Tectonic/structural controls to Au-Cu mineralisation in Papua New Guinea

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Take home

- Terrain scale arc normal and arc parallel structures exhumed and mineralised
- Variations in mineralisation style related to relationship to intrusion source and linkages
- Uplift and erosion
- Geological mapping
Ore shoots in steep dipping vein portions
Plate tectonic setting of Papua New Guinea
Lihir
Luise volcano

Side looking radar
and off shore seismic
Porphyry style alteration
NS long section

Minifie Drill Sections

South

Drill Section 9300 part only
opal veins overprint K-feldspar
bottles-enhydrite cut by banded chaledony veins

Drill Section 9500 E part only
rock type change

North

Drill Section 9775 E part only
intense quartz veined zone
top of anhydrite seal
pyrilitization with sheeted quartz-pyrite + anhydrite veins
Minifie structure
Lihir - structural control

- Fluidised breccia dyke
- Feeder
- Crackle breccia
- Mosaic breccia
MINIFIE
Drill Section 9500 E
Simplified from LMC data

LITHOLOGICAL CONTROL

STRUCTURAL CONTROL

- Drill hole intercepts
- Ore
Lithological control

13.1 g/t Au
Lihir –
epithermal event

123 g/t Au
Lihir – Active geothermal and AAA

Advanced argillic
Lihi Gold Mine

In 2003, 3.5 M oz Au production
163 Mt @ 3.88 g/t Au for 20.5 M oz Au resource
Since then Kapit zone
In 2008, 23.5 M oz resource
Styles of magmatic arc Cu-Au mineralisation
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DISTINCTION BETWEEN HIGH & LOW SULPHIDATION FLUIDS

High Sulphidation

- Steam heated
- Ore system with zoned alteration
- Dissociation of $H_2SO_4 + HCl$ to give $H^+$
- Disproportionation of magmatic $SO_2$
  $4SO_2 + 4H_2O \rightarrow 3H_2SO_4 + H_2S$

Low Sulphidation

- Travertine
- Boiling spring
- Silica sinter

Magmatic volatiles:
- $H_2O$
- $CO_2$
- $SO_2$, $H_2O$
- $HCl$, $HF$

Entrainment of magmatic volatiles in circulating waters

- Quartz-sulphide $Au Cu$
- Epithermal Quartz $Au-Ag$
- Polymetallic $Ag + Au - carbonate-base metal Au$

Oxidised acidic fluid $S$ as $SO_2$

Reduced near neutral fluid $S$ as $H_2S$

Acid sulphate alteration
Acid sulphate and/or oxygenated waters

Corbett
High Sulphidation epithermal Au

MOST
HOT ACID
enargite

LESSER
HOT ACID
Styles of magmatic arc Cu-Au mineralisation
TRANSFER STRUCTURES & PORPHYRY RELATED Au / Cu MINERALIZATION
High arc angle structures

Pascua-Lama-Veladero
Chile-Argentina

Yanacocha, Peru
Porgera – Two intrusion events

Early sulphide veins
Porgera – Two mineralisation events
Porgera - two events
Porgera-Mt Kare
Mt Kare
Mt Kare – supergene Au

25.5 million t @
2.2/t Au and 29g/t Ag
1.8 M oz Au
Porgera

Before

1990-2003 – 12.22M oz Au 2.23M oz Ag
2006 reserves 77.26Mt @ 3.79g/t Au (9.4M oz)
Underground production increasing to 60% of Au

Now
Porgera target generation

Porgera Mine - Deep Mine Targets

Targets revised to test vertical potential from footwall
- Better drilling conditions to increase success
- 18,000m DD
Morobe goldfield
Bulolo Gold
Dredging

2.1 M oz Au @ 0.15 g/t Au
1932-65
Wandumi sinter
Wau-Namie-Ribroaster

About 1 M oz Au
1923-90
Nauti
Nauti diatreme and Edie Creek

[Map and diagrams showing geological features and mineral deposits related to Nauti diatreme and Edie Creek]
Hidden Valley

3.5 Mo oz Au
@ about 2 g/t Au
Hidden Valley looking south along the Upper Watut fault
Kerimenge
Kerimenge

About 1 M oz Au
Hamata

0.41 M oz Au @ 3.9 Au
Hamata
Wafi diatreme breccia
Golpu vertical Cu zonation

263m @ 1.86% Cu
+ 0.27 g/t Au
Including 88m @
2.75% Cu + 0.35 g/t Au
Wafi Au setting

Distribution of Surface Alteration
Mineralogy in the Wafi River Prospect Area
(After Leach & Erceg 1990)
Wafi Link Zone
High to low sulfidation transition
From Leach 1999

- Upflow - outflow hot acidic magmatic fluids
- Zoned high sulfidation Au-Ag+Cu
- Zoned low sulfidation Au-Cu
- Phyllic-argillie
- Epithermal quartz
- Carbonatic-sulfide
- Base metal
- Recharge of cool dilute + CO₂ - bearing oxidizing meteoric waters
Wafi

A porphyry Cu/Au system with high sulphidation epithermal Au overprint

Golpu Porphyry*
163 Mt @ 1.1% Cu, 0.57 g/t Au, 132 ppm Mo
3.9B lb Cu, 47M lb Mo 2.96 Moz Au

Wafi Au Resource*
• 1 g/t grade shell (Blue)
• 2.5 g/t grade shell (Yellow)
110Mt @ 1.85 g/t for 6.51 Moz Au

* Resource inventory available on the Harmony website
Headwaters prospect
Bilimoia porphyry-epithermal
Kora mine

Reference
- Advanced argillic alteration
- Elandera Porphyry
- Akuna Granodiorite
- Karantina Gneiss
- Bena Bena metamorphics
- Diatreme breccia
- Vein Cu / Au
- Low grade porphyry Cu / Au

BILIMOIA - ARAKOMPA Structure

Greg Corbett
Tolukuma gold mine
Tolukuma gold mine

Distances are downhole vein intercepts as m, Au, Ag, e.g., 4.8, 22, 97 is 4.8m, 22 g/t Au, 97 g/t Ag.
Tolukuma
Production > 1 M oz Au

Tolukuma
Tectonic elements of Papua New Guinea
Misima

3.7 Moz Au production
Woodlark
Porphyry Au-Cu-Mo
In 1972
944 Mt @ 0.48% Cu, 0.56 g/t Au
To 1988 produced
3 Mt Cu, 9.6 M oz Au
Ok Tedi

Since 1984 produced
3.8 Mt Cu, 10.6 M oz Au 13 M oz Ag
Due to close 2013
Ok Tedi – Porphyry Cu Au

- Au cap: 2.87 g/t
- 0.7% Cu
- 0.6 g/t Au
- 0.11% Mo
Horse-Ivaal Geology

1 Bt @ 0.5% Cu, 0.3 g/t Au
Frieda Cu-Au porphyry

Horse-Ivaal Plan Frieda River

- Polysac (Biotite-K-Feldspar)
- Propylitic (Epizone-Actinolite)
- Intermediate-Argillic (Chloritic)
- Phyllic (Sericite)
- Advanced Argillic (Alumite-Pyrophyllite)

Faulks

0.9% Cu Contact

Modified from Blitten 1981.
Ekwai Debom
Advanced argillic alteration

Corbett & Bainbridge
modified from Britten, 1981

Silica - alunite
Clay
Sericite
Potassic
Veins

5 Kilometres
Nena high sulphidation Cu-Au

18 Mt @ 0.1% Cu, 1.4 g/t Au
51 Mt @ 2.2% Cu, 0.6 g/t Au
Yandera
Yandera – geology

163 Mt @ 0.5 Cu equ
Solwara
Solwara

**SOLWARA 1 – MASSIVE SULPHIDE INTERCEPTS**

- **8.1m @ 14.8% Cu 8.4g/t Au**
- **13.7m @ 8.5% Cu 8.4g/t Au**
- **18.9m @ 5.0% Cu 3.4g/t Au**
- **5.9m @ 15.3% Cu 11.7g/t Au**
- **7.8m @ 11.8% Cu 15.1g/t Au**
- **6.2m @ 12.2% Cu 12.9g/t Au**
- **6.5m @ 13.4% Cu 9.4g/t Au**
- **9.3m @ 11.0% Cu 6.3g/t Au**
Conclusion – Controls to Cu-Au in PNG

♦ Constant theme of arc parallel and arc normal structures
♦ Linkages between different deposit types at various levels of erosion and distance from intrusion source rocks
♦ Importance of uplift and erosion
♦ Geological mapping continues as the most important element in mineralisation models
Thank you
Thank you
Styles of magmatic arc Cu-Au mineralisation
Barren shoulders of advanced argillic alteration
Barren advanced argillic alteration
Wild Dog