Alteration trends and geochemical characteristics of IOCG deposits in the Olympic Cu-Au Province

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Geological Survey of South Australia
Deposit styles

Epithermal

Hematite-group IOCG
Cu-Au-Ag-REE-U-Mo
e.g. Olympic Dam

Polymetallic skarn
IOCG
Cu-Pb-Zn polymetallic
e.g. Punt Hill

Magnetite-group IOCG
Cu-Au-Co
e.g. Cloncurry, ±Manxman &
Cairn Hill

IOA Magnetite-apatite
Fe, P, V, Th, REE
e.g. Kiruna type, ±Manxman &
Cairn Hill

Alteration facies

Silicification
(<250°C)

Low T K-Fe-H-CO2
Hem-Kfs/Musc-Carb-Chl-
sulfides
(<350°C)

Mag to Hem transition
Kfs/Cpx-Grt-Kfs-sulfides

High T K-Fe
Mag-Bt/Kfs-sulfides

High T Ca-Fe ± Mg (+skarn)
Amp-Maq ± Cpx-Ap-Ttn
(largely barren of sulfides)
(<800°C)

Na ± Ca (albities)
Ab-Scp-Qz-Zrn-Rt (<600°C)

Distal to heat source
Low T, shallow, late

Distal to heat source
Low T, shallow, late

Distal to heat source
Low T, shallow, late

Thermal core
High T, deeper, earlier

High T K-Fe
Mag-Bt/Kfs-sulfides

Fluid evolves or recharges/discharges
elements at each stage

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After Corriveau et al., 2016

Corriveau, L., Montreuil, J.-F., and Potter, E.G., 2016, Alteration facies
linkages among iron oxide copper-gold,
iron oxide-apatite, and affiliated
deposits in the Great Bear Magmatic
zone, Northwest Territories, Canada:
Mapping sodic and potassic alteration in the Olympic Cu-Au Province

- Trends of sodic and potassic alteration relate to mineral system temperatures
- Broad footprints evident
Mapping regional potassic and sodic alteration

Wallaroo Group

Spectral summaries - HyLogger™

- DD86EN60 – Manxman A1
  - Magnetite-rich
- BD1 – Titan
  - Magnetite-rich
- SAE6 – Emmie Bluff
  - Hematite-rich
- SAR8 – Red Lake
  - Polymetallic skarn
- MALD1 – Alford West
  - Magnetite-hematite
• 648 Dhs with TIR (~350 in the Olympic Cu-Au Province)
Mapping regional potassic and sodic alteration

Prominent Hill

Mt Woods

10km

TMI VRTP UC1000 Residual
Mapping regional alteration trends

Mount Woods 1
Hydrothermal Fe oxides ± sulphide with surrounding sodic feldspar + biotite
Manxman A1 (HT Ca-Fe ± Mg + HT K-Fe)

DD86EN25 165.6m – Strongly albite-altered, finely-laminated metasediment with pyroxene-albite-rich bands

DD86EN25 184.1m – massive magnetite alteration containing pyrite and chalcopyrite

DD89EN61 Metased+granite

DD88EN43 ?orthogneiss

DD86EN24 orthogneiss

DD89EN60 paragneiss

Qt

Ab

PX

DD86EN25 Metasediment

TMI VRTP UC1000 Residual Cu mineralisation

400m
Cairn Hill Fe (+Cu-Au)
Cairn Hill
HT Ca-Fe ± Mg (skarn) + HT K-Fe

J. Clark honours thesis - 2014
1. Na-Ca (albite + scapolite + diopside ± actinolite/titanite)
2. K-Fe (localized zones of magnetite-biotite ± pyrite-pyrrhotite-chalcopyrite)
Mapping regional potassic and sodic alteration

Central Olympic Domain

Acropolis

Carrapateena

Punt Hill
Mapping regional potassic and sodic alteration

Alteration facies

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After Corriveau et al., 2016

Distal to heat source
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Thermal core
High T, deeper, earlier

IOA

IOCG

SAE7 – ab-mag ± px-amp

HUD1 - background

TD3 – kfs-px ± ab-mag

IHAD5 – Hem-kfs-chl-ser-sulfide
Mapping alteration using magnetic response
The exploration model

CRUST

SUB-CONTINENTAL LITHOSPHERIC MANTLE

ASTHENOSPHERE

© Thiel, Reid, Animate Your Science: https://www/animateyour.science

Metasomatised mantle

- Crustal Material Flux
- Mantle Material Flux
- Heat

?Ore deposit
Geochemical characteristics
Most publically available data is for an economic element suite

77 Drill holes (2032 samples)

Within 10 km of known Cu-Au prospect

Categorized: hematite-dominated, magnetite-dominated
Aims

1. ‘Fingerprint’ their minor and trace element values

2. Determine if deposits have unique geochemical characteristics
Magnetite-dominated IOCG (n=529)

- Enrichment: Cu, Au, Co, S, Se, Sn, Te, Th, Tl, U and LREE (Rudnick & Gao, 2003)
Hematite-dominated IOCG (n=1503)

Common element associations
- Hematite- and magnetite-group IOCG’s are enriched in Cu, Au, S, Se, Sn, Te, Tl, U and LREE relative to BCC. Ag, Co, Ni, Pb and Re are progressively enriched with Cu mineralisation.
Hematite-dominated IOCG systems

• Distinct characteristics of hematite-dominated IOCG’s are significant enrichment in Ag, As, Bi, F, In, Mo, Sb, W ± Mn-Pb-Zn.
geochemical characteristics

Hematite-dominated IOCG (n=1503)

<table>
<thead>
<tr>
<th>Trend with increasing Cu values</th>
<th>Hematite-dominated systems</th>
</tr>
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<tbody>
<tr>
<td>Enrichment</td>
<td>Ag, As, Au, Bi, Cd, Co, Eu, F, In, Mn, Mo, Ni, Pb, Re, S, Sb, Se, Sn, Te, U, W, Zn.</td>
</tr>
<tr>
<td>Depletion</td>
<td>Cs, Hf, Rb, Ta, Th, Ti, Zr.</td>
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Magnetite-dominated IOCG (n=529)

Hematite-dominated IOCG (n=1503)

Trend with increasing Cu values

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<td>*Ag, Au, Ce, Co, La, *Ni, Nd, *Pb, Pr, *Re, S, Se, Sm, Sn, Te, Th, U.</td>
<td></td>
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Significant enrichment

Depletion

Magnetite-dominated IOCG (n=529)  
Hematite-dominated IOCG (n=1503)  

Trend with increasing Cu values

**Hematite-dominated systems**

- Ag, As, Au, Bi, Cd, Co, F, In, Mn, Mo, Ni, Pb, Re, S, Sb, Se, Sn, Te, U, W, Zn.

**Magnetite-dominated systems**

- *Ag, Au, Ce, Co, Gd, In, La, Mo, Nd, Pb, Pr, Re, S, Se, Sm, Te, U, W.*

**Enrichment**

- Cr, Cs, Hf, Rb, Ta, Th, Ti and Zr.

**Depletion**

- As, Ba, Be, *Bi, Cd, Cr, Cs, Ga, Ge, Hf, *F, *Li, Mn, *Pd, Rb, Sb, Sc, Sr, Ta, Ti, *V, W, Zr.

Implication: these elements can be used to map the lower T and more oxidized part of system.
• Are large systems geochemically distinct?

• Compared results from Carrapateena and Prominent Hill samples to Ehrig et al., 2012.
Geochemical characteristics

- Flat to positive Eu anomaly as found by Krnerta et al., 2016, 2017 in apatite

**Olympic Dam** (Ehrig et al., 2012)

**Prominent Hill**

**Carrapateena**

- Associated elements: Ag, As, Au, Bi, Co, Cu, F, Mo, Re, S, Sb, Se, Sn, Te, U, W, REE
Geochemical maps

Prominent Hill, Carrapateena, Olympic Dam, Emmie Bluff, Tea Tree Glen

Ce

Sb
Forming trace element halos

• Coupled dissolution-replacement reactions = mechanism of forming trace element footprints

• FOX project: Mineral chemistry, trace element deportment (particularly in iron oxides) - follow the project through Researchgate https://www.researchgate.net/project/FOX-Project

Verdugo-Ihl et al., 2017, Ore Geology Reviews v, 91
Kontonikas-Charos et al., 2017, Ore Geology Reviews v, 80
Geochemical maps

Prominent Hill
Carrapateena
Olympic Dam
Emmie Bluff

Potassic
Sodic
Background

Geochemistry_Sb.ppm

km
• Minor and trace elements can be used as a fingerprint of IOCG mineralisation (do I have an IOCG?)

• Unique elements of hem systems will be useful to locate them around mag dom mineralisation

• Economic deposits are characterised by significantly higher Au, Ba, F, Mo, Re, Te, U and LREE values. Trends are evident in relatively unmineralised samples (<300 ppm Cu).

• LREE enrichment of >10x BCC and positive Eu anomalies are a characteristic of economic systems and provide key exploration criteria.
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