Spectral studies at Kanmantoo Copper Mine, South Australia

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Peter Rolley, Hayden Arbon, John Keeling
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Location
40 Km south east of Adelaide
Hillgrove Resources: Kanmantoo Copper Mine, South Australia

- Projected to operate as a
  - ten year open-cut mine with
  - throughput of over 3.0Mt pa,
  - producing approximately 100,000t of concentrate,
  - containing about 20,000t of copper metal and associated gold pa
  - with potential for further copper-gold mineralisation.
- The deposit appears to remain open along strike and down dip where additional drilling could increase the resource inventory.

http://www.hillgroveresources.com.au
Tectonic Context

- Kanmantoo Trough
- Rift basin in the Foreland of the Arc of the Delamarian Orogeny
Regional Geology

- Deposit located in Kanmantoo Trough
- Cambrian Rift sediments host
- N-S axial folding
- N-S faulting
Kanmantoo Lithology: Tapanappa Fm

Prograding submarine fan:
- Massive meta-greywacke, interbeds of sulphide rich meta-siltstones lenses, and pyritic-schists. Thin BIFs and laminated garnet quartz units.

Alteration at Kanmantoo includes
- Garnet, andalusite, staurolite, biotite, chlorite

Mineralisation includes:
- Zn-Pb-(Ag)-(Au) at Angas, Wheal Ellen, Mt Torrens
- Cu-Au at Kanmantoo, Bremer

McPherson, 2017, MSc
Mineralisation

• Copper-gold zones variable continuity and orientation
• Mineralisation structurally controlled
• Biotite alteration halo
• Andalusite proximal to ore zones
• Garnet and intense chlorite adjacent to Cu lodes
• Gold with chalcopyrite and with quartz veins

Rolley, 2018, SAREIC
Issues to consider

- How to use legacy drill core assets to guide exploration drilling?
- Develop spectral and spatial characterization of minerals associated with system
- Key minerals:
  - Kaolinite
  - White mica
  - Garnet
  - Andalusite
  - Biotite
  - Chlorite
Selection of Drill Holes

14 Legacy drill holes selected to cover,
• Lateral extent
• Breadth
• Vertical extent
Kaolinite

- Largely antithetic to Andalusite
- Andalusite grains coated with fine Kaolinite and partially replaced by Kaolinite—visible in SEM

Kaolinite coating biotite and andalusite
Andalusite replaced by Kaolinite

Pitted Andalusite partially infilled and coated by Kaolinite

Andalusite grains etched and partially infilled with Kaolinite
White Mica

- Close to Kanmantoo Mine White Mica is approx. 200m distal to Cu mineralization
- White Mica is outboard of Andalusite
- Phengitic White Mica can be proximal to Au mineralisation
Garnet

- Complex mineral with range of compositions in a single crystal
- McPherson, 2017, MSc
- Example:
  - Sample 54-2
  - Almandine Fe 87.93%
  - Pyrope Mg 7.78%
  - Spessatine Mn 3.57%

<table>
<thead>
<tr>
<th>Table A2. Average Major Element Compositions of Garnet</th>
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<tbody>
<tr>
<td>Deposit</td>
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<tr>
<td>Sample no.</td>
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<tr>
<td>Depth (m)</td>
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<tr>
<td>Si</td>
</tr>
<tr>
<td>TiO₂</td>
</tr>
<tr>
<td>Al₂O₃</td>
</tr>
<tr>
<td>FeO</td>
</tr>
<tr>
<td>MnO</td>
</tr>
<tr>
<td>MgO</td>
</tr>
<tr>
<td>CaO</td>
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<tr>
<td>Total</td>
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Number of atoms in formulae (oxygen basis 12)

<table>
<thead>
<tr>
<th></th>
<th>Alm</th>
<th>Pyr</th>
<th>Grs</th>
<th>Sps</th>
<th>And</th>
<th>Ca-Ti Gr</th>
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</thead>
<tbody>
<tr>
<td>Si</td>
<td>2.955</td>
<td>2.995</td>
<td>2.993</td>
<td>2.991</td>
<td>2.991</td>
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<td>Ti</td>
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<td>0.000</td>
<td>0.002</td>
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<tr>
<td>Al</td>
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<td>1.954</td>
<td>1.968</td>
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<td>Fe</td>
<td>2.695</td>
<td>2.710</td>
<td>2.644</td>
<td>2.486</td>
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<tr>
<td>Mn</td>
<td>0.106</td>
<td>0.083</td>
<td>0.155</td>
<td>0.262</td>
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<tr>
<td>Mg</td>
<td>0.230</td>
<td>0.266</td>
<td>0.233</td>
<td>0.292</td>
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<tr>
<td>Ca</td>
<td>0.021</td>
<td>0.021</td>
<td>0.027</td>
<td>0.030</td>
<td>0.030</td>
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<tr>
<td>Total</td>
<td>8.032</td>
<td>8.028</td>
<td>8.021</td>
<td>8.026</td>
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</tr>
</tbody>
</table>

Type of garnet

- Alm 87.93% 87.69% 86.17% 80.50%
- Pyr 7.78% 8.87% 7.78% 9.76%
- Grs 0.69% 0.66% 0.86% 0.97%
- Sps 3.37% 2.75% 5.17% 8.74%
- And 0.03% 0.03% 0.03% 0.04%
- Ca-Ti Gr 0.00% 0.00% 0.00% 0.00%
- Total 100.00% 100.00% 100.00% 100.00%
Almandine Spectral Features

- Polynomial Fitting Spectra (PFIT) 11279nm
- Identify:
  - PFIT(11085,11448) wvl
- Abundance:
  - PFIT(11085,11448) Rel Depth
- Mn chemistry:
  - PFIT based on 10710nm
  - PFIT(10500,10982) wvl

Source of Spectra: CSIRO
Spessatine Spectral Features

- 10710 nm of Almandine moves towards 10860 nm of Spessatine with increasing Mn

Source of Spectra: CSIRO
Andalusite c.f. Almandine Spectral Features

Andalusite
10365nm
PFIT(10142:10551)

Differs significantly from Almandine

Andalusite
10860 nm shared with Spessatine
Andalusite PFIT

- Detect occurrence based on wavelength 10365nm
Andalusite depth 10365 PFIT

- Depth i.e. Rel. Abundance measure
Biotite

- Yangyang Iron-Oxide-Apatite deposit, South Korea. Correlation between Mg#, wavelength and alteration. (Yong-Hwi Kim et al, 2018)
- Short feature (2254nm) vs Long feature (2357nm)
- Both features tend towards longer wavelengths with increasing Fe (Yangyang)
  - Fe enrichment of Biotite proximal to Cu (Kanmantoo)
- Abundance of Biotite vs Cu occurrence
  - Depleted in proximity to Cu (Kanmantoo)
- Calculate by 1. Filter by TSA then 2. PFIT the shorter feature
Biotite: Key features

- Biotite short (2254)
- Biotite long (2357)
- Both go to longer wavelengths with increasing Fe
- 2254 seems to have greater sensitivity
Biotite: wavelength vs Cu

- Cu associated with longer wavelengths
Kanmantoo Model: Pattern Associated with Copper

- White mica distal
- Depleted Andalusite
- Almandine Fe rich (Mn poor)
- Depleted Biotite & Fe rich
- Chlorite Fe
WHITE MICA

Y

2200W PHENGITIC

Y

INTERMEDIATE PROXIMAL

DISTAL

Y

ANDALUSITE

Normal W

ABUNDANT DISTAL

DISTAL

ALMANDINE GARNET

Mn rich

DISTAL

Mn poor

PROXIMAL

DISTAL

Biotite

Normal W

DEPLETED PROXIMAL

Longer W

Mg

Fe

DISTAL

CHLORITE

DEPLETED PROXIMAL

PROXIMAL

PROXIMAL

Department for Energy and Mining
Conclusion

• Two key gradients
  • Changes in relative abundance
  • Changes in chemistry as measured by wavelength of spectral features
  • Fe alteration appears key

• Key minerals
  • Biotite
  • Chlorite
  • Almandine
  • Andalusite
  • White mica
  • Kaolinite
Contacts

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References


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