Alteration at the Olympic Dam IOCG-U Deposit

Dr Alan J Mauger
Geological Survey of South Australia

2 December 2019, IOCG Workshop, Adelaide
2013 saw the commencement of an ambitious program to scan 30 drill holes or 20,000 metres in a cross-section through the Olympic Dam deposit.

Five years on in 2018 the model began to be extended with another 60 drill holes planned, representing an extra 40,000 metres to form the framework of a 3D model of the deposit.
Olympic Dam

• World’s largest endowment of contained metal
• Au, Cu, Ag, U – highly economic
• What can HyLogger tell us that BHP Billiton don’t already know?
Location of Olympic Dam
In relation to Gawler Silicic Large Igneous Province

After McPhie et al
What minerals can be measured?

• Not all minerals have a distinctive spectral response at the wavelengths HyLogger measures
  • SWIR
    – OH Bond predominantly, harmonics
  • TIR
    – Primary molecular vibrations
What the HyLogger saw...

**SWIR**
- 00 = Opal
- 01 = Dickite
- 02 = Kaolinite-PX
- 03 = Kaolinite-WX
- 04 = Nacrite
- 05 = Muscovite
- 06 = Paragonite
- 07 = Phengite
- 08 = Montmorillonite
- 09 = Nontronite
- 10 = Saponite
- 11 = Diaspore
- 12 = Gibbsite
- 13 = Prehnite
- 14 = Pyrophyllite
- 15 = Topaz
- 16 = Chlorite-Fe
- 17 = Chlorite-FeMg
- 18 = Chlorite-Mg
- 19 = Biotite
- 20 = Phlogopite
- 21 = Actinolite
- 22 = Hornblende
- 23 = Tremolite
- 24 = Riebeckite
- 25 = Serpentine
- 26 = Brucite
- 27 = Talc
- 28 = Epidote
- 29 = Zoisite
- 30 = Tourmaline
- 31 = Tourmaline-Fe
- 32 = Rubellite
- 33 = Ankerite
- 34 = Siderite
- 35 = Calcite
- 36 = Dolomite
- 37 = Magnesite
- 38 = Alunite-K
- 39 = Alunite-Na
- 40 = Alunite-NH
- 41 = Gypsum
- 42 = Jarosite
- 43 = Pyrolyogorskite
- 44 = Vegetation-Dry
- 45 = IsaWhite
- 46 = IsaYellow
- 47 = PlasticChipTray
- 48 = Teflon
- 49 = WhiteMarker
- 50 = Wood
- 51 = YellowMarker
- 52 = Muscoviticllite
- 53 = Paragoniticllite
- 54 = Phengiticllite
- 55 = Muscovite
- 56 = Paragonite
- 57 = Montmorillonite
- 58 = Montmorillonite-Na
- 59 = Montmorillonite-Na
- 60 = Montmorillonite-Na
- 61 = Montmorillonite-Na
- 62 = Montmorillonite-Na
- 63 = Montmorillonite-Na
- 64 = Montmorillonite-Na
- 65 = Montmorillonite-Na
- 66 = Montmorillonite-Na
- 67 = Arfvedsonite
- 68 = Glaucophane
- 69 = Riebeckite
- 70 = Antigorite
- 71 = Chrysoite
- 72 = Lizardite
- 73 = Talc
- 74 = Clinozoisite
- 75 = Epidote
- 76 = Zoisite
- 77 = Tourmaline
- 78 = Cerussite
- 79 = Smithsonite
- 80 = Strontianite
- 81 = Witherite
- 82 = Azurite
- 83 = Malachite
- 84 = Ankerite
- 85 = Rhodoehrosite
- 86 = Siderite
- 87 = Aragonite
- 88 = Calcite
- 89 = Dolomite
- 90 = Dolomite-Fe
- 91 = Magnesite

**TIR**
- 000 = Opal
- 001 = Quartz
- 002 = Anorthoclase
- 003 = Microcline
- 004 = Orthoclase
- 005 = Albite
- 006 = Anorthite
- 007 = Biotite
- 008 = Labradorite
- 009 = Andesine
- 010 = Oligoclase
- 011 = Andradite
- 012 = Grossular
- 013 = Uvarovite
- 014 = Almandine
- 015 = Spessartine
- 016 = Augite
- 017 = Diopside
- 018 = Hedenbergite
- 019 = Enstatite
- 020 = Fayalite
- 021 = Forsterite
- 022 = Olivine
- 023 = Zircon
- 024 = Andalusite
- 025 = Cordierite
- 026 = Marialite
- 027 = Meinonite
- 028 = Vesuvianite
- 029 = Anatolite
- 030 = Chabazite
- 031 = Heulandite
- 032 = Laumontite
- 033 = Mesolite
- 034 = Natrolite
- 035 = Phillipsite
- 036 = Thomsonite
- 037 = Kaolinite
- 038 = Kaolinite-Fe
- 039 = Illite
- 040 = Muscovite
- 041 = Paragonite
- 042 = Montmorillonite
- 043 = Montmorillonite-Na
- 044 = Nontronite
- 045 = Smeectite-Fe
- 046 = Saponite
- 047 = Axinite
- 048 = Prehnite
- 049 = Pyrophyllite
- 050 = Topaz
- 051 = Chlorite
- 052 = Biotite
- 053 = Phlogopite
- 054 = Stilpnomelane
- 055 = Actinolite
- 056 = Amphibole-ML48
- 057 = Edénite
- 058 = Ferrohomblyende
- 059 = Hornblende
- 060 = Kaersutite
- 061 = Tschermakite
- 062 = Anthophyllite
- 063 = Gedrite
- 064 = Grunerite
- 065 = Holmquistite
- 066 = Mangano
cummingtonite

163 substances
82 - OD
**Which wavelength region is best?**

<table>
<thead>
<tr>
<th>Mineral Group</th>
<th>VNIR</th>
<th>SWIR</th>
<th>TIR</th>
<th>Mineral Group</th>
<th>VNIR</th>
<th>SWIR</th>
<th>TIR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400-1000 nm</td>
<td>1000-2500 nm</td>
<td>6000-14500 nm</td>
<td></td>
<td>400-1000 nm</td>
<td>1000-2500 nm</td>
<td>6000-14500 nm</td>
</tr>
<tr>
<td>REEes</td>
<td></td>
<td></td>
<td></td>
<td>Artefacts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron Oxides</td>
<td></td>
<td></td>
<td></td>
<td>Carbonates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaolins</td>
<td></td>
<td></td>
<td></td>
<td>Sulfates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Micas</td>
<td></td>
<td></td>
<td></td>
<td>Phosphates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smeectes</td>
<td></td>
<td></td>
<td></td>
<td>Borates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other ALOH</td>
<td></td>
<td></td>
<td></td>
<td>OXides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrophyllite</td>
<td></td>
<td></td>
<td></td>
<td>Sulfides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prehnite</td>
<td></td>
<td></td>
<td></td>
<td>Quartz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topaz</td>
<td></td>
<td></td>
<td></td>
<td>K-Feldspars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diopside</td>
<td></td>
<td></td>
<td></td>
<td>Plagioclases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Axinite</td>
<td></td>
<td></td>
<td></td>
<td>Garnets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gabbro</td>
<td></td>
<td></td>
<td></td>
<td>Pyroxenes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorites</td>
<td></td>
<td></td>
<td></td>
<td>Clinores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dark micas</td>
<td></td>
<td></td>
<td></td>
<td>Misc. Anhydrous Silicates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amphiboles</td>
<td></td>
<td></td>
<td></td>
<td>Vesuvianite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serpentines</td>
<td></td>
<td></td>
<td></td>
<td>Cordierite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other MgOH</td>
<td></td>
<td></td>
<td></td>
<td>Some</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrogorzie</td>
<td></td>
<td></td>
<td></td>
<td>Andalujast</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talc</td>
<td></td>
<td></td>
<td></td>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brucite</td>
<td></td>
<td></td>
<td></td>
<td>No response</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg-Clays</td>
<td></td>
<td></td>
<td></td>
<td>Weak or selective response</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epidotes</td>
<td></td>
<td></td>
<td></td>
<td>Legend</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tourmalines</td>
<td></td>
<td></td>
<td></td>
<td>OK response but other region better</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Good responses but hard in mixtures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clear unambiguous response</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What the HyLogger saw...
Location

2013 – Section A-A – 30 Holes
2018 – Section B-B – 24 Holes
2013/18 – 75 Holes completed
Current campaign 60% completed
Cross section along A-A (not to scale horizontally). Thermal infrared responsive minerals summarised for each drill hole. Note the K-feldspar distribution highlighting the presence of Roxby Downs Granite towards the margins and at depth. Note the hematite-magnetite towards the centre of the section.

Cross section along B-B (not to scale horizontally).
Preliminary Plots from 75 Holes

Showing maximum Cu assay per hole.
Phyllosilicate trends showing depletion of Phengite proximal to mineralisation.
2013 -2014 Transect

• The remaining slides focus on Section A-A
Feldspar Story

- Absence of Albite (?)
- HyLogger identified Plagioclase
- Alkis revealed presence of Plagioclase
- HyLogger maps Orthoclase and Microcline as distinct K-Feldspar species
- Plotted the HyLogger results in a QAP diagram
K-Feldspar in the TIR

Orthoclase

Microcline

Mixtures compare slopes
For the sake of modelling

• Calculated single value per hole
• Used “metres of mineral” as an approximation of abundance in a hole.
• Wavelengths – used averages
• Assays – used maximums
Copper values
Sericite and Chlorite

Sericite: Decreasing Al
Chlorite: Increasing Fe
K-Feldspar and Plagioclase

- Microcline
- Orthoclase
- Oligoclase
- Albite
QAP (modified)

Q – Quartz
A – K-Feldspar
P – Plagioclase

Biotite Out

Barren Core
Ore
Distal
From 1D to 2D

• Next few slides depict cross sections derived from HyLogger data and presented in GoCAD

• Blue is low number (wavelength or abundance). Red is a high number.
The information contained in this presentation has been compiled by the Department for Energy and Mining (DEM) and originates from a variety of sources. Although all reasonable care has been taken in the preparation and compilation of the information, it has been provided in good faith for general information only and does not purport to be professional advice. No warranty, express or implied, is given as to the completeness, correctness, accuracy, reliability or currency of the materials.

DEM and the Crown in the right of the State of South Australia does not accept responsibility for and will not be held liable to any recipient of the information for any loss or damage however caused (including negligence) which may be directly or indirectly suffered as a consequence of use of these materials. DEM reserves the right to update, amend or supplement the information from time to time at its discretion.
Contact

Department for Energy and Mining – Mineral Resources Division
Geological Survey of South Australia
Level 4, 11 Waymouth Street
Adelaide, South Australia 5000

T: +61 4 3283 5504
E: alan.mauger@sa.gov.au