Spectral logging in skarn systems – making a difficult task easy

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Pyroxene skarn
Garnet skarn
Retrogressed garnet-pyroxene skarn

Spectral mineral summary

TIR – GHDD3

Depth

725m

902m

Retrogressed garnet-pyroxene skarn
Garnet skarn
Garnet-pyroxene skarn
Pyroxene skarn

OXIDE
SULPHATE
CARBONATE
OTHER-MGOH
SERPENTINE
AMPHIBOLE
DARK-MICA
CHLORITE
SMECTITE
WHITE-MICA
KAOLIN
PYROXENE
GARNET
PLAGIOCLAS
K-FELDSPAR
SLICA
1. Skarn systems

2. Geological background

3. Improved geological understanding enabled by spectral data
- Mapping prograde v retrograde mineralogy critical for understanding extent of the system and vectoring to potential ore.
• Need to know your mineralogy and mineral compositions, which is not always that easy visually
• Garnet:pyroxene used as a proximity vector

Skarn mineralogy

- Garnet
- Pyroxene
- Olivine (Mg-rich)
- Amphibole
- Epidote
- Plagioclase
- K Feldspar
- Chlorite
- Mica
- Talc (Mg-rich)
- Serpentine (Mg-rich)
- Prehnite
- Carbonate
- others

Pyroxene-K Feldspar-amphibole-chlorite-talc-carbonate, GHDD1
Key observations

1. Skarn mineralogy – characterize type of skarn and likely commodity
2. Skarn zonation - garnet:pyroxene ratio
3. Skarn zonation - map prograde vs retrograde mineralogy

• Hyperspectral instruments provide a robust and consistent method of measuring these.
Regional Geology

- Cover: 400-800m Mesoproterozoic to Recent
- Host – Wallaroo Gr (~1760Ma) within NW-trending grabens (gravity high)
- Cu-Au-Fe skarn style mineralisation age equivalent to Olympic Dam (Sm-Nd - Reid et al., 2011)

<table>
<thead>
<tr>
<th>Prospect</th>
<th>Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundhog</td>
<td>159 m @ 0.47 % Cu, 0.12 g/t Au, 5.3 g/t Ag, 0.48% Zn</td>
</tr>
<tr>
<td>Prairie Dog</td>
<td>99 m @ 0.24% Cu</td>
</tr>
<tr>
<td>Woodchuck</td>
<td>70 m @ 0.41 % Cu</td>
</tr>
</tbody>
</table>

From Swain et al. 2007
Punt Hill – alteration & mineralisation

- Garnet-skarn, ~900 m, GHDD2
- Garnet-skarn, ~928 m, GHDD1
- Pyroxene-skarn, GHDD1

Amphibole-pyroxene-sulfide-fluorite-skarn, 952 m, GHDD1
Punt Hill study

- 39 spectrally logged drillholes (~3000 m of skarn) – HyLogger™ - 3
- VSWIR (380nm-2500nm)
- TIR (6000nm – 14,500nm)
- 17000 spectral measurements after rescaling
1. Characterise skarn mineralogy

- Garnet compositions are primarily andradite with lesser grossular garnet. Pyroxene species are dominated by diopside and lesser augite and hedenbergite.
1. Characterise skarn mineralogy

- Retrograde minerals identified spectrally include chlorite, talc, amphibole (hornblende/?hastingsite), K-feldspar, white mica (muscovite and illite), carbonate (calcite and siderite), epidote, barite and hematite. There is only minor serpentine, rare magnetite (few holes only) and no known pyrrhotite or olivine.

= Oxidised Cu skarn
2. Map garnet to pyroxene ratio

- Where are the causative intrusions?

Proximal

- Gt>Pyx
- Gt=Pyx
- Pyx>Gt

Distal

WDDD1
Mineral summary - TIR
780m

WDDD2
Mineral summary - TIR
760m
980m
2. Map garnet to pyroxene ratio

<table>
<thead>
<tr>
<th>Prospect</th>
<th>Drillhole</th>
<th>Garnet:pyroxene*</th>
<th>Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundhog</td>
<td>GHDD7</td>
<td>Gar&gt;&gt;pyx (5.30)</td>
<td>High temperature fluid source from south</td>
</tr>
<tr>
<td></td>
<td>GHDD5</td>
<td>Gar&gt;&gt;pyx (4.42)</td>
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<tr>
<td></td>
<td>GHDD4</td>
<td>Gar&gt;pyx (4.06)</td>
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<tr>
<td></td>
<td>GHDD3</td>
<td>Gar&gt;&gt;pyx (4.04)</td>
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<tr>
<td></td>
<td>GHDD6</td>
<td>Gar&gt;pyx (2.82)</td>
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</tr>
<tr>
<td></td>
<td>GHDD1</td>
<td>Gar&gt;pyx (2.18)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GHDD2</td>
<td>Gar ≈ pyx (1.07)</td>
<td></td>
</tr>
<tr>
<td>Woodchuck</td>
<td>WDD1</td>
<td>Gar&gt;pyx</td>
<td>High temperature fluid source from southwest</td>
</tr>
<tr>
<td></td>
<td>WDD2</td>
<td>Pyx&gt;gar</td>
<td></td>
</tr>
<tr>
<td>Whistle Pig</td>
<td>WPDD1</td>
<td>Gar&gt;pyx</td>
<td>High temperature fluid source from southeast</td>
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<tr>
<td></td>
<td>WPDD2</td>
<td>Gar&gt;pyx</td>
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<tr>
<td>Prairie Dog</td>
<td>PDDD1</td>
<td>Gar&gt;pyx</td>
<td>High temperature fluid source from southwest</td>
</tr>
<tr>
<td></td>
<td>PDDD2</td>
<td>Gar = pyx</td>
<td></td>
</tr>
<tr>
<td>Hoary</td>
<td>HODD1</td>
<td>No garnet or pyroxene</td>
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</tr>
<tr>
<td></td>
<td>HODD3</td>
<td>Gar&gt;pyx</td>
<td>High temperature fluid source from east</td>
</tr>
</tbody>
</table>

*Measured ratios indicated in brackets for the GHDD series of drillholes were derived using “The Spectral Assistant.”
3. Map prograde vs retrograde

- Block model with interpolation of prograde and retrograde zones
Relationship to Cu

- Interpolated geochemistry on alteration shells of prograde- and retrograde-dominated zones
- Clipped to drillhole envelope
Summary

• Skarn systems involve complex mineralogy that is difficult to recognise and understand by visual observation only.

• Spectral mineralogy provides a consistent and accurate method of recognizing key minerals, and these can be used to
  • Characterise mineralogy of a skarn
  • Map zonation patterns – towards causative intrusion and mineralization

• Hyperspectral scanning of drill core makes a difficult task easy.
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