The geology and ore genesis of the Omitiomire copper deposit, central Namibia

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A good companion
A careful observer
An excellent geologist
A valued colleague
... sadly missed
Location

[Map showing geological locations with labels for Omitionire, Windhoek, and other geological features like the Atlantic Ocean, Congo Craton, Damara Belt, and Kalahari Craton.]

Legend:
- Cover sequences
- Nama Group
- Damara Sequence & equivalents
- Pre-Damara basement

Distance Scale: 0 km to 200 km
The Omitiomire deposit is hosted by a Mesoproterozoic basement inlier
Project Area

Located in semi-arid grazing land. Very little rock outcrop
Outline of Presentation

• Introduction - Setting the scene - Ken Maiden
• Microscopic - Looking at the details - Nick Steven
• Mesoscopic - Looking at the rocks - Ken Maiden
• Macroscopic - Looking at the deposit - Karl Hartmann
• Megascopic - Looking at the regional setting - Nick Steven
• Wrap-up - Kite-flying & conclusions - Ken Maiden
Section 2: Microscopic - Looking at the Details
Geological Setting of Mineralisation
1. Felsic gneiss
   
   Dacite >> Tonalite

2. Amphibolite

3. Continuum of amphibolite to hornblende schist – Minor Cu

4. Biotite + epidote schist – Best Ore
SHRIMP U-Pb Umkondo - Irumide Ages for Zircon Cores

- **Amphibolite**: 1115 ± 13 Ma
- **Felsic gneiss**: 1084 ± 7 Ma
- **Chalcocite-sphene-hornblende schist**: 1081 ± 10 Ma
- **Foliated tonalite**: 1063 ± 9 Ma

- *All zircons are igneous with metamorphic edges*
- *Zircon rims & overgrowths* ~ 600 Ma
- *Sphenes also have 1100 Ma cores & Damaran rims*

Richard Armstrong, ANU
OED3-TS2 Biotite gneiss (metadacite) zircon: 1084 ± 7 Ma

Weighted Mean $^{207}$Pb/$^{206}$Pb age gives 1084 ± 7 [95% conf.]
[MSWD = 0.74, probability = 0.70]
(error bars are 2$\sigma$)
Geochronology: The Damaran Overprint

OED3-TS20 Chalcocite-hornblende schist sphene: 517 ± 24 Ma
Geochemistry: The Damaran Overprint

OED3-TS5 Amphibolite sphene: $485 \pm 19$ Ma

Richard Armstrong, ANU
Late-tectonic epidote porphyroblasts overgrowing biotite
Silicate Mineral Interpretation

• Amphibolite-facies metamorphic textures
• Gneissic, incipient melting
• But biotite+epidote schists are retrograde zones
• Epidote is late-to-post-tectonic
• Epidote especially associated with chalcocite
• To form epidote, one needs -
  - water
  - Ca (from hornblende and possibly calcite breakdown)
  - oxidising conditions (Fe$^{3+}$)
• High Cr suggests derivation from metabasite
The Ore Zone

Yellow epidote poikiloblasts with magnetite & chalcocite inclusions in biotite-epidote schist

HFOV = 6.5 mm
Best Copper Indicators

Spatial association between copper and -
- biotite
- Cr-epidote
- sphene & fuchsite
- Cr- & Ti-magnetite

Retrograde silicate assemblage of biotite + epidote
Hypogene Ore Mineralogy

- Chalcocite (Cu$_2$S) / digenite (Cu$_9$S$_5$) ~ 90%
- Bornite ~ 8%
- Chalcopyrite trace
- Minor hypogene hematite
- No pyrite/pyrrhotite
- No Zambian-type copper mineral zonation pattern
- Deeper drill intersections show chalcocite after bornite
- Various generations of magnetite
  - Early Cr-bearing magnetite (typical ‘mafic magnetite’)
  - Metamorphic Ti-bearing magnetite
Chalcocite - Magnetite Association

Metamorphic Ti-magnetite surrounding earlier, pitted Cr-magnetite
Chalcocite Replaced by Hematite

Interstitial chalcocite (white, good polish) replaced by platy hematite in hornblende-biotite schist

HFOV = 2.25 mm
Hi Temp Chalcocite Exsolving Bornite

OCR191-P130NM Grain 1
Chalcocite Exsolving Bornite

Note Au-Ag-Te
Cr- and Younger Ti-magnetite & Rutile
Epidote with Chalcocite & Magnetite Inclusions

ORC 128 D4
Cr-Epidote porphyroblast with inclusions of chalcocite, Ti-Mte, Cr-Mte, Titanite surrounding rutile
Ore Mineral Summary

- Chalcocite as inclusions in epidote & silicates – not supergene
- Lamellar chalcocite-digenite-bornite intergrowths – high T°C
- Evidence for replacement of bornite by chalcocite – significance?
- Spatial association between chalcocite & magnetite
- Chalcocite XRD crystallinity study shows 3 polymorphs
  - high-pressure type modified by uplift
- Omitiomire chalcocite is metamorphogenic
Fluid Inclusions in Quartz & Epidote

- Two-phase aqueous inclusions: saline (19 – 27 wt% NaCl$_{equiv}$)
- Dissolved species being strongly dominated by CaCl$_2$
- Appear cogenetic with a CO$_2$-rich fluid
- Lack of Br and low Na suggest fluids not from evaporites

Hartwig Frimmel, UCT
Section 3: *Mesoscopic* - Looking at the Rocks
Host Rocks

Mafic metavolcanics -
  • Amphibolite
  • Biotite-amphibole-plagioclase schist

Felsic metavolcanics
  • Quartz-feldspar-biotite gneiss

Intrusive sills
  • Foliated tonalite
Banding

Amphibole schist, quartz-feldspar-biotite schist, felsic gneiss, biotite schist.

Banding on a scale of cm to metres
Banding & Foliation

- Coarse banding may be original $S_0$ fabric
- Fine banding interpreted as metamorphic fabric
Recumbent Folds
Recumbent Folds

Z-folds support ESE-directed tectonic transport

Drill core looking north
Copper Concentration

- Copper in mafic (biotite-amphibole-plagioclase) schist
- Bands of felsic gneiss are barren
Shear Zones

Biotite-epidote schist with chalcocite, sphene & fuchsite
Shear Zones

Coarse-grained chalcocite overprints cleavage
Shear Zones

Coarse chalcocite overprints cleavage

Retrograde mineral assemblage - Cr-epidote, sphene, fuchsite
• Chalcocite associated with Cr-epidote
• Chalcocite introduction is a retrograde event
Biotite-epidote schist with coarse chalcocite - interpreted to be zones of strong retrograde fluid flow
Section 4: Macroscopic - Looking at the Deposit
Copper-rich mafic band piercing into the hangingwall
Drill Section

15m

Hanging-wall

contact

Bulk sample box-cut

Ramp

ORC275

ORC274

ORC273
Hanging Wall Contact

Piercement structure
Multiple Lenses

Three main lenses ...
... and several small hanging wall lenses
Long Section

B & C Lenses open to NNE
• Deposit extends 3,500m north-south
• Plunges at a shallow angle to the NE, E and to the SSE
Grade x Thickness
## Omitionmire Resource

<table>
<thead>
<tr>
<th>Cut-off grade (% Cu)</th>
<th>Indicated + Inferred Resource</th>
<th>Resource + Potential</th>
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<tbody>
<tr>
<td></td>
<td>Resource (Mt)</td>
<td>Grade (% Cu)</td>
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<tr>
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<tr>
<td>0.4</td>
<td>71</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Approx 73\% Indicated

Oxidation

Oxidised to 20m depth, partly oxidised to 40m, plus oxidation down faults.

Main oxide mineral is malachite, some chrysocolla, minor native copper
En echelon array of lenses
Additional lenses postulated to the NE
Lenses in the hanging-wall outside this corridor
Satellite Deposit Potential

- Detailed soil geochemistry defined anomalies on the Dome
- Shallow drilling has identified the same geology and mineralogy as at Omitiomire

Soil geochemistry - Copper anomalies in “warm” colours
Section 5: Megascopic - the Big Picture
Omitiomire Host Rocks

What can we say about the origin of the gneisses?

- Minimal rock exposure
- Amphibolite-facies metamorphism
- ~1100 Ma igneous zircons
- ~550 Ma zircon rims
- Late Damaran sphenes
Dacite is by far the most common rock type in continental volcanic terranes such as the Andes.
Whole-rock Chemistry

Le Maitre’s classification
Calc-alkaline Chemistry

AFM plot of Omitiomire gneisses (n = 19)

Biotite+epidote schist

Felsic gneisses

Amphibolites
~1100 Ma Oorlogsende & Kgwebe Volcanism

Ekuja Dome

Hegenberger & Burger (1985)

Figure 1: Generalised geological map of the area between Witvlei (S.W. Africa/Namibia) and Toteng (Botswana). Nama and post-Damara rocks omitted. (After Geol. Map of Botswana (1973) and Geol. Map of S.W. Africa/Namibia (1980)).
Volcanic Setting

Andesitic pyroclastics – 60 ppm Cu reservoir
Ecuador andesites: Cu in magnetite & feldspar

Rhyo-dacitic ignimbrites

Oligocene – Miocene volcanics at Talabre–Lascar, CAVZ, NE Chile
Tectonic Setting of Volcanism

1370 - 1100 Ma

Volcanic rocks
Magma chambers / plutons
Continental crust
Oceanic crust
Mantle lithosphere
Asthenosphere

Back-arc setting of Omoitiomire

Basaltic magma ponding

After Hoal, 1990
Current Regional Setting
Regional Cross-Section

- Ekuja Dome
- Omitiomire
- Foreland-dipping duplex

Metagabbro, Anorthosite

Kuiseb Formation (620-600 Ma)
Ekuja Dome (~1100 Ma)
Okatjuru Complex (~1300 Ma?)
Pre-Damara strata (~1800 Ma?)

Tectonic transport direction

Kudu Lineament
Tectonic History

• Early S- or SW-directed nappes & thrusts (Karl Kasch)
  – $D_1$ at 580 – 575 Ma; $D_2$ at 550 Ma

• Main architecture of Ekuja Dome is syn-$D_3$ at 540 Ma

• Metamorphic peak & collision at 535-530 Ma (M2)

• Peak P/T conditions of 600$^\circ$C and 7-8 kbar

• Cu mineralisation associated with retrograde schists

• Thus Cu event was late in tectonic cycle – syn-$D_4$

• Maybe multiple retrograde cycles 520 – 485 Ma
Orthogonal $D_3$ Collision & $D_4$ Transpression

- Strong vergence to SE overall
- $D_3$ collision occurred at $\sim 530$ Ma
- Orogen was then ‘locked up’
- Change in regional stress field
- $D_4$ transpression: NNE folds
A Late Damaran Cu-Mineralising Event

- D₃ collision at ~530 Ma
- Sphene dates of 520 – 485 Ma
- Cu mineralisation is syn-D₄

- No ESE-WNW lineations
- NNE fold axes are ‘b’ direction (σ₂)
- Cu concentrated in NNE corridor
- NNE zones host Damaran D₄ Au & U
  (Rössing, Navachab, Otjikoto)
Section 6: Kite-flying,
Discussion & Conclusions
A Likely Source of Copper - Basalts

- Calc-alkaline basalts at Omitiomire became amphibolites
- Tectonised, sheared & were loci for retrograde fluid flow
- All Kgwebe volcanics have 1 – 10% magnetite
- Magnetite-bearing volcanics typical of continental arcs
- Many Chilean Cu-magnetite ores in basaltic andesites
- Up to 3% Cr- and Ti-bearing magnetite in Omitiomire copper ore assemblage from retrograde breakdown of amphibolite
- Voluminous subaerial Cu-bearing mafic rocks in SMZ
- If looking for Cu reservoir, does mafic rock chemistry matter?
- Tectonism and fluid pathways/precipitation more important
- Omitiomire deposit variant of ‘basalts as source rock for Cu’
Ore Genesis

- Chalcocite >> bornite
- System with high Cu : S ratio (sulphur-poor)
- Retrograde Cu fluids channeled into discontinuities / shears
- Reacted with tectonised amphibolites - quartz+calcite+magnetite
- Eh-pH change caused Cu precipitation
  - hornblende breakdown
  - calcite breakdown ?
  - magnetite redox reaction ?
- Local chalcocite replacement by hypogene hematite
- Hot, saline, oxidised retrograde metamorphic fluid to carry Cu
- Retrograde biotite proves K mobility (potassic alteration)
Conclusions

• Late deformational deposit on margin of dome
• Tectonic setting reminiscent of Lumwana Cu, Zambia
• Hosted by retrograde assemblage – epidote & biotite
• Late Damaran Cu event (520 – 485 Ma)
• Chalcocite-dominated system
• Open-ended 4 km x 1 km Cu system
• Result of regional retrograde fluid flow
Discussion Points

• Timing of copper emplacement
  – 520 – 485 Ma - but multiple pulses?

• Imbricate shear zones
  – Dilatant bend in a fault zone?

• Structural history/setting
  – Influence of $D_1$ & $D_2$ deformation events?
  – Mineralisation in syn-$D_4$ corridor – other explanations?

• Relationship to Kudu Lineament?

• Relationship to Steinhausen Magnetic Anomaly?
Steinhausen Magnetic Anomaly

Ekuja Dome
Discussion Points

• Is Omitionire an IOCG variant?
  – Biotite = Potassic alteration related to Cu emplacement?
  – Magnetite = Inherited mafic debris or syn-Cu event?
Widespread geochemical anomalies show that Omitiomire is part of a regional copper system.

There should be other deposits formed during the same event.

They might have quite different geometry, host rocks, mineralogy.
Omitiomire Copper Project
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