IOCQ Workshop - Gawler Craton
Stuart Shelf hematite rich end members

2 – 3rd December 2019
Mitchell Neumann – Project Exploration Geologists
OZ Mineral has four significant hematite end member IOCG deposits

They are all hematite end member IOCG deposits but each of our deposits have different grade distributions, tonnage, and paragenesis.

This work started by asking the following questions:

- Why does the Fremantle Doctor have higher gold copper ratio relative to the major deposits?
- Why does Khamsin have so much siderite relative to other Gawler IOCGs?
- Why is there no oxidised sulphide or sulphate phases (bornite/barite) or reduced examples of typical iron minerals (magnetite/siderite) at Fremantle Doctor?
- Why is the size of the barren hematite domain highly variable across different deposits?
- Carrapateena, Olympic Dam and Khamsin have volcanogenic derived conglomerates that are absent from Fremantle Doctor – why?

Our observations show this variability is controlled by each deposit’s unique geometry and evolution of the mineralising hydrothermal fluid composition.
The Olympic IOCG province is on the western margin of the Gawler Craton.

Hosted in the Moonta-Wallaroo to Hutchison aged metasedimentary belt with numerous Hiltaba and Donington intrusives.

The changeover between the Archean core and the Proterozoic metasediments is marked by the north west trending Elizabeth Creek Fault.

All developed deposits sit within the hanging wall of this crustal scale structure.
MT large scale
Time to think in 3D and along strike

/ Olympic Dam section
MT large scale
Time to think in 3D and along strike

/  But does it continue south?
MT large scale
Time to think in 3D and along strike

/ What about the Elisabeth Creek Fault?
Geophysical response of known systems
Gravity with magnetic contours

**OD**: Olympic Dam, **WW**: Wirrda Well, **TI**: Titan, **TO**: Torrens, **AC**: Acropolis, **OKD**: Oak Dam, **EB**: Emmie Bluff, **CA**: Carrapateena, **PH**: Prominent Hill, **MX**: Manxman.

**Density**: Colour, **Magnetics**: Contours.
Gravity

- Semi-coincident magnetic and gravity anomaly for all three deposits
- Response due to the Iron oxides with the larger gravity anomaly (hematite + magnetite) containing a smaller deeper magnetic (magnetite rich) zone
- Fremantle Doctor gravity anomaly is discrete from the larger Carrapateena anomaly with infill and processing
- Unlike Carrapateena and Khamsin, the large magnetic anomaly to the south east of Fremantle Doctor is yet to be explained by drilling, likely from a deeper source
Magnetics

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Carrapateena

The breccia complex type example

/ Carrapateena is a large, near vertical breccia complex emplaced within the Palaeoproterozoic Donington Suite granitoids.

/ The clast component within Carrapateena suggests a large amount of hydrothermal brecciation and incorporation of the host Donington suite granitoid clasts into the deposit.

/ The copper sulphides are zoned across the deposit with paragenetic replacement sequence of pyrite → chalcopyrite → bornite
Carrapateena Lithologies

Host and mineralisation

/ Carrapateena is hosted in the Donington Granite intruded by pre mineralisation dykes.

/ The granite clasts become less frequent and more rounded trending towards the centre of the deposit.

/ The granite has increasing alteration towards the centre of the deposit with the biotite, feldspars then quartz being altered to other minerals or destroyed.

/ Copper and gold grades are proportional to the matrix percentage within the breccias.
Carrapateena Lithologies

Other lithologies

Volcanogenic conglomerate
/ Rounded clasts of volcanic and clean quartz in a fine grained matrix.
/ Chlorite and hematite altered but barren of sulphides and REEs
/ Found within the Carrapateena and Khamsin Breccia complexes

Internally derived sediments
/ Commonly well mineralised altered
/ Most prevalent in the central portion of Carrapateena and in the upper portion of Khamsin
Volcanogenic conglomerate
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Carrapateena Lithologies

O Z M I N E R A L S - I O C G W o r k s h o p  P A G E 13

Down hole
Volcanogenic conglomerate
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Carrapateena Lithologies

O Z M I N E R A L S
I O C G W O R K S H O P
Carrapateena Lithologies

Introduced lithologies

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Carrapateena

Petrography and important relationships
Iron oxides, copper sulphides, micas and accessory minerals are all zoned across the deposits.

- The systems started with reduced magnetite, carbonate (siderite/calcite) chlorite rich.
- This is overprinted by shallow oxidised hematite, sericite, fluorite and barite.
## Alteration

<table>
<thead>
<tr>
<th>Copper Mineralisation</th>
<th>Oxidised late</th>
<th>Reduced early</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper barren zone</td>
<td>Deep magnetic zone</td>
</tr>
<tr>
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<td>Bornite</td>
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### Phyllosilicates
- White sericite / None
- Green Sericite
- Sericite / Chlorite
- Chlorite

### Accessory minerals
- Barite / Anhydrite
- Fluorite / Siderite
- Siderite
- Calcite

### Iron oxides
- Earthy hematite
- Grey hematite
- Hematite / Magnetite
- Magnetite

### Gold mineralisation
- None / Spikey
- High
- Moderate
- low
- low

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**Copper Mineralisation**

- Barren
- Bornite
- Chalcopyrite
- Pyrite
- Pyrite

**Gold mineralisation**

- None / Spikey
- High
- Moderate
- low
- low

**Iron oxides**

- Earthy hematite
- Grey hematite
- Hematite / Magnetite
- Magnetite

**Phyllosilicates**

- White sericite / None
- Green Sericite
- Sericite / Chlorite
- Chlorite

**Accessory minerals**

- Barite / Anhydrite
- Fluorite / Siderite
- Siderite
- Calcite
Carrapateena overview

Section location

- Barren
- Bornite
- Chalcopyrite

A

Carrapateena

A'

B

Fremantle Doctor

B'
Carrapateena Zonation
Full spectrum of minerals

- Earthy hematite
- Grey hematite
- Magnetite
- Bornite
- Chalcopyrite
- Sericite
- Chlorite
- Barite
- Fluorite
- Siderite
- Pyrite

Copper Mineralisation
Gold mineralisation
Iron oxides
Phyllosilicates
Accessory minerals

Carrapateena

Oxidised late
Upper barren zone
Reduced early
Deep magnetic zone

Barren
None / Spiky
Earthly hematite
White sericite / None
Barite / Anhydrite

Bornite
High
Grey hematite
Green Sericite
+ Fluorite

Chalcopyrite
Moderate
Hematite / Magnetite
Sericite / Chlorite
Fluorite / Siderite

Pyrite
low
Magnetite
Chlorite
Siderite

Pyrite
low
Magneteite
Chlorite
Calcite
Fremantle Doctor is ~4 Km to the north East of Carrapateena with a strong NE strike.

/  Fremantle Doctor is a grey hematite-chalcopyrite-pyrite system with the large barren zone, oxidised and reduced endmembers absent.

/  The massive hematite breccias at Fremantle Doctor don’t come all the way up to the unconformity and don’t include the volcanogenic conglomerate.

/  No post formation supergene weathered zone and no controlling fault introducing oxidised fluids.

/  Both Carrapateena and Prominent Hill have 1% Cu for 0.5 g/t Au, however Fremantle Doctor has higher gold ratio with 1% Cu for 0.7-0.8 g/t Au.

/  Is this copper gold ratio similar to a Gawler IOCG without oxidised fluid interaction? Would an IOCG be economic without oxidised portion?

Great system to understand the effects and importance of interaction with oxidised fluids, or the lack of. Even though the massive hematite breccias at Fremantle Doctor don’t come to the unconformity, it is still a hematite dominant system.
Reduced and oxidised endmembers absent

Copper minerals

Iron Oxides

Phyllosilicates

Accessory minerals

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Copper minerals
Iron Oxides
Phyllosilicates
Accessory minerals
Khamsin
A hematite siderite breccia complex

Khamsin is ~10km to the north west of Carrapateena

- The breccia complex has a NNW trending structure on the western side with the minerals zoned out from this.
- Khamsin has a similar full zonation pattern to Carrapateena, but the brecciation and alteration is not as strong.
- The central portion of Khamsin is iron carbonate rich.
- Khamsin has a barite rich barren zone in the west but it is smaller, not as intense and more porous than the barren zone at Carrapateena.
- The bornite zone at Khamsin in lower grade that that at Carrapateena.

Does the size of the barren zone correlate with the size and grade of the bornite zone?
Khamsin
Full spectrum of minerals +

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Oxidised late
Upper barren zone
Reduced early
Deep magnetic zone

Copper minerals
Iron Oxides
Phyllosilicates
Accessory minerals
Siderite at Khamsin
Two generations of siderite

/ Coarse grained siderite – Khamsin and Carrapateena
  – Coarse grained siderite commonly intergrown with dark grey hematite grains
  – This generation includes disseminated chalcopyrite with lesser bornite

/ Micritic siderite – Khamsin
  – Super fine and rarely mineralised
  – Typically intergrown with chlorite, earthy hematite or as a clean white/creamy siderite

The later micritic siderite is unique to Khamsin, overprinting the earlier mineralised coarse grained generation.
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There are two generations of siderite:

- **Sparry siderite** – Khamsin and Carrapateena
  - Coarse grained siderite commonly intergrown with dark grey hematite
  - This generation includes blebby disseminated chalcopyrite with lesser bornite

- **Micritic siderite** – Khamsin
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Summary
Unpack the paragenesis of your deposits

Carrapateena
/ IOCG deposit with a well developed breccia complex and the full spectrum of minerals.

Fremantle Doctor
/ Doesn't come up to the unconformity and doesn't have the oxidised or reduced endmembers, but isn't magnetite rich and has good gold ratio.

Khamsin
/ Has the full spectrum of mineral zonation, however didn’t develop as far as Carrapateena and includes extra, late generations of siderite.