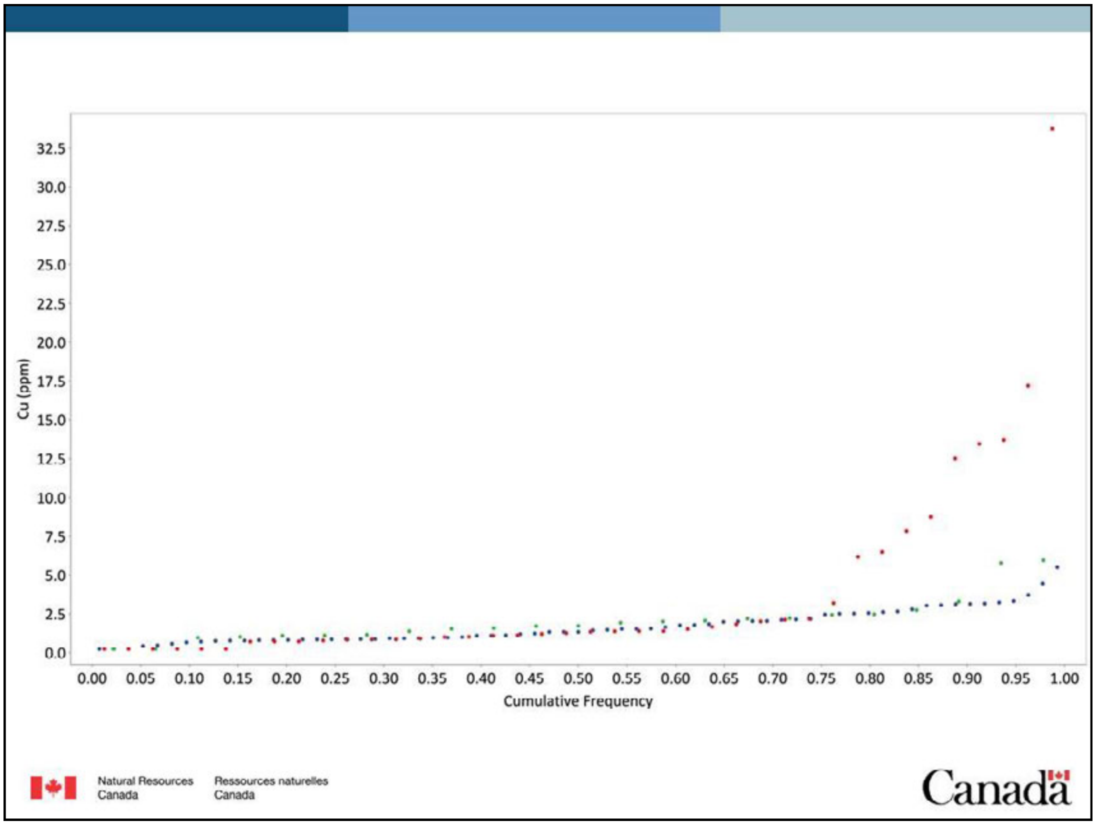

Cu (ppm)
Cumulative Frequency
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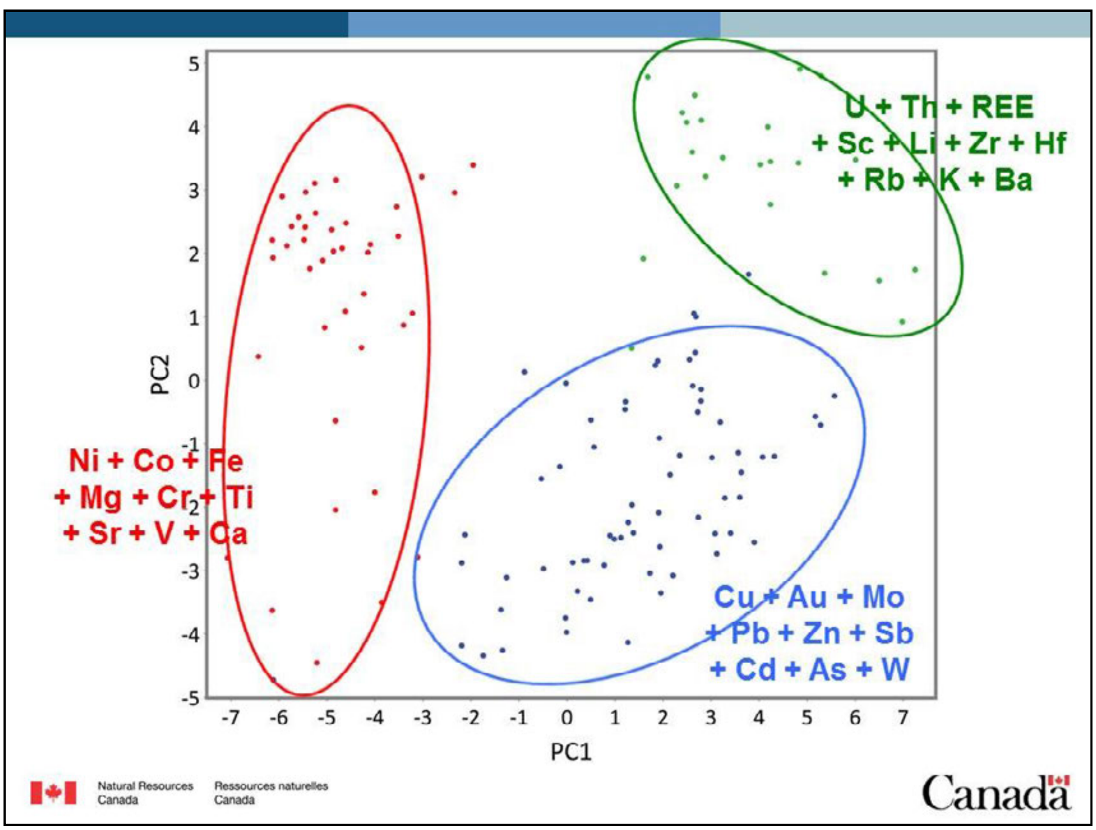

U + Th + REE
+ Sc + Li + Zr + Hf
+ Rb + K + Ba
Ni + Co + Fe
+ Mg + Cr + Ti
+ Sr + V + Ca
Cu + Au + Mo
+ Pb + Zn + Sb
+ Cd + As + W
PC1
PC2
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Conclusions

- Major element composition and mineralogy can distinguish porphyry from non-porphyry tourmaline, but…
- Barren magmatic-hydrothermal species have very similar major element character to ore associated species

- Trace element chemistry cannot be employed as simple, one-dimensional fingerprint indices, but…
- Multivariate statistics can identify element clusters that can be formed into complex indices, but this may be deposit specific. Needs testing!

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Many thanks!

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