Exploration history, geochemical/alteration zonation and structural controls on the Wafi-Golpu porphyry Cu-Au resource, a world class deposit in PNG

Doug Menzies – (Acting Geology Manager - Wafi-Golpu Project, 2013)

Menzies, D., Shakesby, S., Morehari, G., Tekeve, B., Fitzpatrick, N, Kur, J., Kulinasi, N., Miam, G., Larsen, J., Alupian, B, Finn, D., Peter, D., Golias, P., Read, R., Hayward S., and Wass, J.

Wafi Golpu JV

50 : 50 Joint Venture [2008]

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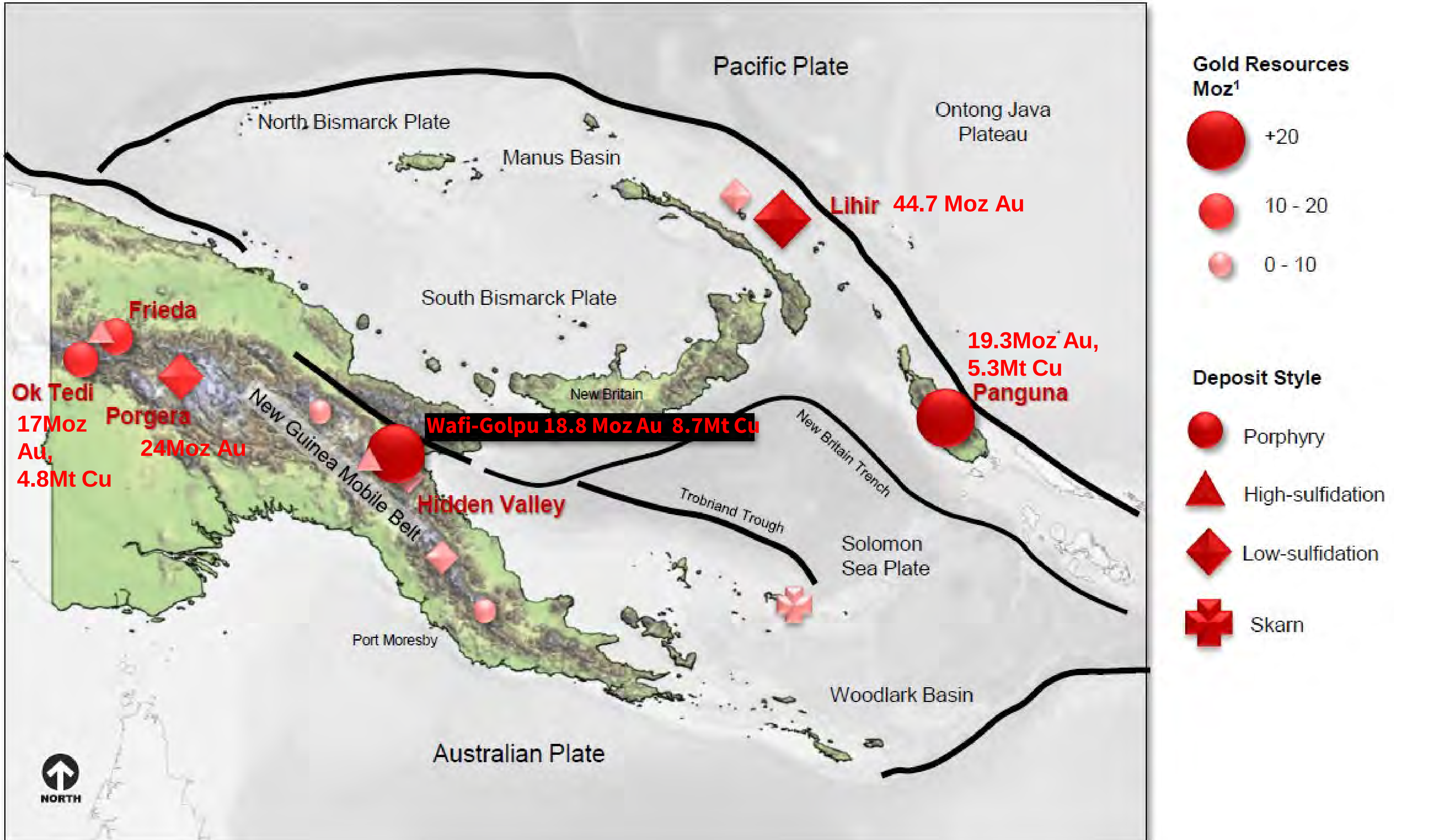
Wafi-Golpu

- Location
- Resource size
- Exploration history
- Regional and local structural
- Geology model
- Alteration and mineralisation zonation
- Surface geochemical expression
- Paragenetic model

PNG/Papuan Mobile Belt- elephant country



(1) Mineral Resource quoted 2022 (Ref: Harmony website, 2022; and figure after Moorehead, 2013)

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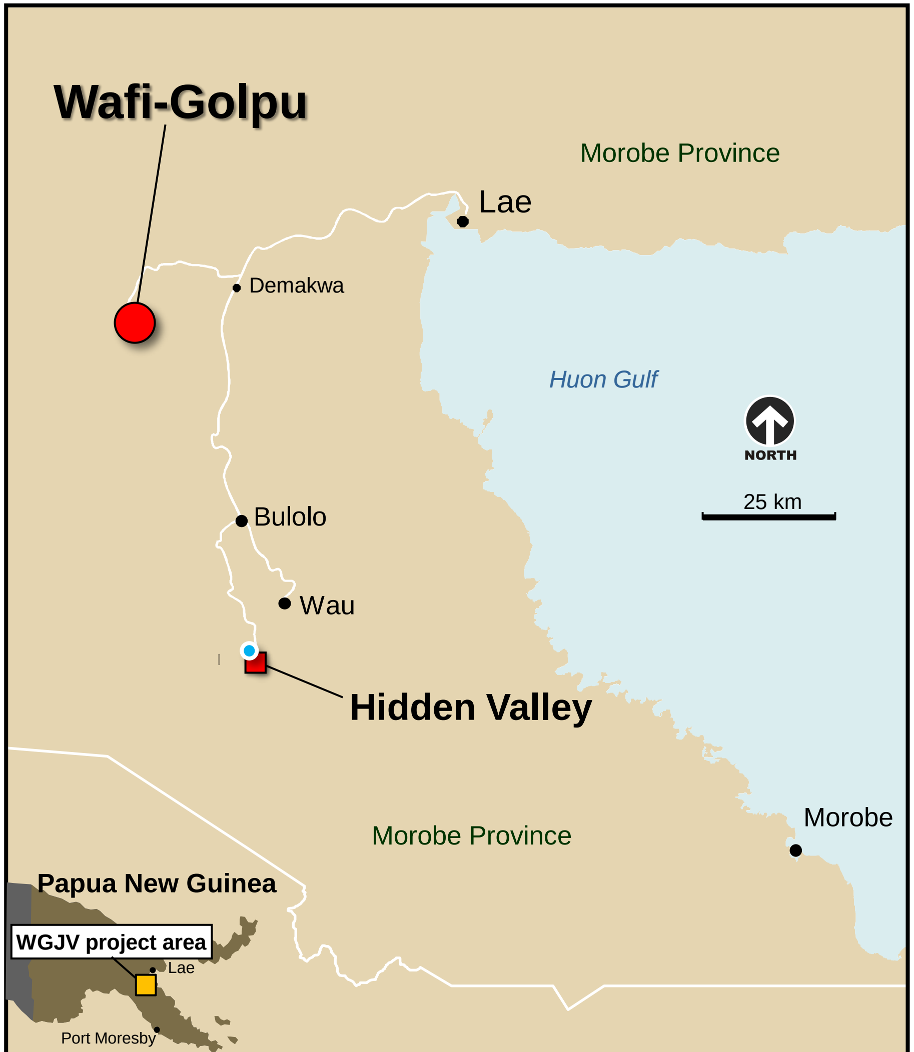
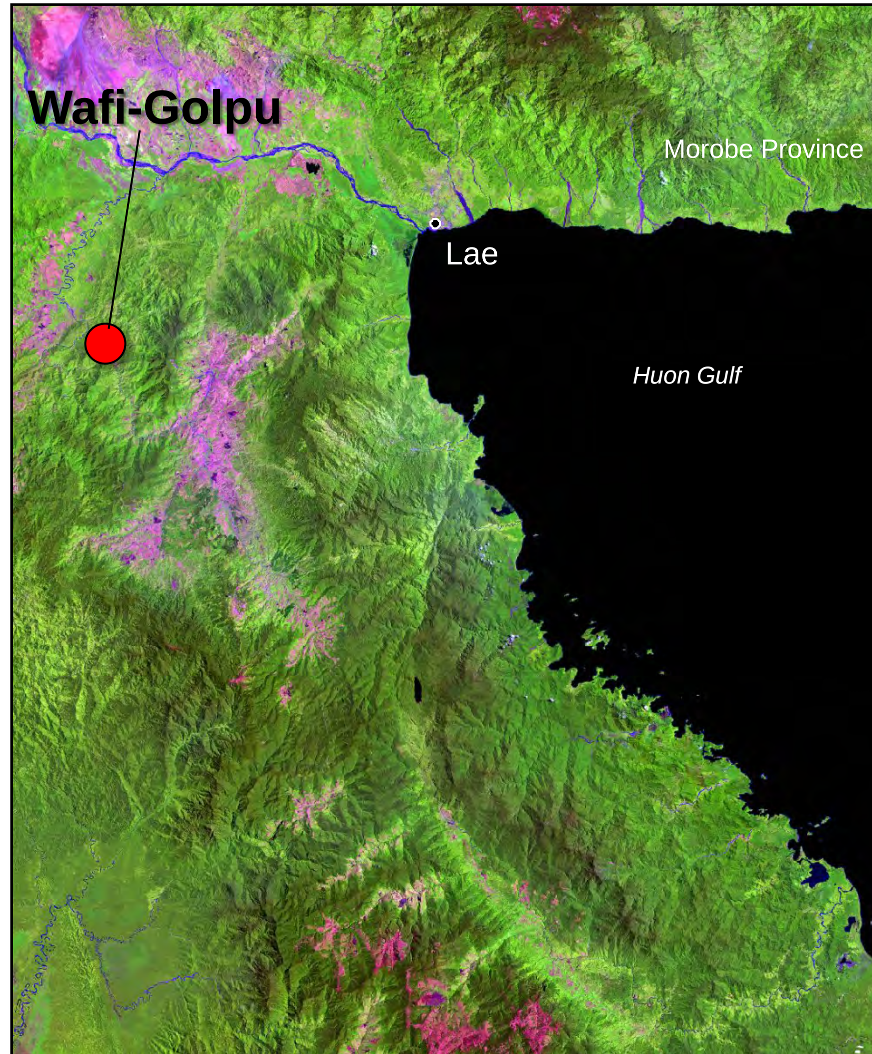
WAFI-GOLPU JOINT VENTURE

Location





Landsat/Geo-eye Image

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Mineral Resource Estimation

Table 1-1: Golpu Deposit Measured and Indicated Mineral Resource Statement

Confidence Category	Tonnage (Mt)	Grade			Contained Metal		
		Au (g/t)	Cu (%)	Ag (g/t)	Au (Moz)	Cu (Mt)	Ag (Moz)
Measured	—	—	—	—	—	—	—
Indicated	690	0.71	1.1	1.3	16	7.5	28
Measured + Indicated	***690***	***0.71***	***1.1***	***1.3***	***16***	***7.5***	***28***

Table 1-2: Golpu Deposit Inferred Mineral Resource Statement

Confidence Category	Tonnage (Mt)	Grade			Contained Metal		
		Au (g/t)	Cu (%)	Ag (g/t)	Au (Moz)	Cu (Mt)	Ag (Moz)
Inferred	140	0.63	0.85	1.1	2.8	1.2	4.6

Ref: Newcrest NI 43101 report 2020

1. Mineral Resources are reported inclusive of Mineral Reserves. Mineral Resources that are not Mineral Reserves do not have demonstrated economic viability.
2. Mineral Resources at Golpu are reported assuming a bulk mining underground extraction method and metallurgical recovery for copper and gold by sulphide flotation. Mineral Resources are reported above a net smelter return (NSR) cut-off, which assumes a gold price of US$1,300/oz Au, a copper price of US$3.40/lb Cu, mining cost of US$8.37/t mined, processing cost of US$9.75/t processed, general and administrative (G&A) costs of US$4.17/t processed, copper concentrate treatment charge of US$100/dmt of concentrate, transport cost of US$33.50/wet tonne of concentrate, and copper refining charges of US$0.10/lb of recovered copper. Silver and molybdenum were not valued in the NSR cut-off; however, these elements were reported within the Mineral Resource as they were expected to be recovered with minor circuit modifications or concentrate contract negotiations. Over the life-of-mine, it is anticipated that copper recoveries will average 94% and gold recoveries will average 68%
3. Tonnages are metric tonnes. Gold and silver ounces are estimates of metal contained in tonnages and do not include allowances for processing losses. Copper tonnes are estimates of metal contained in tonnages and do not include allowances for processing losses.

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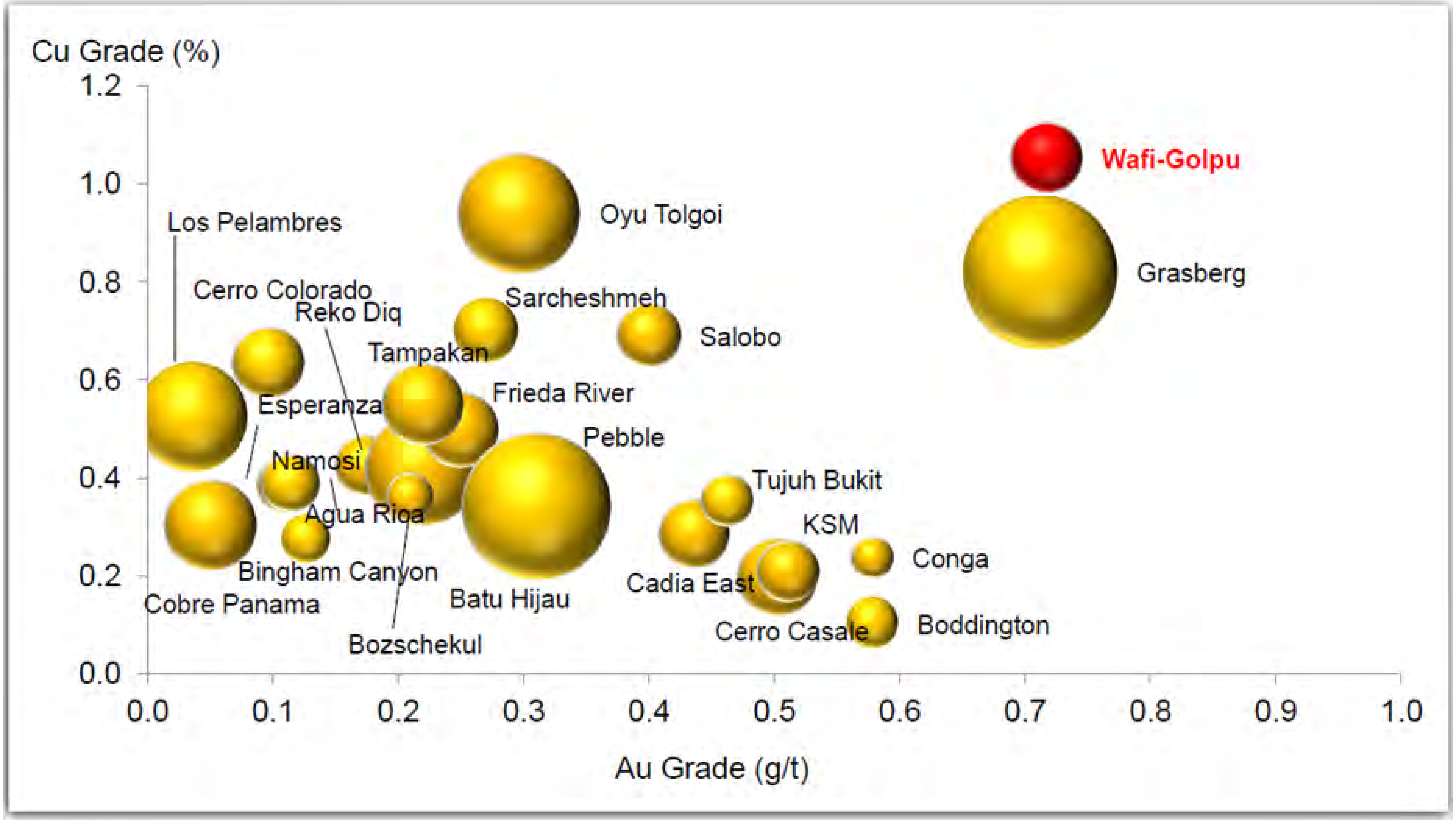
High Grades v Global Benchmark Deposits



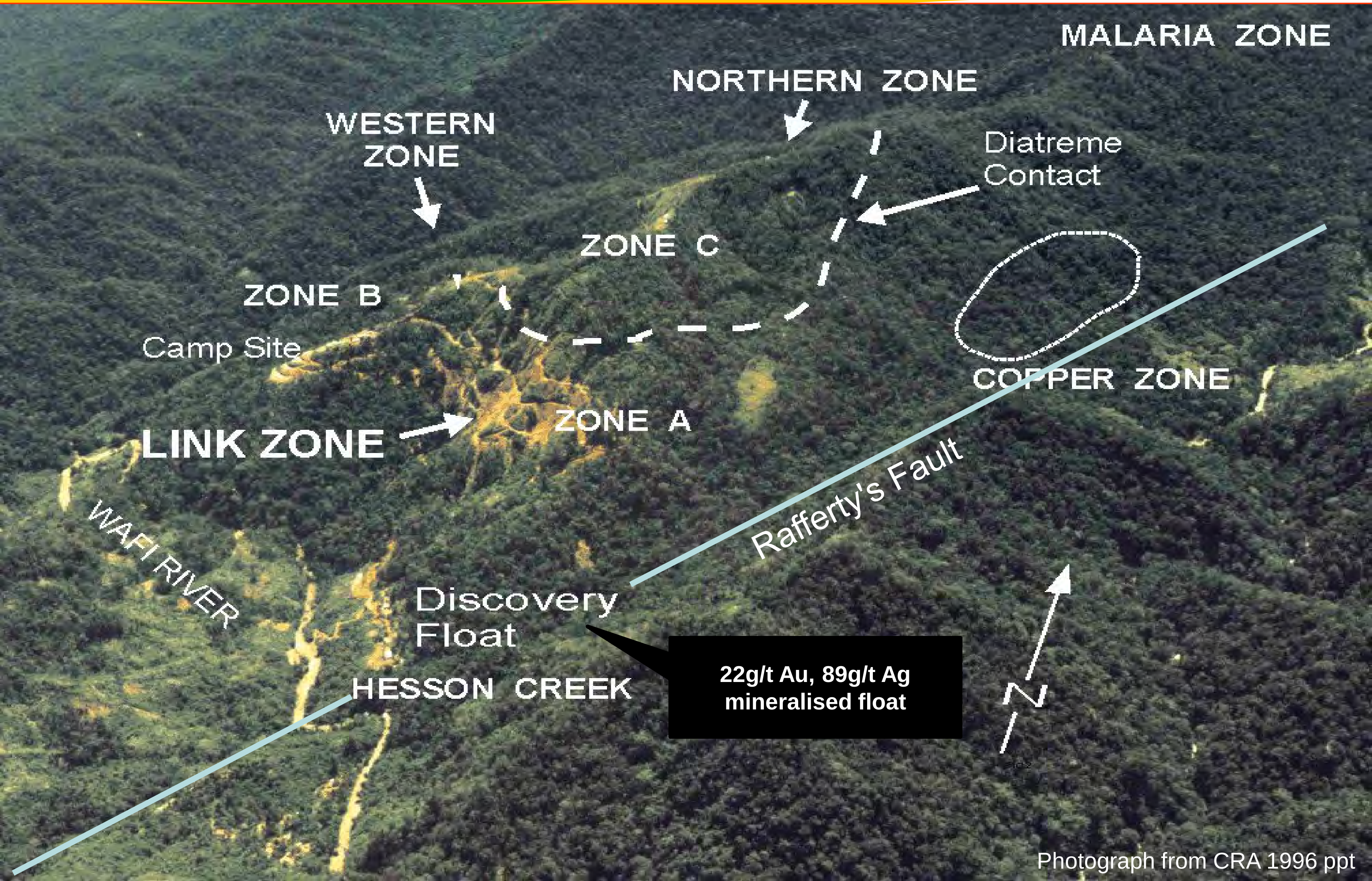
Source: modified from Moorehead, (2013) which used Bank of America Merrill Lynch Gold equivalent based on US$1150/oz Au, US$2.50/lb Cu at 100% recovery for both metals.

WAFI-GOLPU JOINT VENTURE

Exploration history

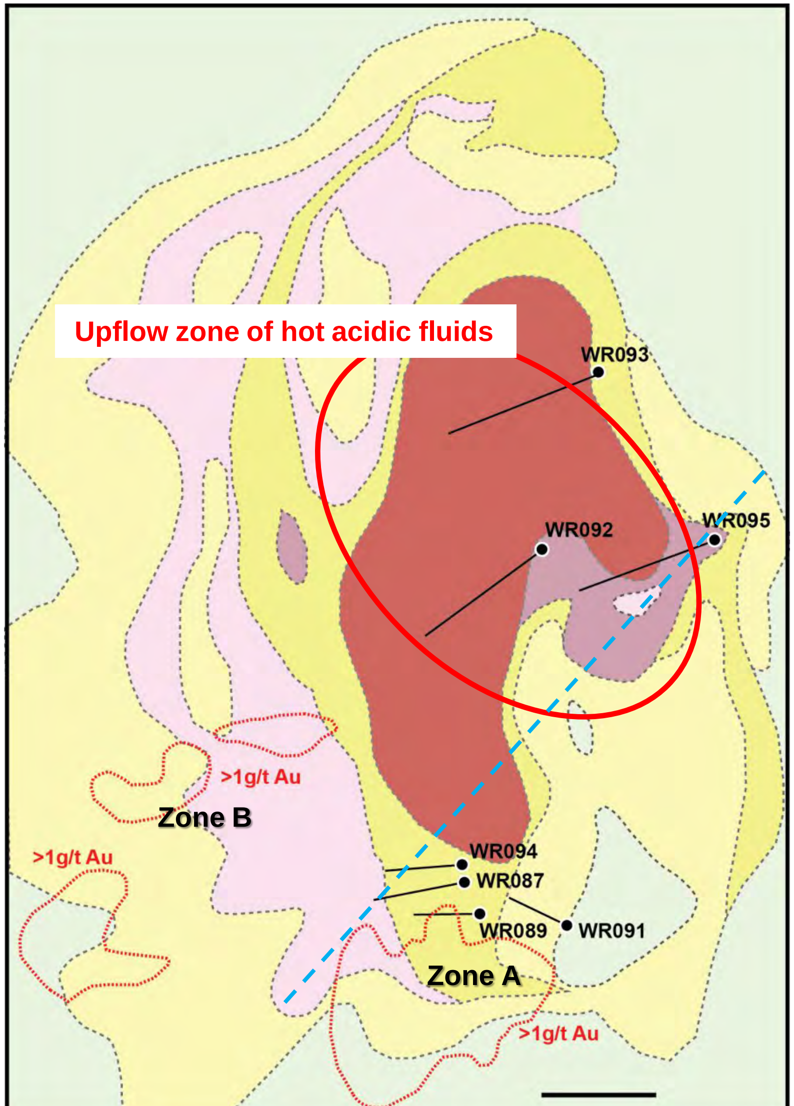
- 1977 – 1987: CRA Exploration
  - 60s CRAE star drainage sampling reported base metal in drainages
  - Wafi discovery (22g/t Au + 89g/t Ag float) (Karl Every)
- 1987 – 1990: CRA – Elders JV
  - Wafi: 18Mt @ 2.5 g/t Au.
  - Mike Erceg asked Greg Corbett proposed a hole into a Terry Leach interpreted upflow zone of hot fluid based on surface alteration and regional structures.
  - Rafferty's porphyry Cu-Au (later renamed Golpu) deposit discovery with hole WR95
- 1990 – 1997: CRA Exploration
  - Golpu concept studies
  - High grade “Link” zone Discovery
- 1997 – 2004:
  - Periods on care and maintenance
  - Ownership changes(AGF, Aurora, Abelle)
- 2004 – 2008: Harmony Gold
  - Golpu prefeasibility study
  - Nambonga Discovery
- 2008 – current: Wafi-Golpu JV
  - Nambonga resource
- 2009 Golpu re-discovery hole WR321

Early exploration

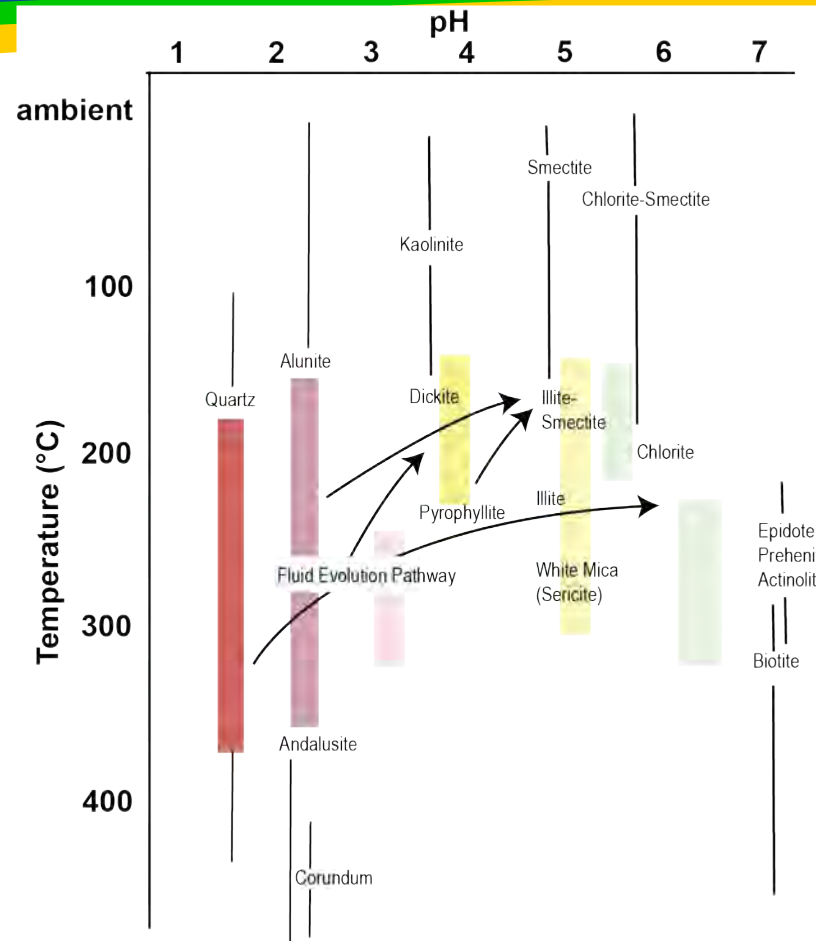


Photograph from CRA 1996 ppt

Surface a hydrothermal alteration

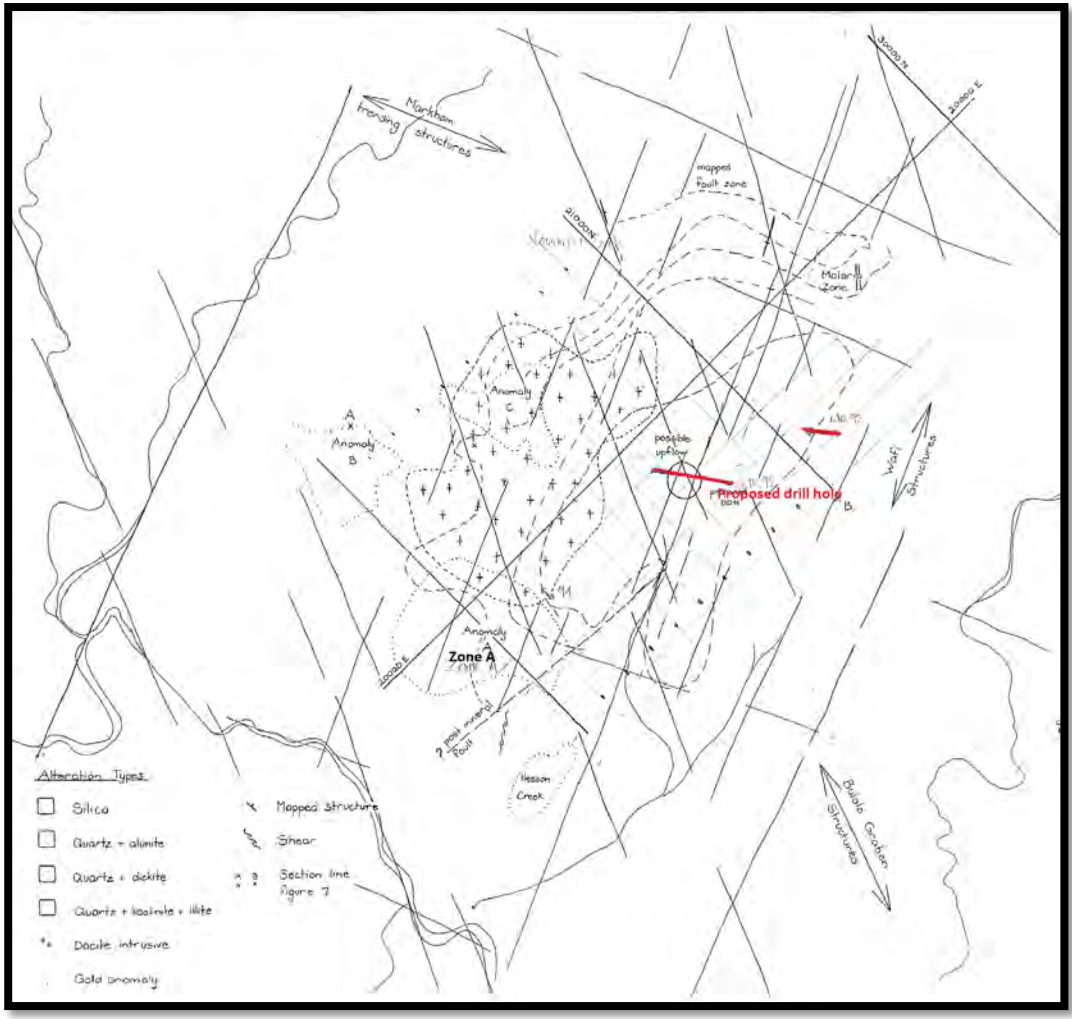


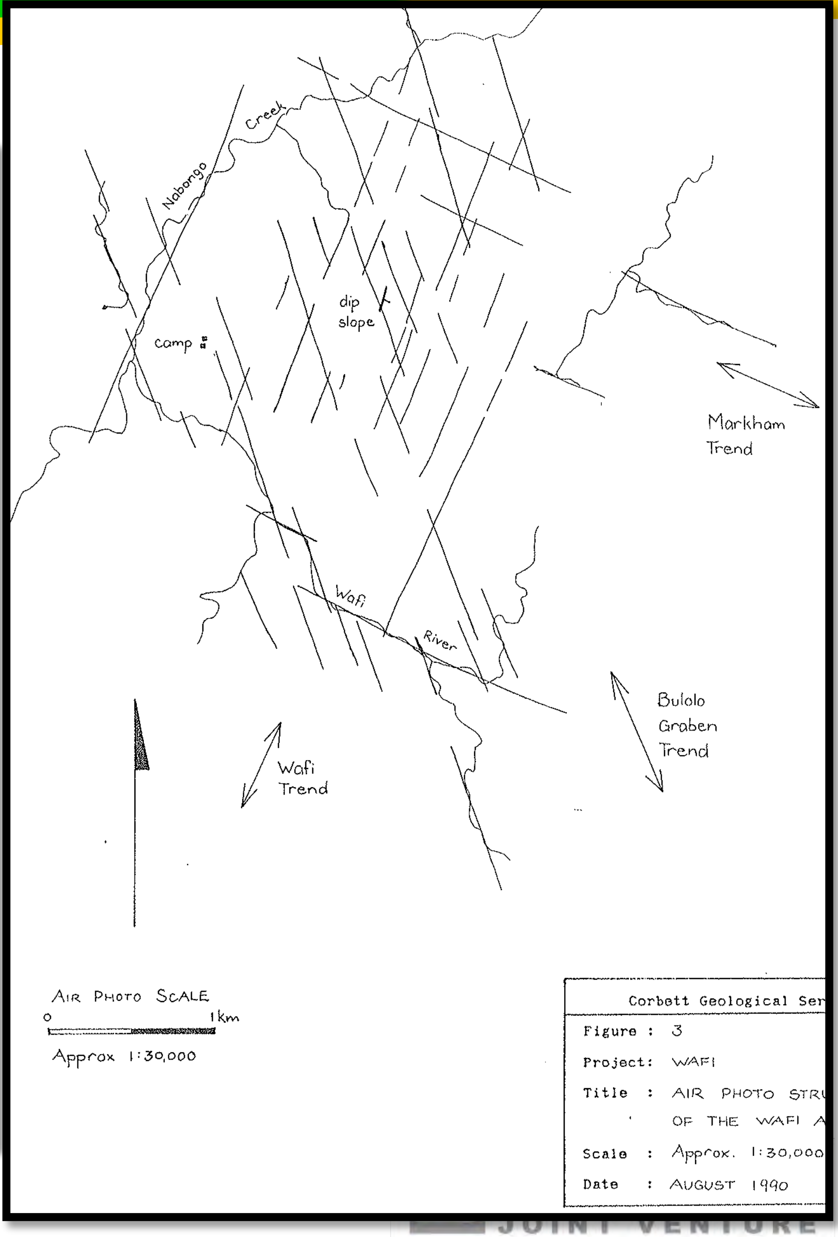
Wafi Local Grid



Transition from dickite/kaolinite-illite-smectite-quartz → dickite/kaolinite-quartz → quartz ± alunite was recognized a reflecting lateral changes in temperature and pH of the causative fluids

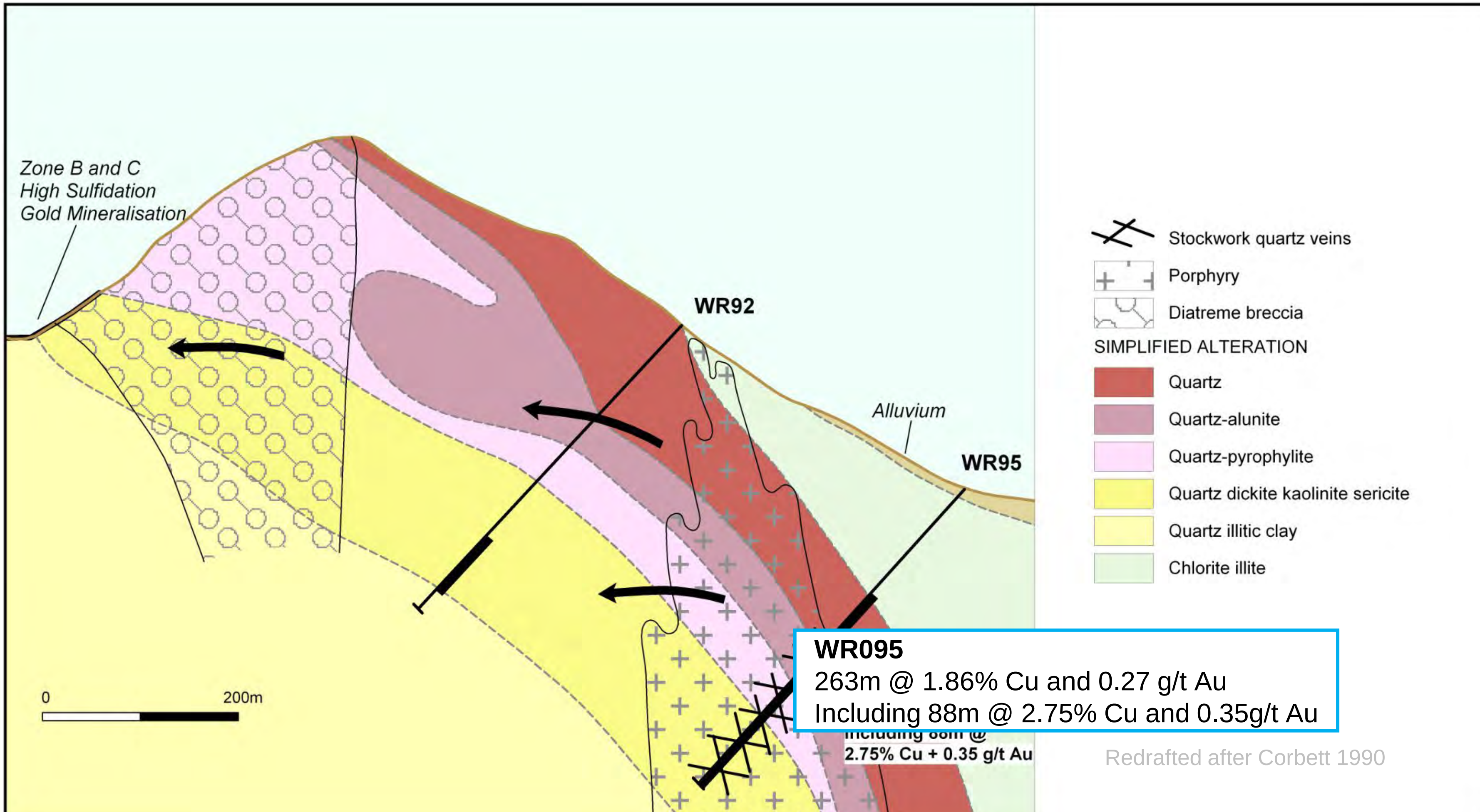
Feeder structure





Conceptual Model – Leading to Golpu Discovery

Elders proposed to drill a conceptual hole further east targeting an inclined feeder to the high-sulphidation system

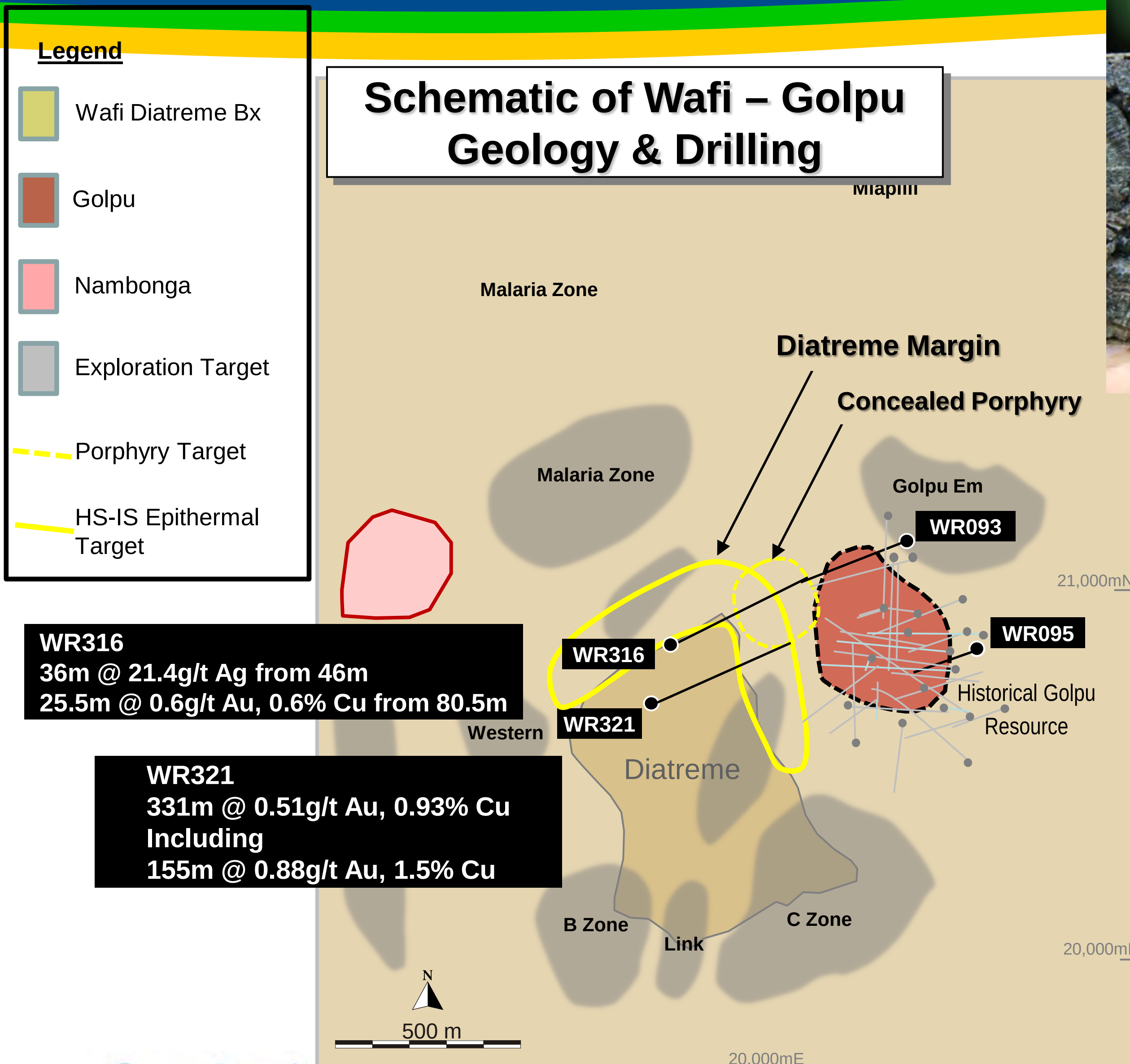


WR095
263m @ 1.86% Cu and 0.27 g/t Au
Including 88m @ 2.75% Cu and 0.35g/t Au

Redrafted after Corbett 1990

Discovery of the so-called ***Rafferty's porphyry Cu deposit*** in early 1991

Target Testing – Re-discovery 2009



WR93: 291m: Thick magnetite vein + bornite

- A review of historical core by Greg Corbett identified magnetite bearing M-veins in WR93.
- A site geologist identified an increase in Cu grades downhole

Wafi Local Grid, Ref Hayward et al 2011

WR321 –rediscovery hole

- WR321 was extend beyond planned 800m depth by the project geologist Priscilla Golias owing to the identification of anomalous alteration, increase in stockworked A-type veins & presence of chalcopyrite. Diorite porphyry intersected at 890m.

- WR321 reported 331m at 0.51g/t Au and 0.93% Cu

WR321: 762.5m Biotite altered metasediments with quart-chalcopyrite bearing (~1%) veins

WR321: Diss and veined chalcopyrite, 1m at 0.7g/t Au and 2.1% Cu, 955m

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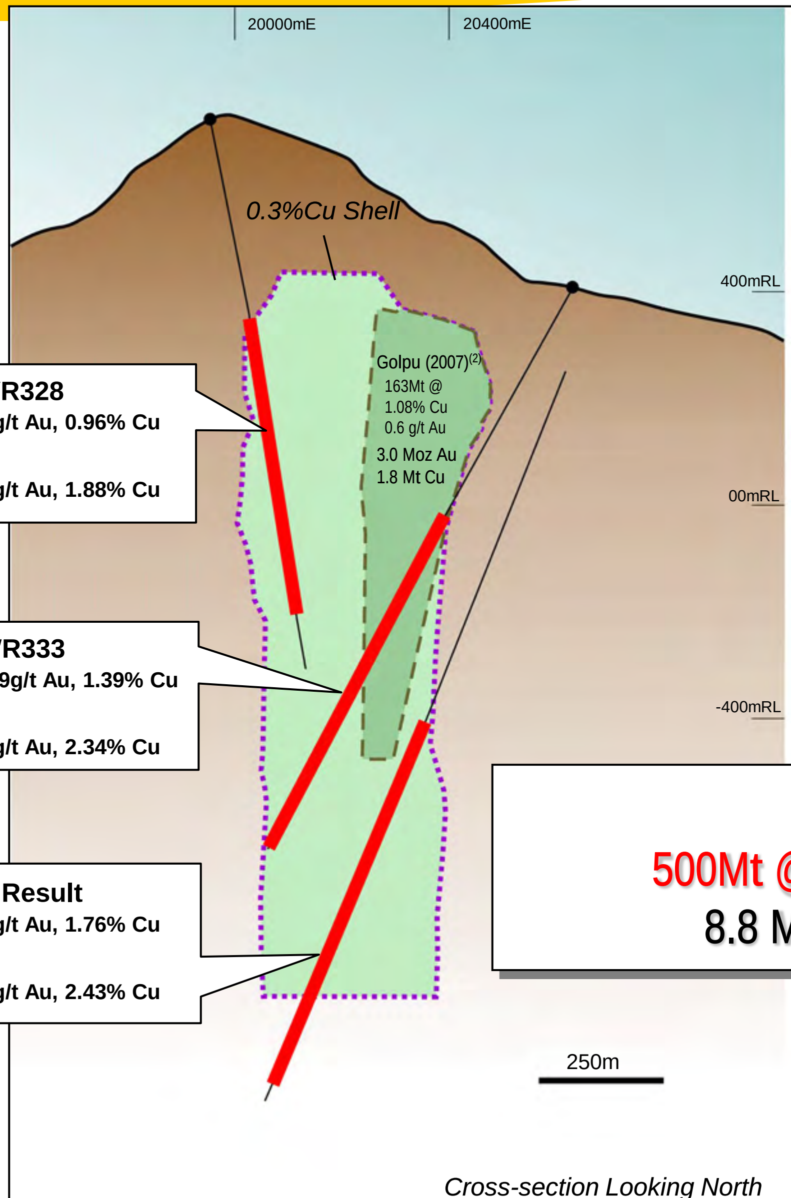
Golpu Resource Expansion 2010



WR328
597m @ 0.57g/t Au, 0.96% Cu
Includes
198m @ 1.13g/t Au, 1.88% Cu

WR333
727.5m @ 0.69g/t Au, 1.39% Cu
Includes
353m @ 1.18g/t Au, 2.34% Cu

WR337 Q4 Result
802m @ 1.13g/t Au, 1.76% Cu
Includes
516m @ 1.58g/t Au, 2.43% Cu

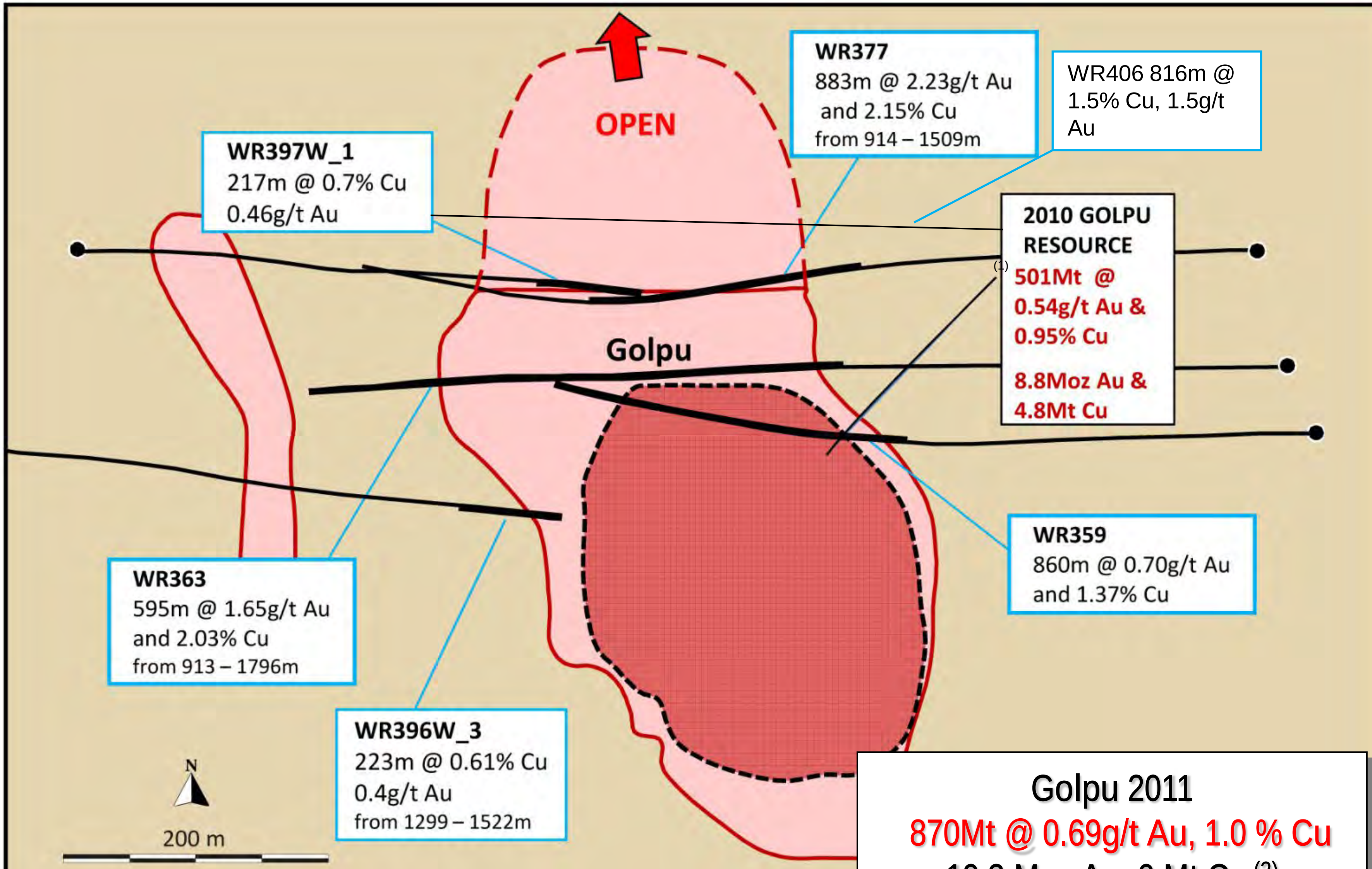
Golpu 2010
500Mt @ 0.54 g/t Au, 0.95% Cu
8.8 Moz Au, 4.8 Mt Cu (1)

(1) Newcrest & Harmony Annual Statement of Mineral Resources & Ore Reserves to June 30, 2010

(2) Published Harmony Resource 2007

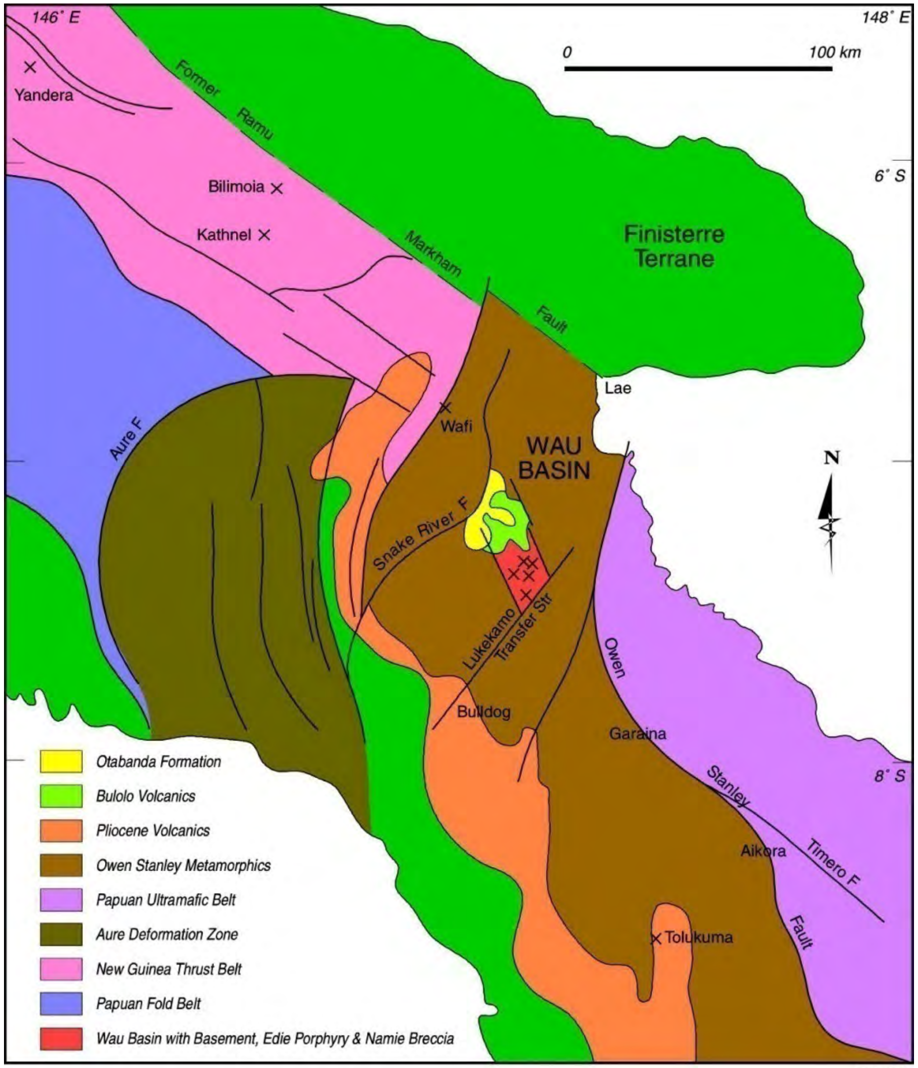
WAFI-GOLPU JOINT VENTURE

Golpu –Mineralised Intercepts 2011

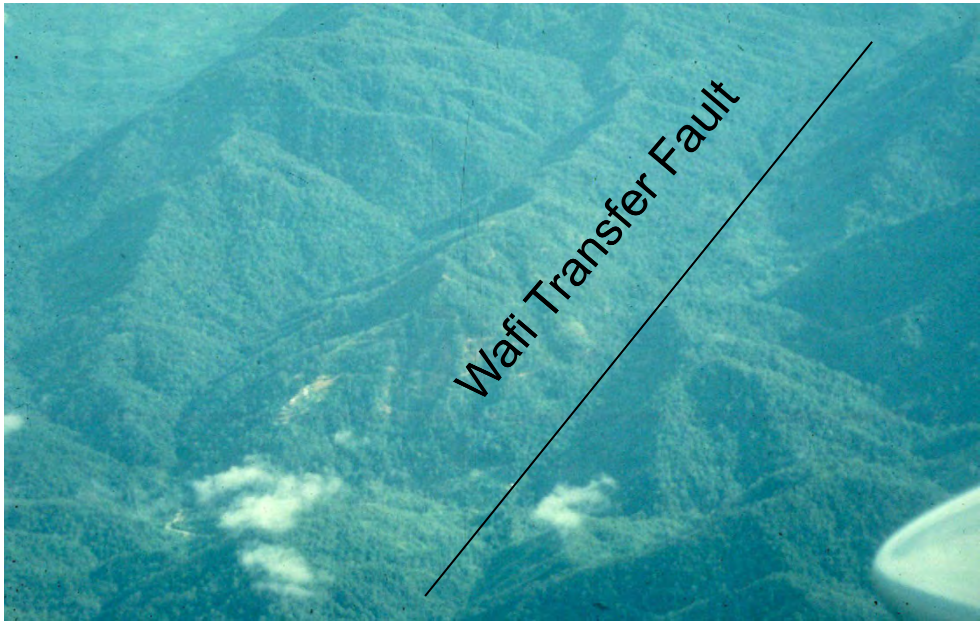


(1) Newcrest & Harmony Annual Statement of Mineral Resources & Ore Reserves to June 30, 2010
(2) Newcrest & Harmony Annual Statement of Mineral Resources & Ore Reserves to June 30, 2011

Regional structural controls – Wafi Transfer Structure

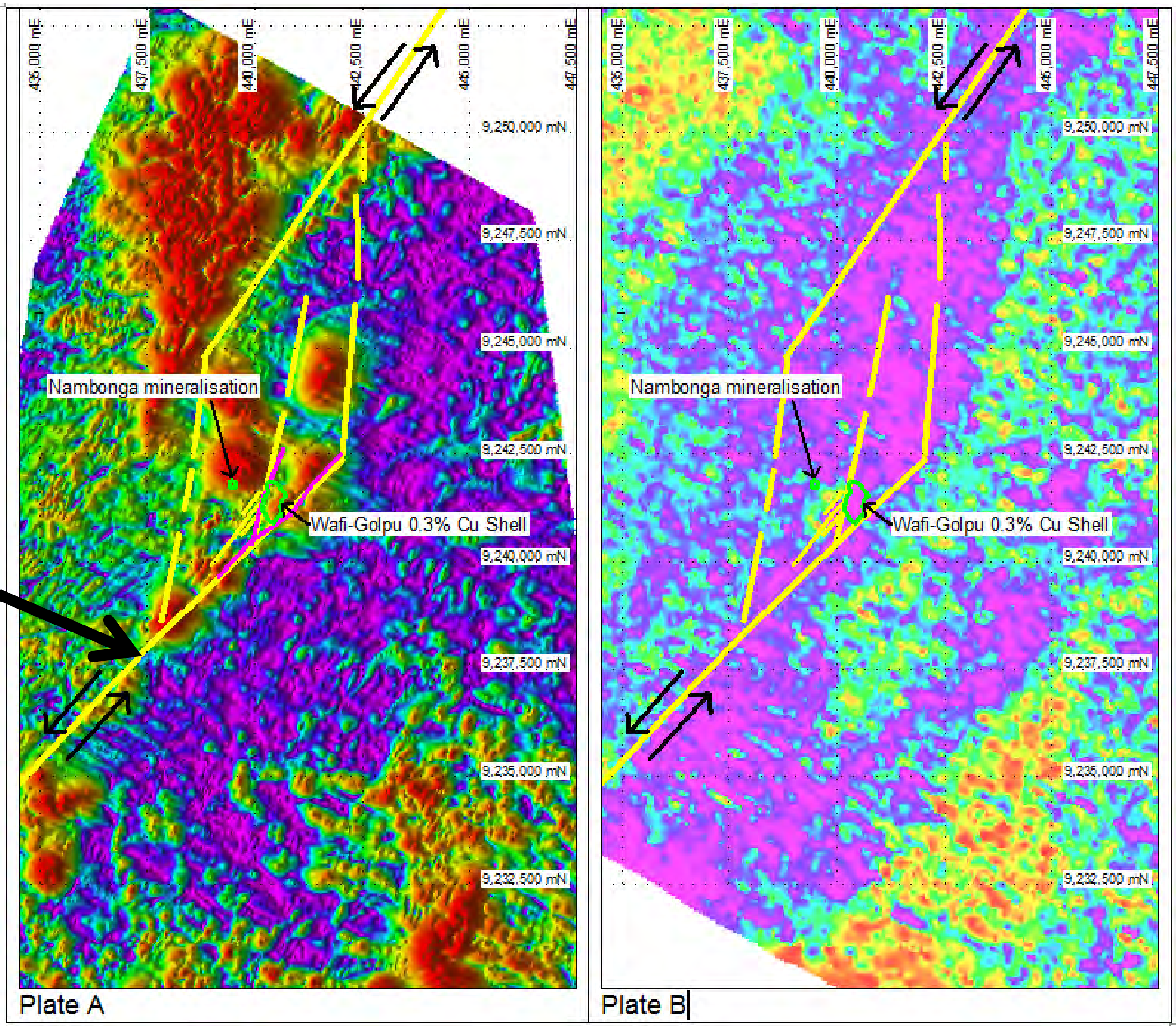


Ref: Corbett (2013)



Regional magnetic and radiometric data

Wafi Transfer



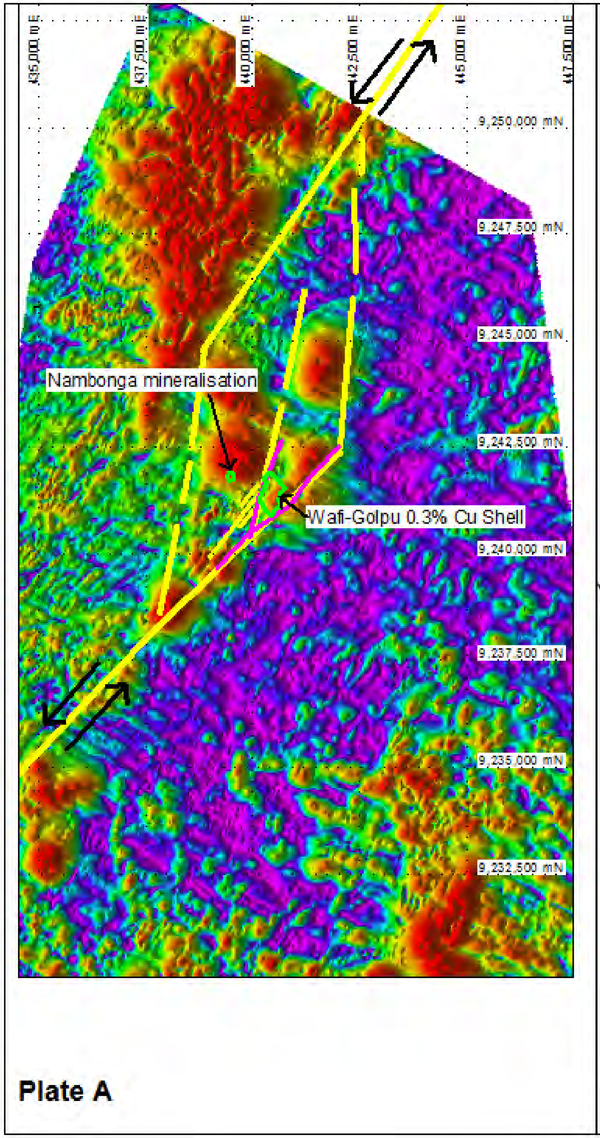
TMI aeromagnetic data

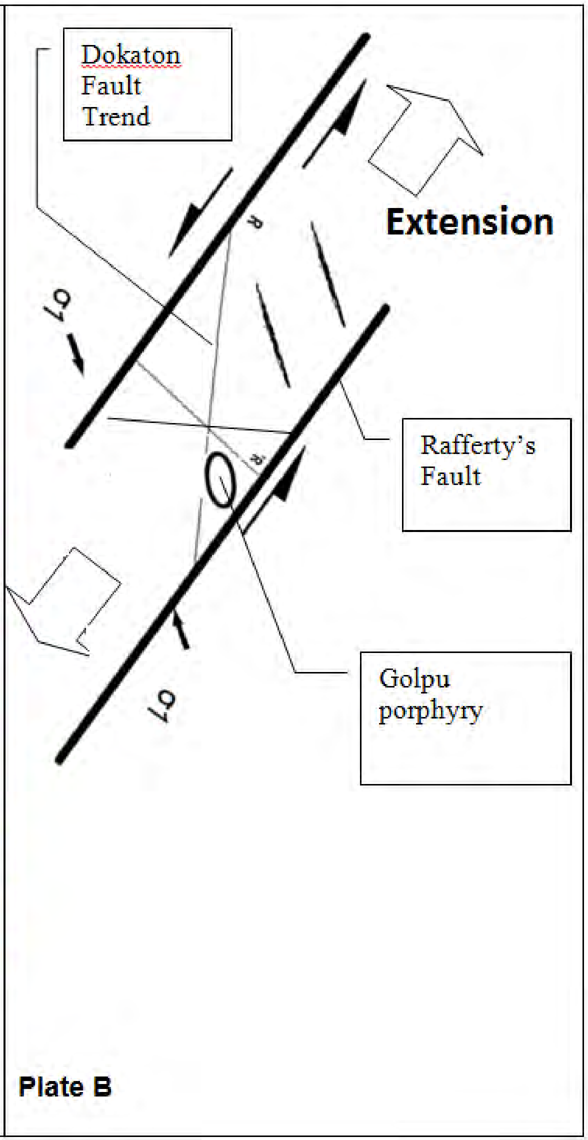
K channel radiometric data

Ref: Menzies et al (2013)

WAFI-GOLPU
JOINT VENTURE

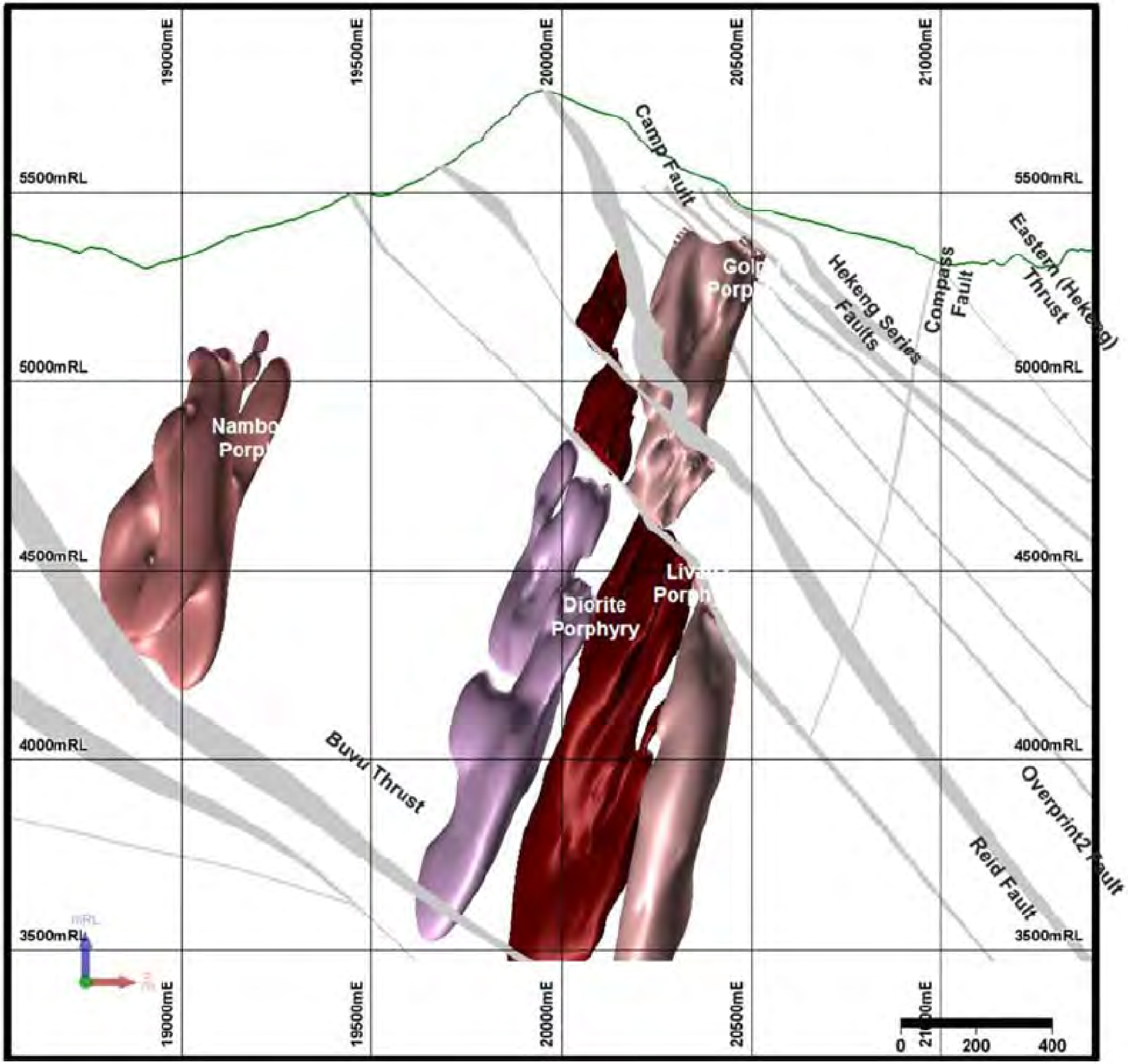
Structural model for emplacement





Ref: Menzies et al (2013)

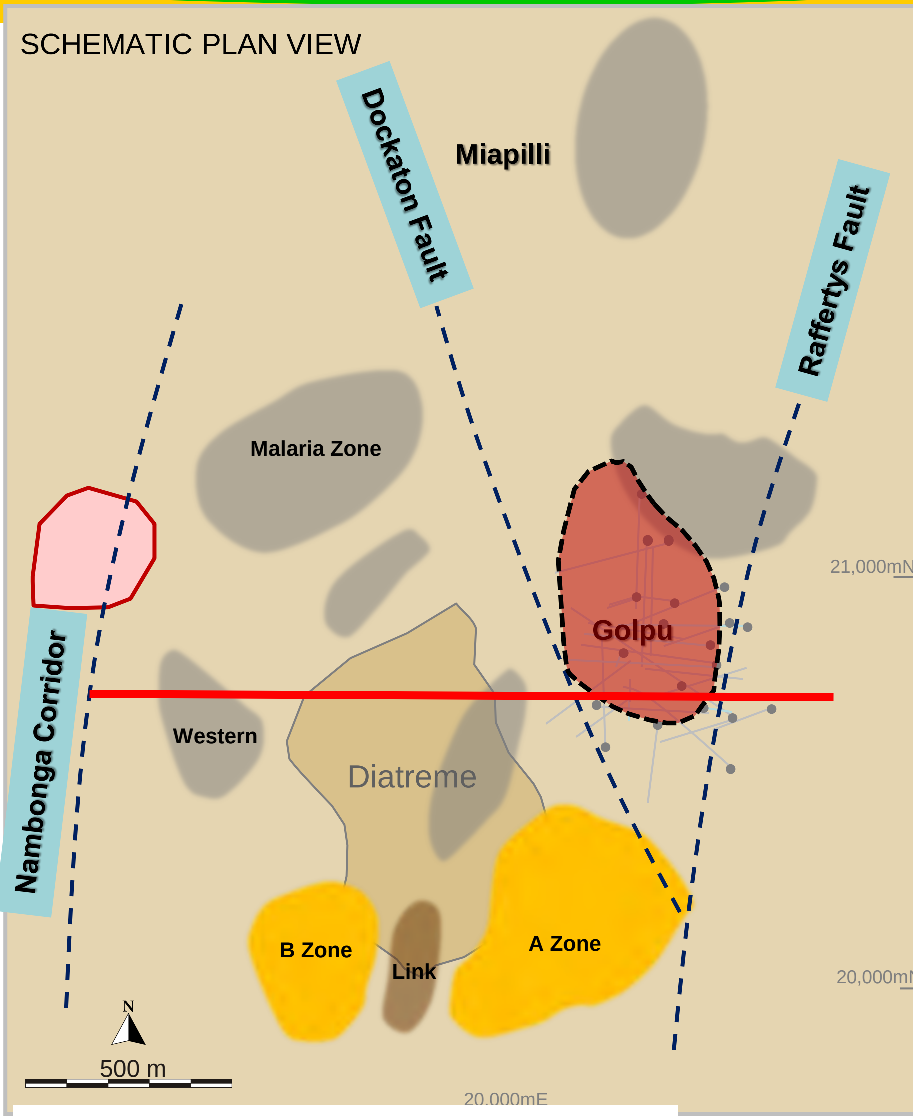
Thrust faults



Work by Ron Reid and David Finn identified an en echeleon set of thrust faults have truncated the sequence and orebody.

Ref: Newcrest NI 43101 (2020)

Wafi-Golpu geology model - mineralisation



Wafi Local Grid

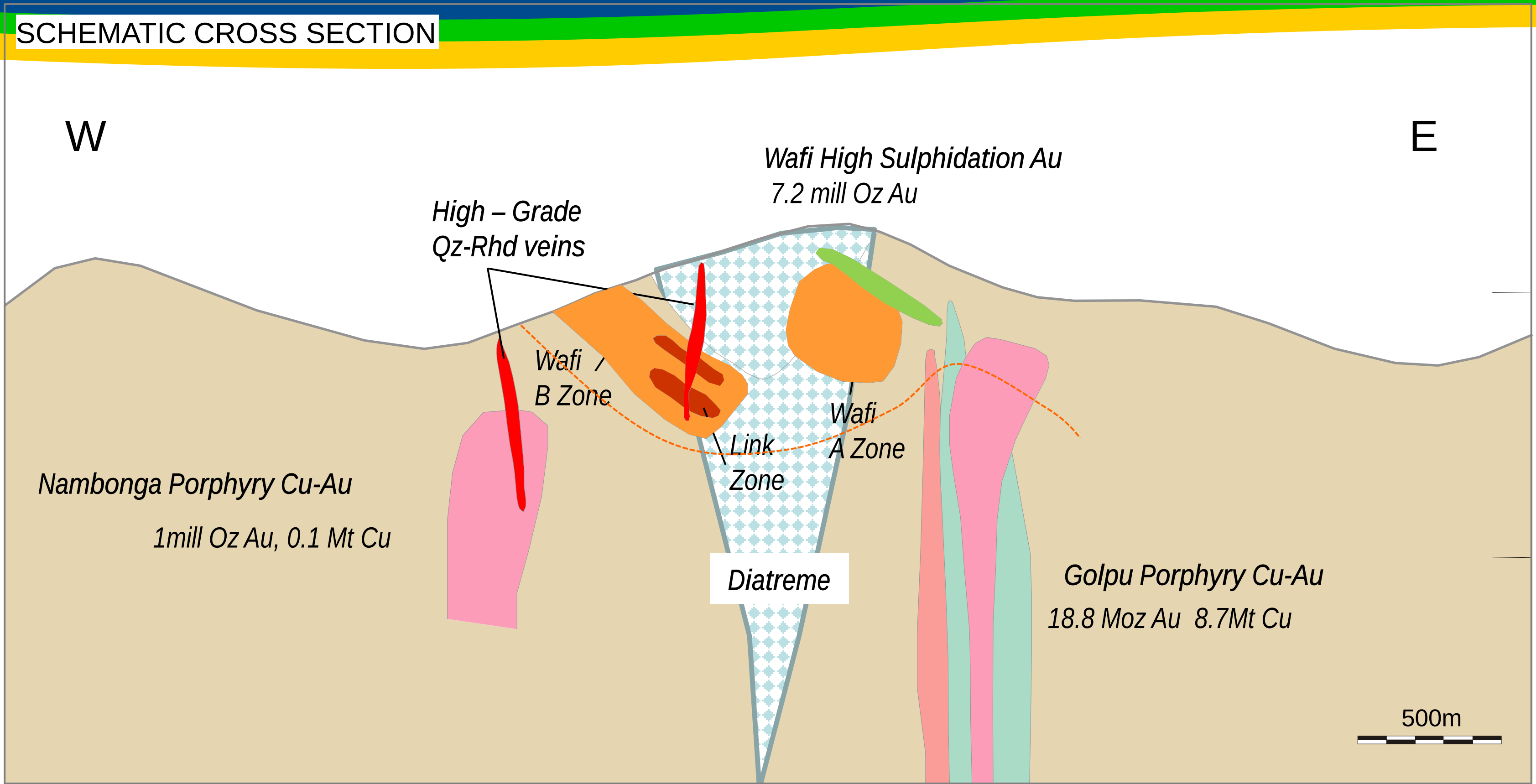
Modified Hayward et al (2011)

Legend

- Wafi Diatreme Bx
- Golpu Porphyry Cu-Au
- Nambonga Porphyry Cu-Au
- Carb-BM Epithermal Au (Qtz-Rh-BM veins)
- High Sulphidation Epithermal Au

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu mineralised system



- Telescoped mineralisation events/systems
  - •Multiple Porphyry Cu-Au centres (Golpu, Nambonga)
  - •High Sulphidation epithermal overprint (Wafi (Au))
  - •Intermediate sulfidation Carbonate-Base metal (Quartz-Rhodochrosite) veins

.

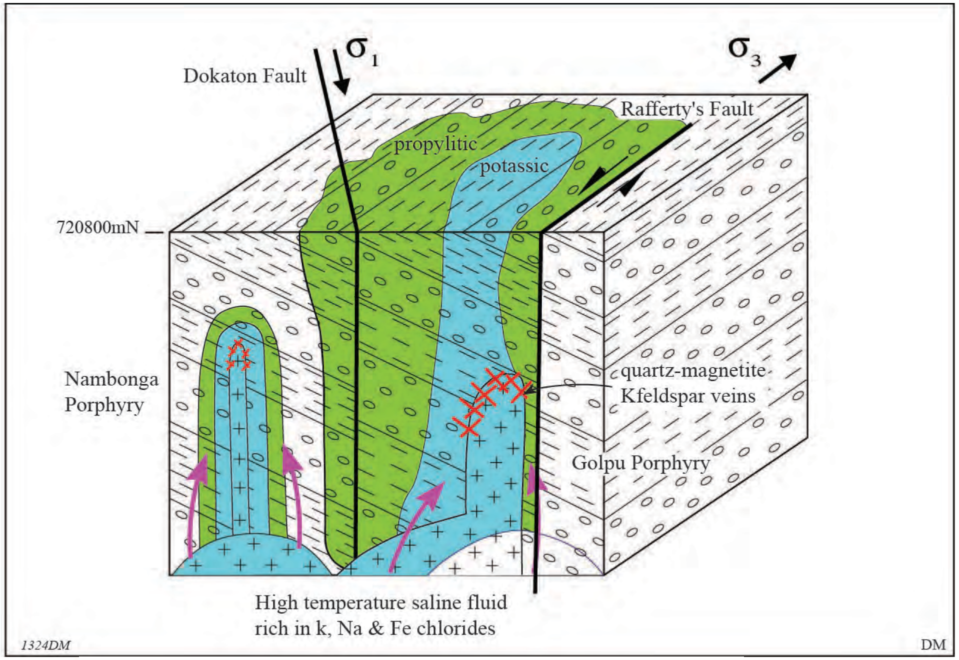
•Global resource inventory Wafi-Golpu to 28.3 Moz of Au and 9.06 Mt of copper or 73.5Moz of Au equivalent.

Modified Hayward et al (2011)

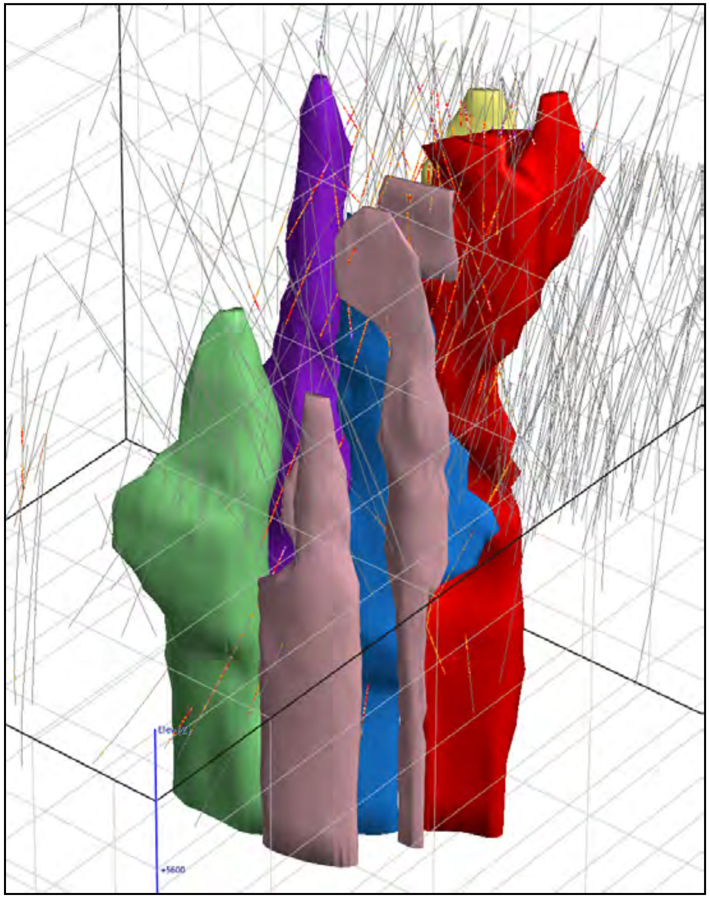
WAFI-GOLPU JOINT VENTURE

The Golpu porphyry intrusive complex.

- Five separate porphyries coalesce in central area
- All can be described as ‘hornblende porphyry’
- Can be mineralised or barren at different locations
- Meta-sediments caught up in the complex and in the halo are mineralised.
- Bounded on east and west by Rafferty’s and Dokaton Faults.

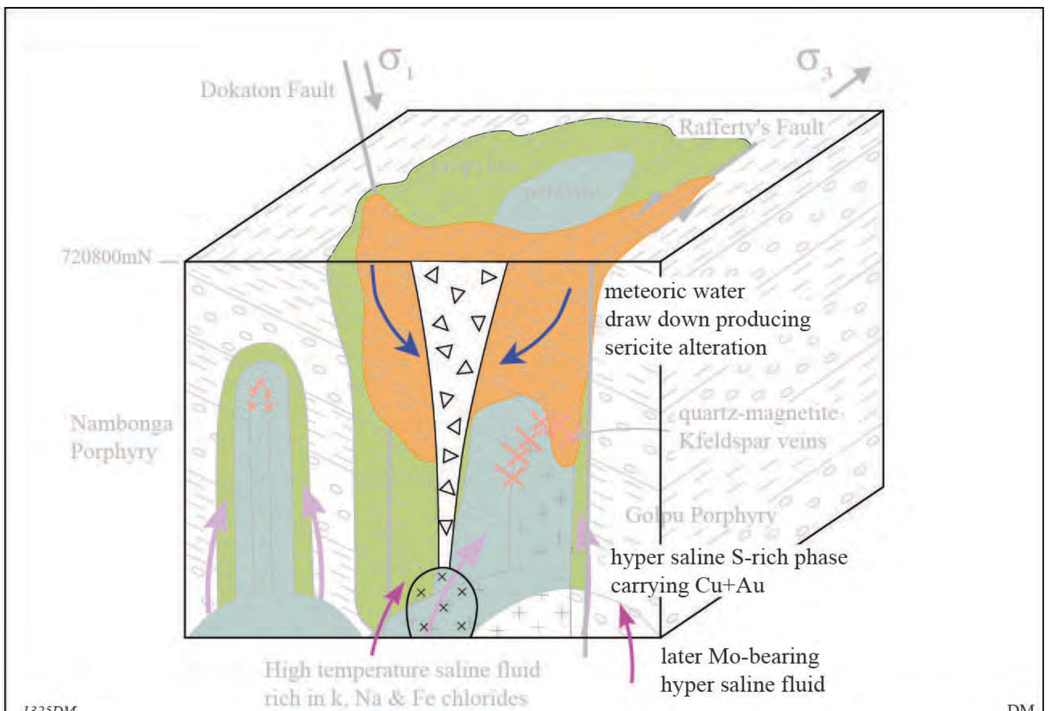


Ref: Menzies et al (2013)



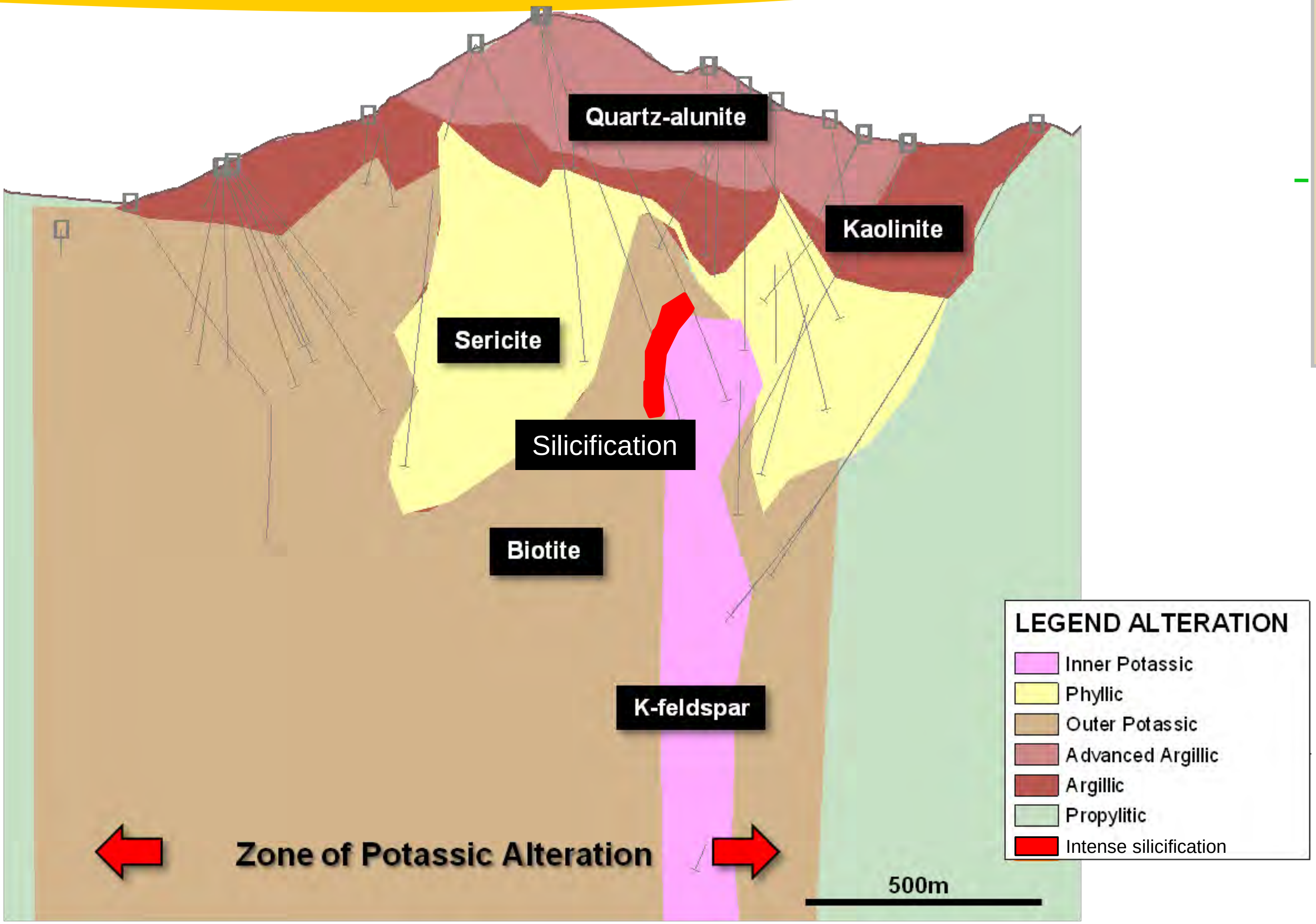
Diatreme

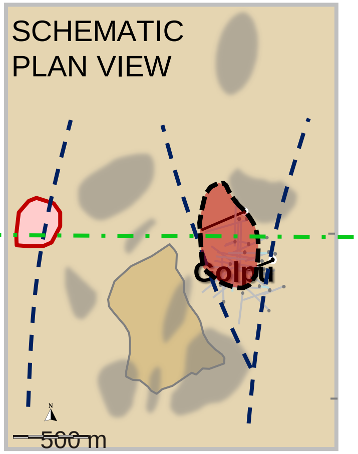
- Conical / “wine glass” geometry
- Milled and angular clasts in feldspar & pyrite after hornblende rich matrix.
- Dominantly matrix supported.
- Pervasive silica-sericite-koalinite-pyrite alteration
- Accretionary lapilli at surface – suggestive of venting
- Pebble dykes on the margins
- Produced by meteoric incursion on a magma chamber



Ref: Menzies et al (2013)

Alteration model





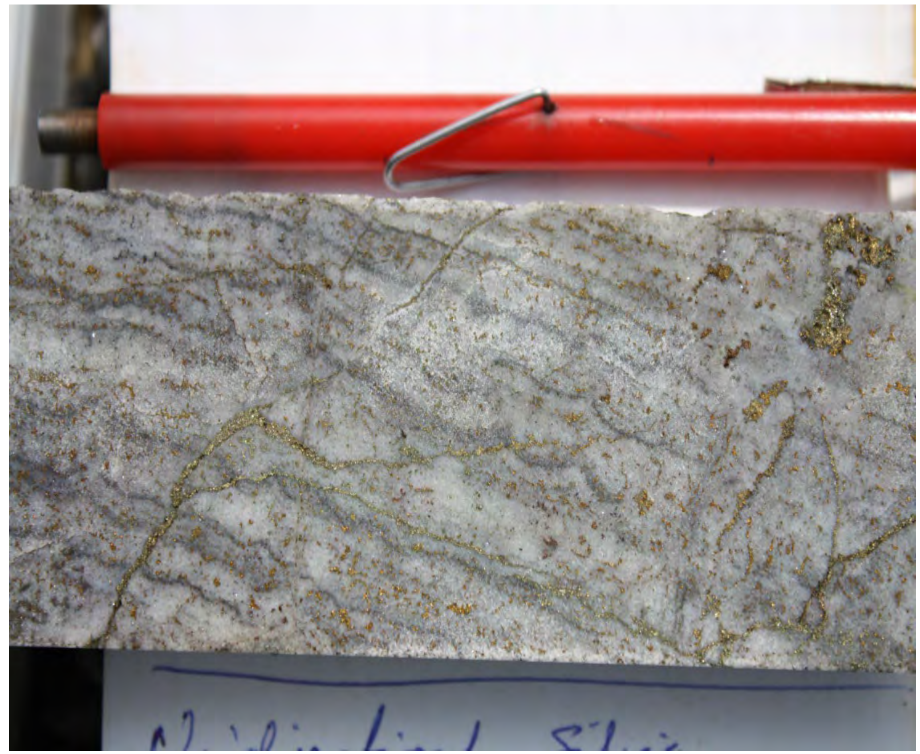
Hot spot of alteration is much larger than known intrusions

Ref: Menzies et al (2013) modified after Finn (2013)

WAFI-GOLPU JOINT VENTURE

Zone of intense silicification

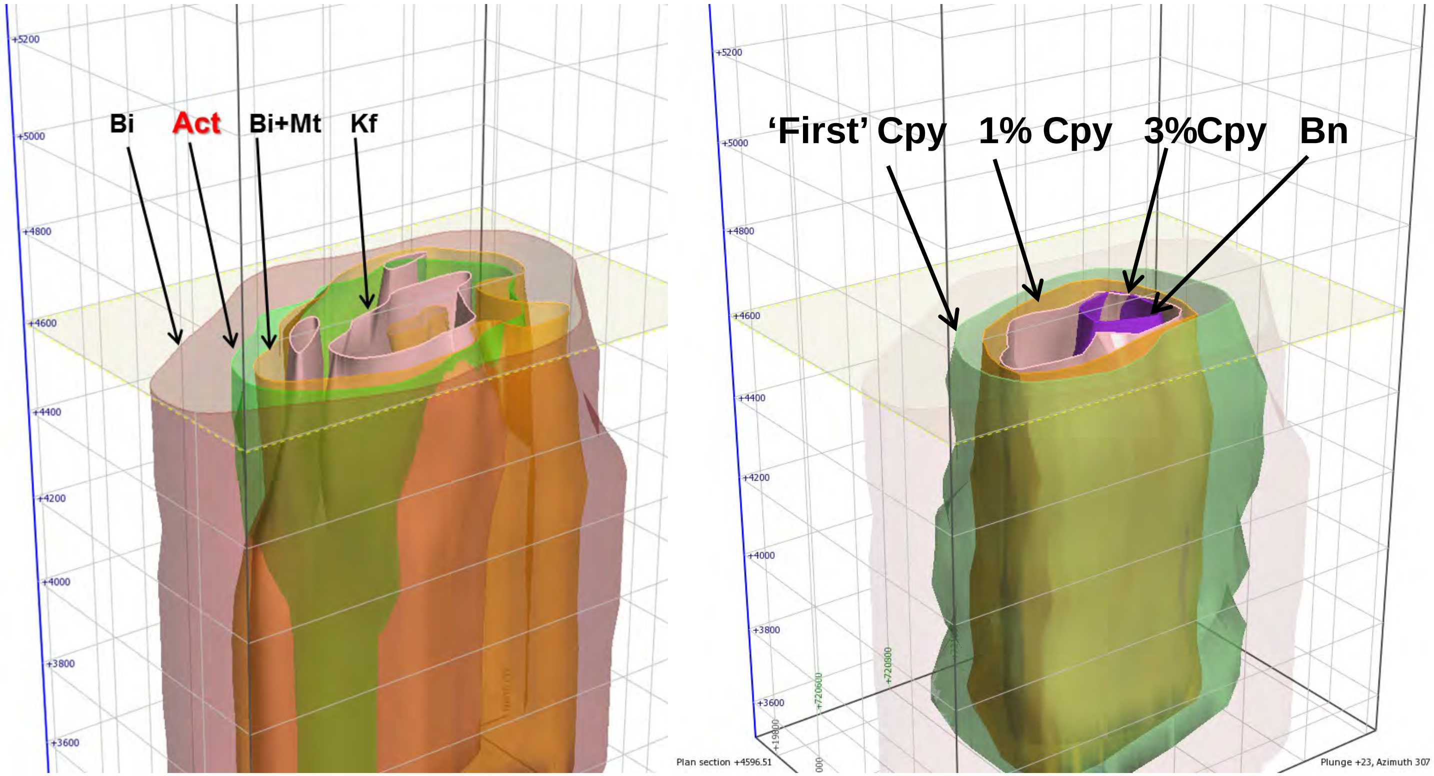
- On western and upper parts of Golpu
- Locally exhibits Uni-directional Silica Textures (UST), indicative of transition between magmatic and hydrothermal conditions (Seedorff *et al,* 2005)



Golpu alteration/mineralisation zonation

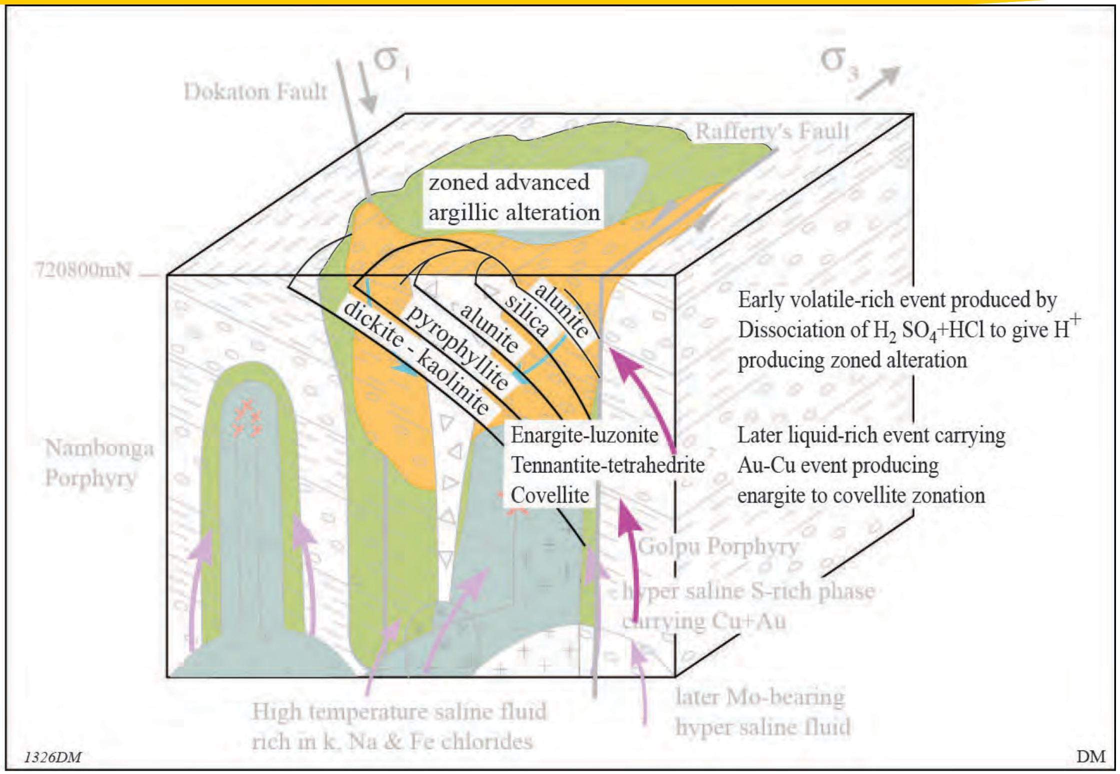
Concentric Shells

- Alteration Kf - Bi+Mt - Act - Bi - Chl
- Sulphides Bn - Cpy – Py
- First Cpy is coincident with first actinolite

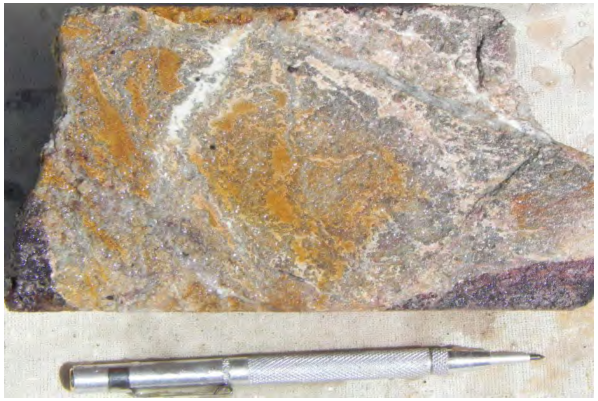


Modified after Finn (2013)

Advanced argillic alteration overprint



- Lilthological control to advance argillic alteration
- Zonation from vuggy silica, alunite, pyrophyllite to dickite/kaolinite caused by a volatile rich event
- Later Au-Cu producing event giving a sulphide zonation from enargite-tennantite-tetrahedrite-to covellite.



Ref: Menzies et al (2013)

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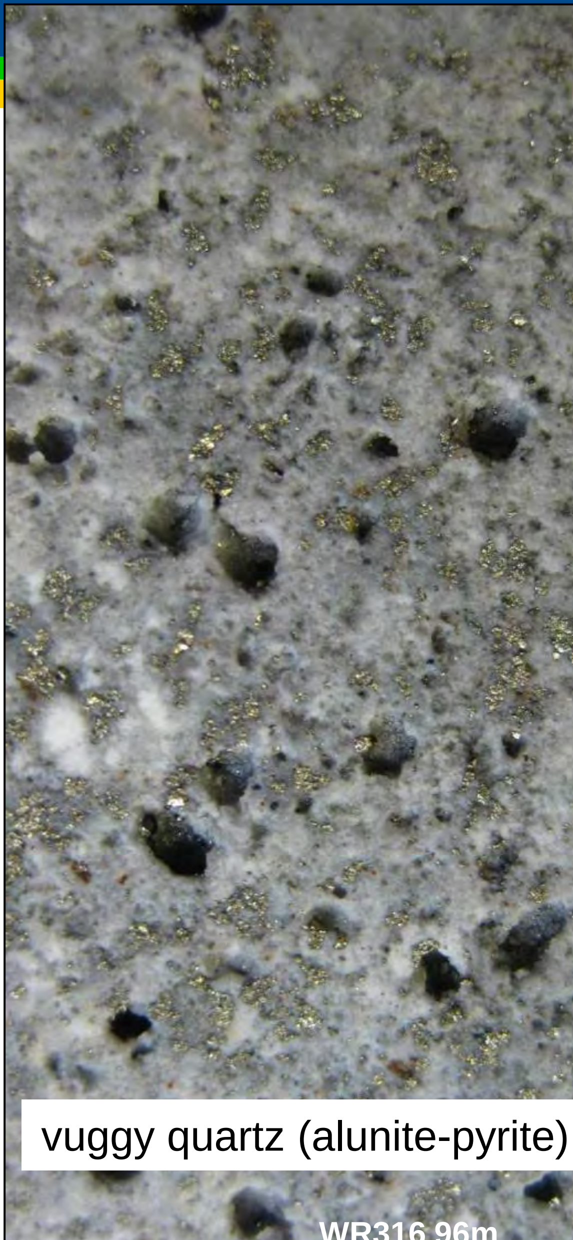
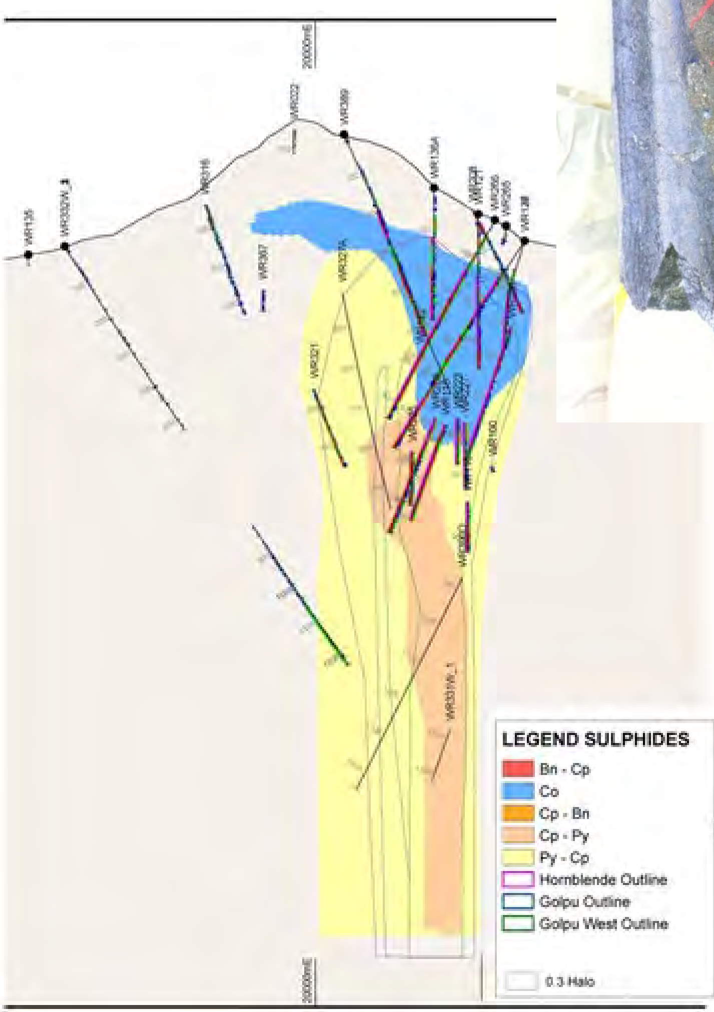
Advanced argillic alteration overprint



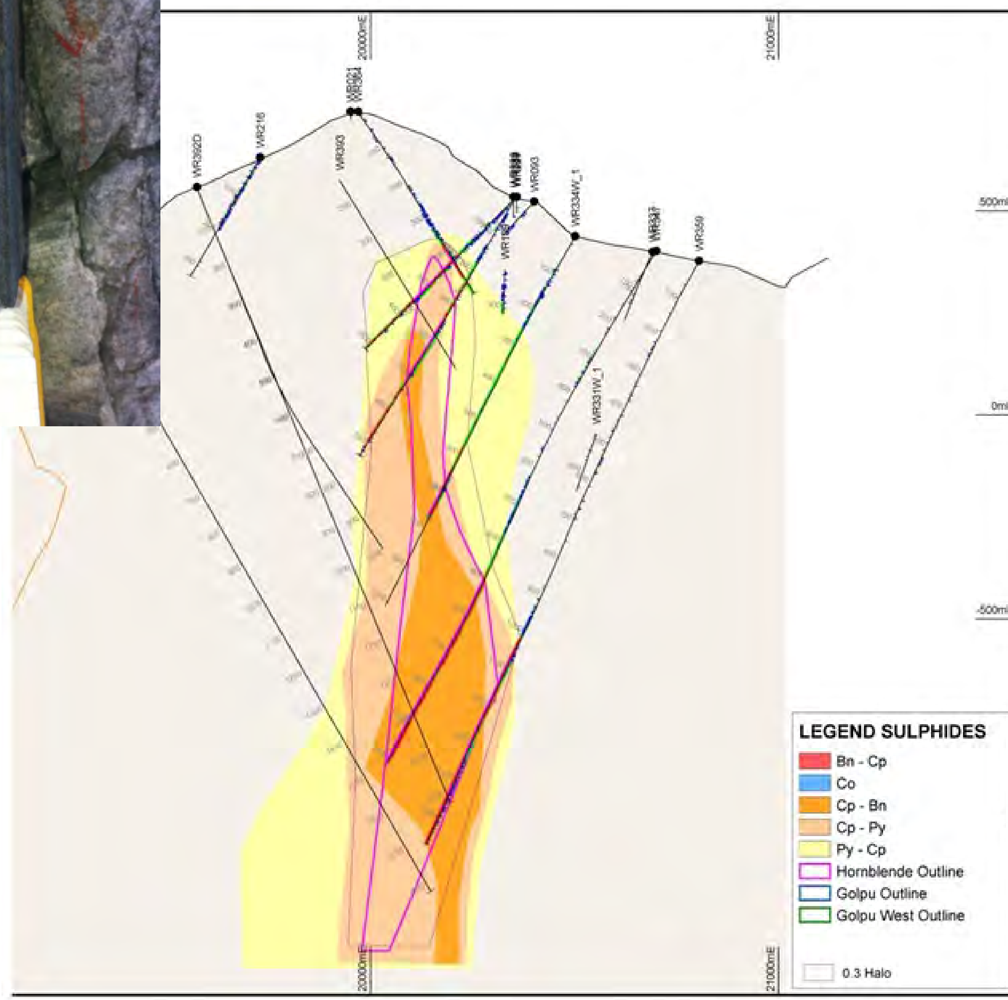
Ref: Hayward et al (2011) and Harris (2010)

Sulphide zonation

Southern Section



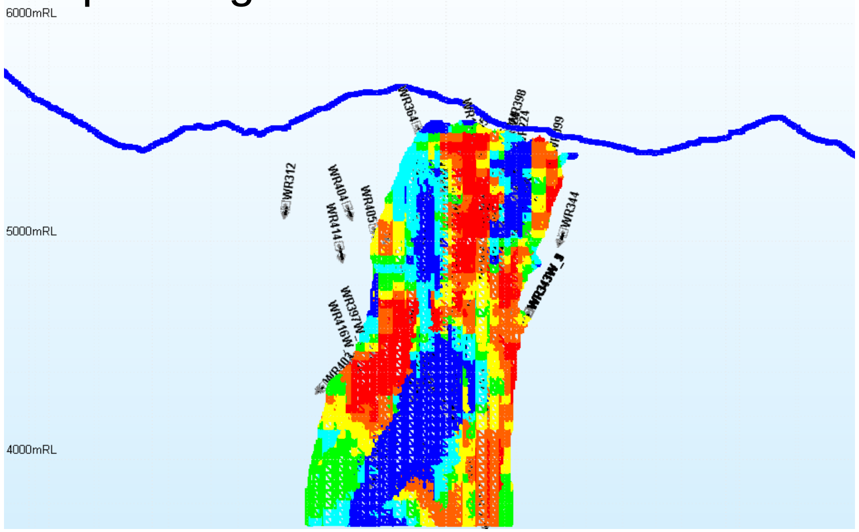
Northern Section



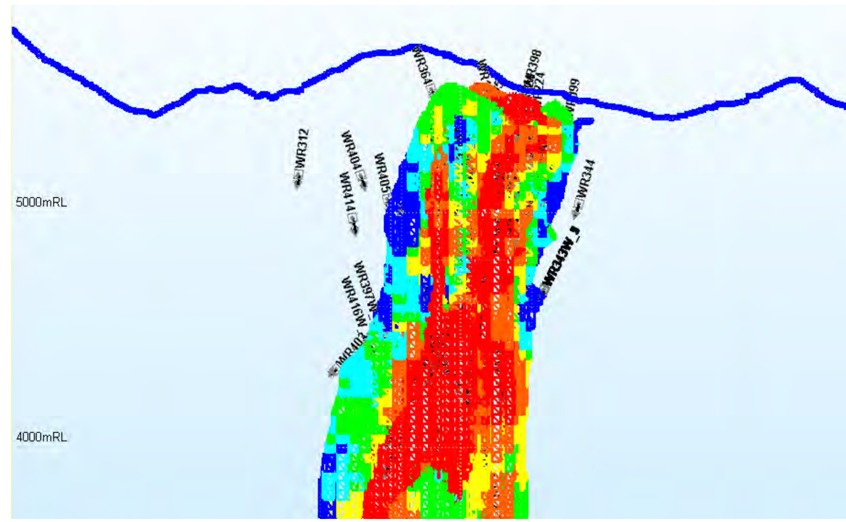
Ref: Hayward et al (2011)

Au vs Cu vs Mo zonation

Golpu Long section - Mo in block model



Golpu Long section - Au in block model



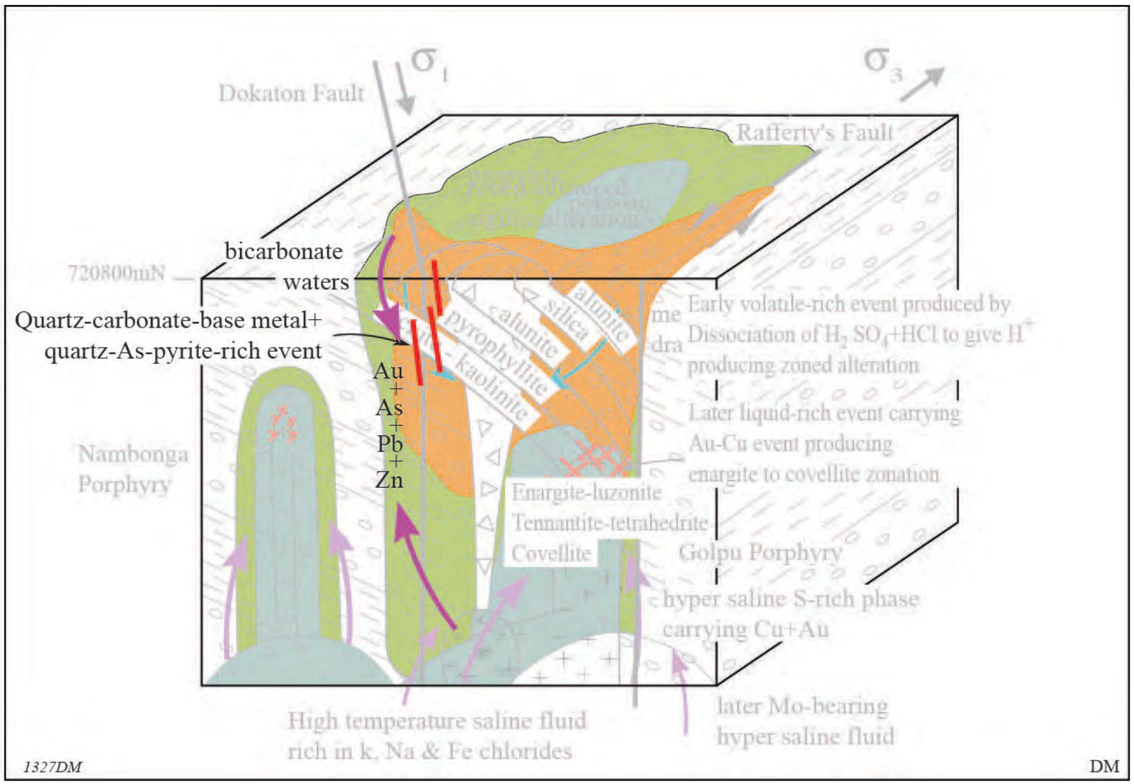
- Au:Mo Pearson correlation r = -0.024, n=32653 **(negative correlation)**
- Cu:Au Pearson correlation r = 0.607, n=32653 **(positive correlation)**
- Au:bornite Pearson correlation r = 0.21, n = 1890 **(positive correlation)**

Interpretation:

- **Greater Au deposition associated with bornite as proposed by Simon *et al.* (2000).**
- **Separate metal deposition event for Mo vs Cu/Au.**

Carbonate base-metal epithermal Au veins

- Occurs at Link Zone, Northern Zone, Upper Nambonga
- Vein assemblages of quartz-rhodochrosite-Au-As+/- galena-sphalerite



Ref: Menzies et al (2013)

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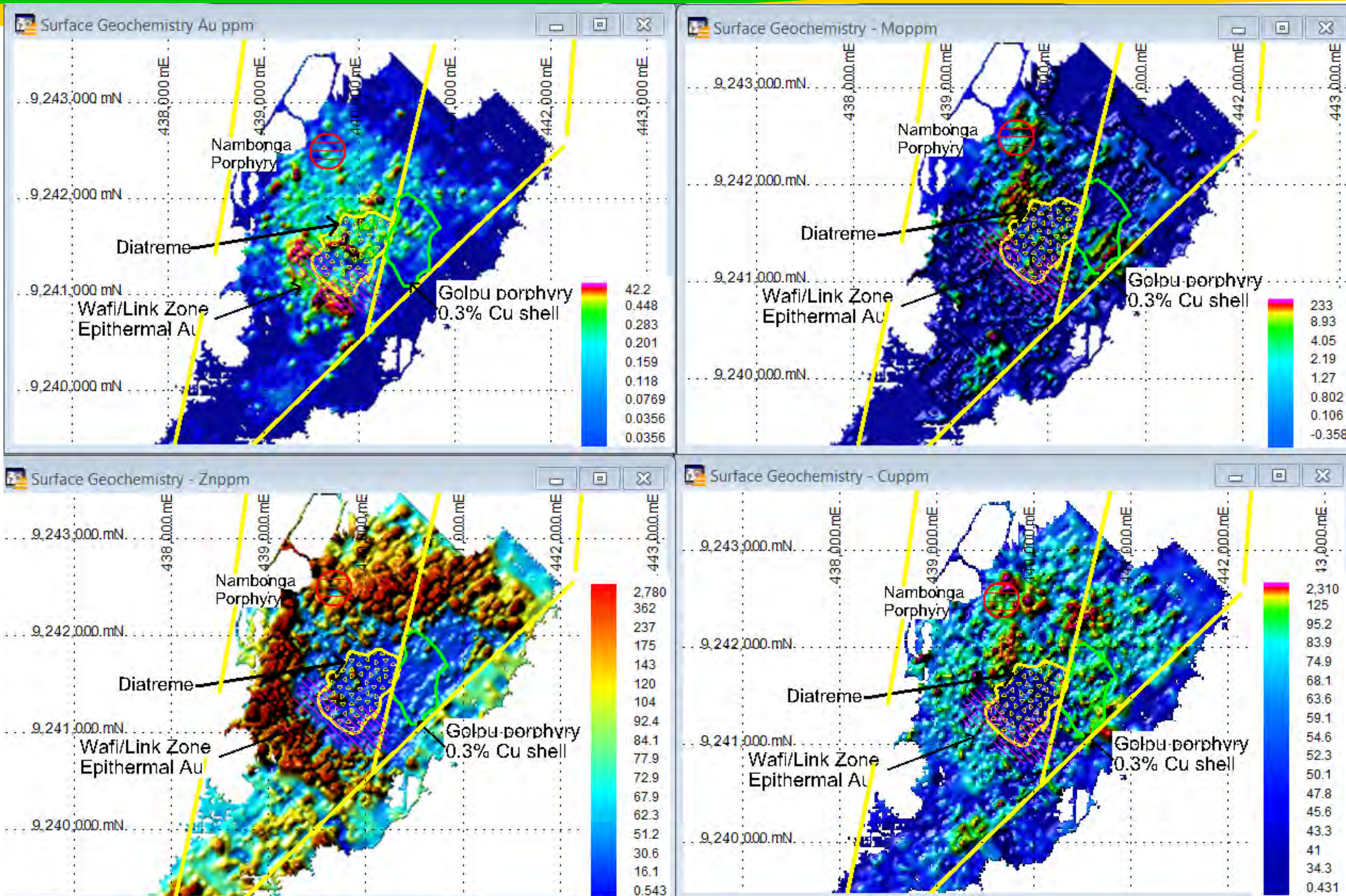
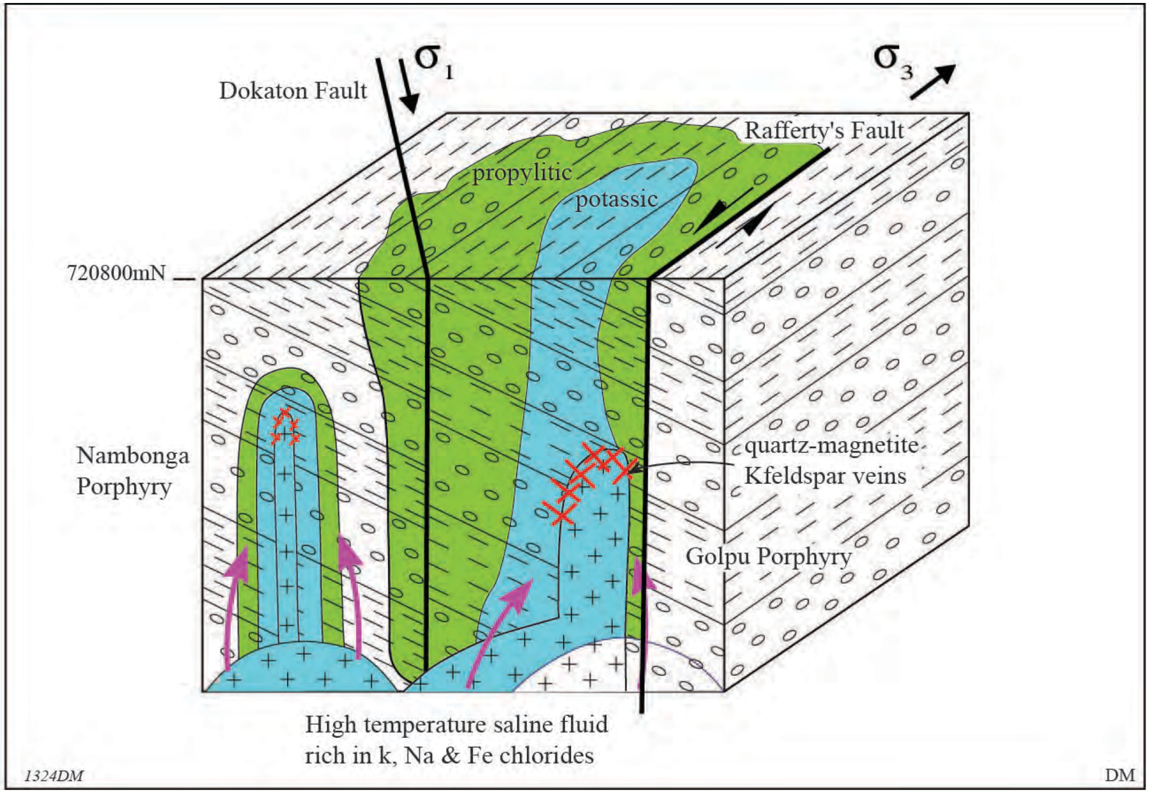
Surface geochemical



Ref: Menzies et al (2013)

JOINT VENTURE

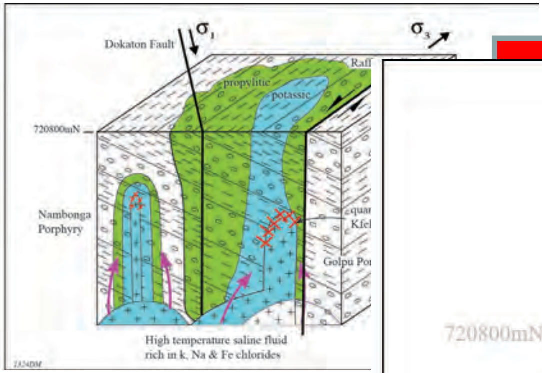
Paragenetic model – porphyry intrusion

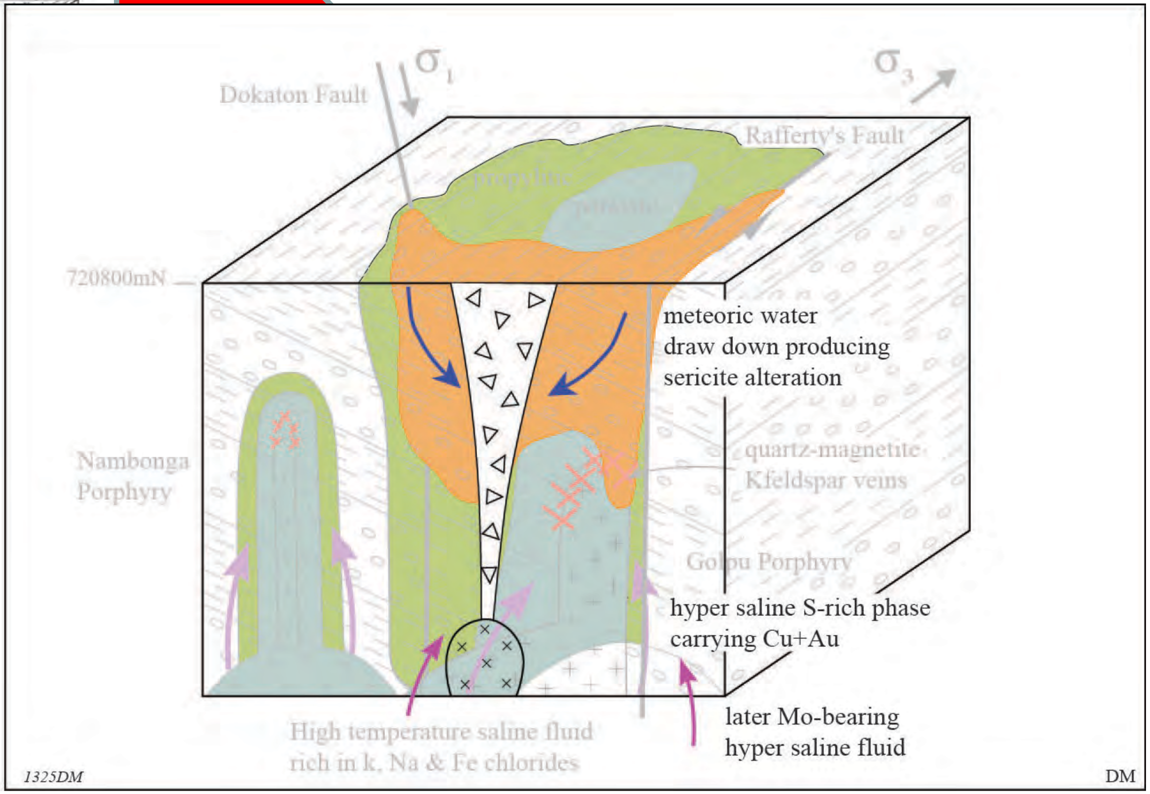


Structural emplacement of porphyry intrusion associated with left-stepping sinistral fault jog, showing zonation of blue potassic (biotite-K-feldspar-Magnetite) to green propylitic alteration (chlorite-actinolite+/- epidote) produce by hyper-saline fluids rich in K, Na, Fe chlorides.

Ref: Menzies et al (2013)

Paragenetic model – diatreme intrusion





Intrusion of the diatreme due to meteoric incursion on a magmatic source, causing a phreatomagmatic erruption. Sericite alteration overprint on porphyry due to meteoric draw-down.

Ref: Menzies et al (2013)

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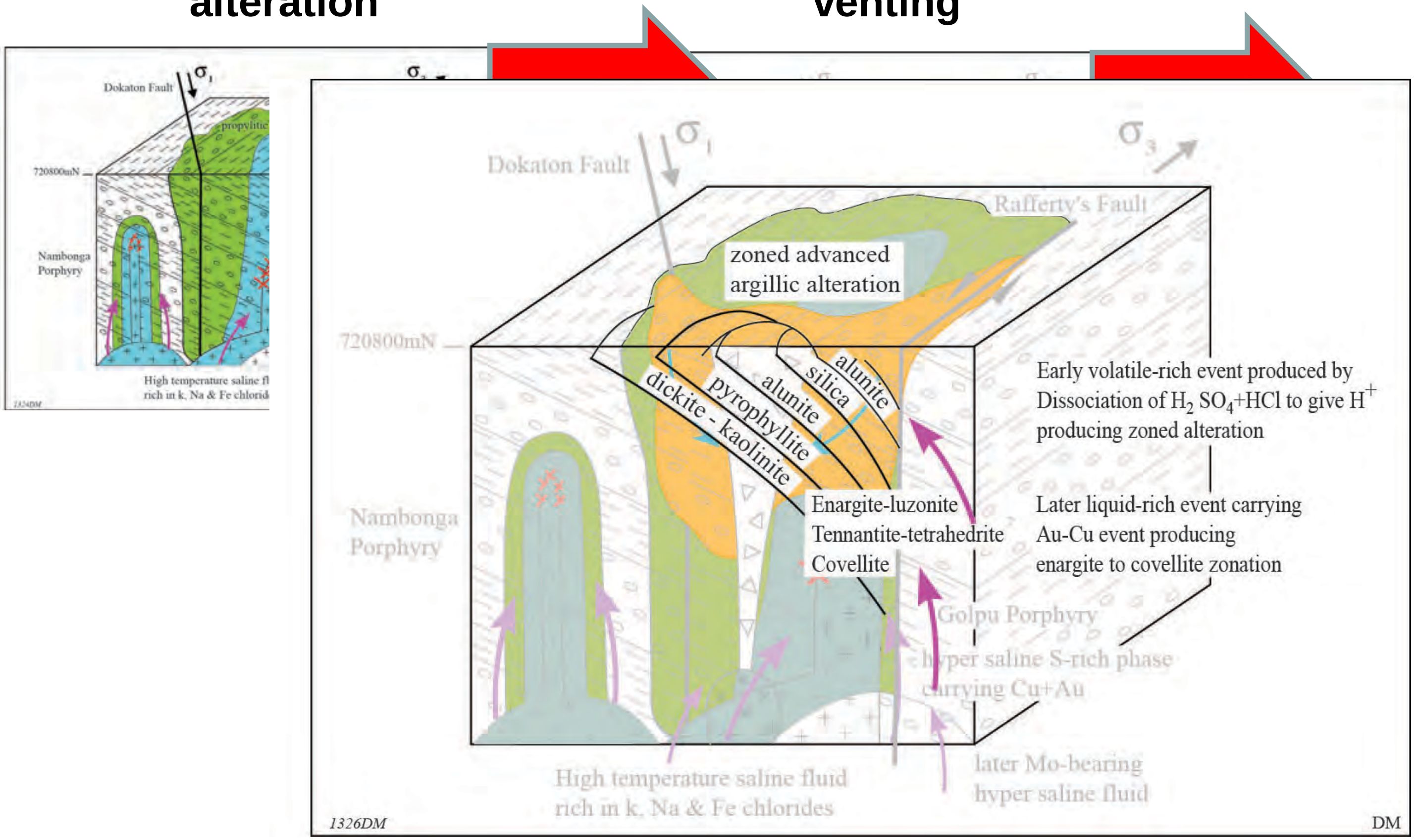
Paragenetic model – High sulphidation

Porphyry intrusion and alteration **Diatreme emplacement and venting**

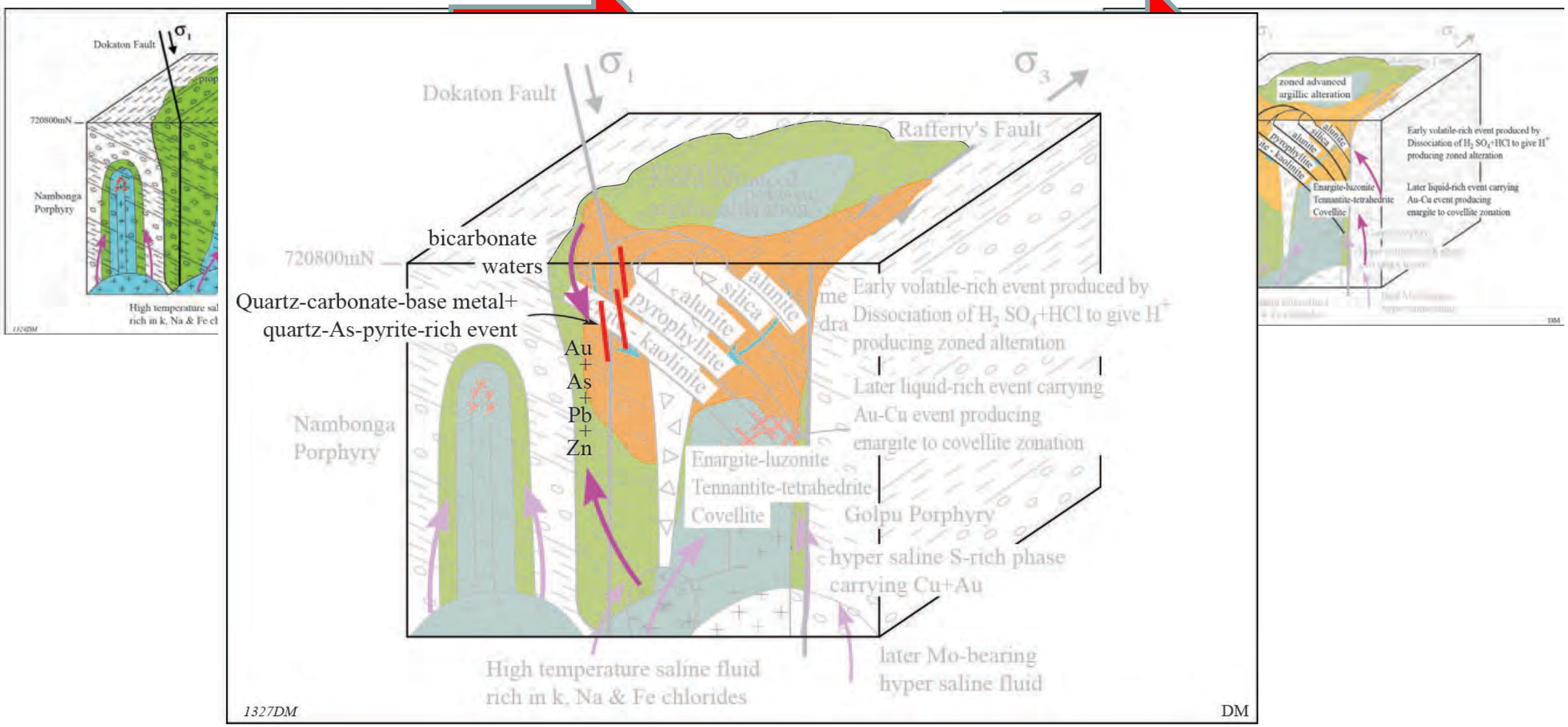


High sulphidation epithermal vuggy silica-alunite-pyrophyllite to dickite-kaolinite alteration produced by an early volatile rich event. A later liquid-rich event carrying Au-Cu-As producing a zonation from enargite-luzonite, tennantite-tetrahedrite to covellite.

Ref: Menzies et al (2013)

Paragenetic model – Carbonate BM

Porphyry intrusion and alteration | **Diatreme emplacement and venting** | **High Sulphidation epithermal overprint**



Quartz-carbonate-base metal + quartz-As-pyrite-rich low sulphidation epithermal mineralisation

Ref: Menzies et al (2013)

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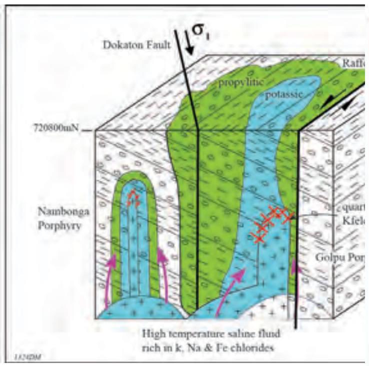
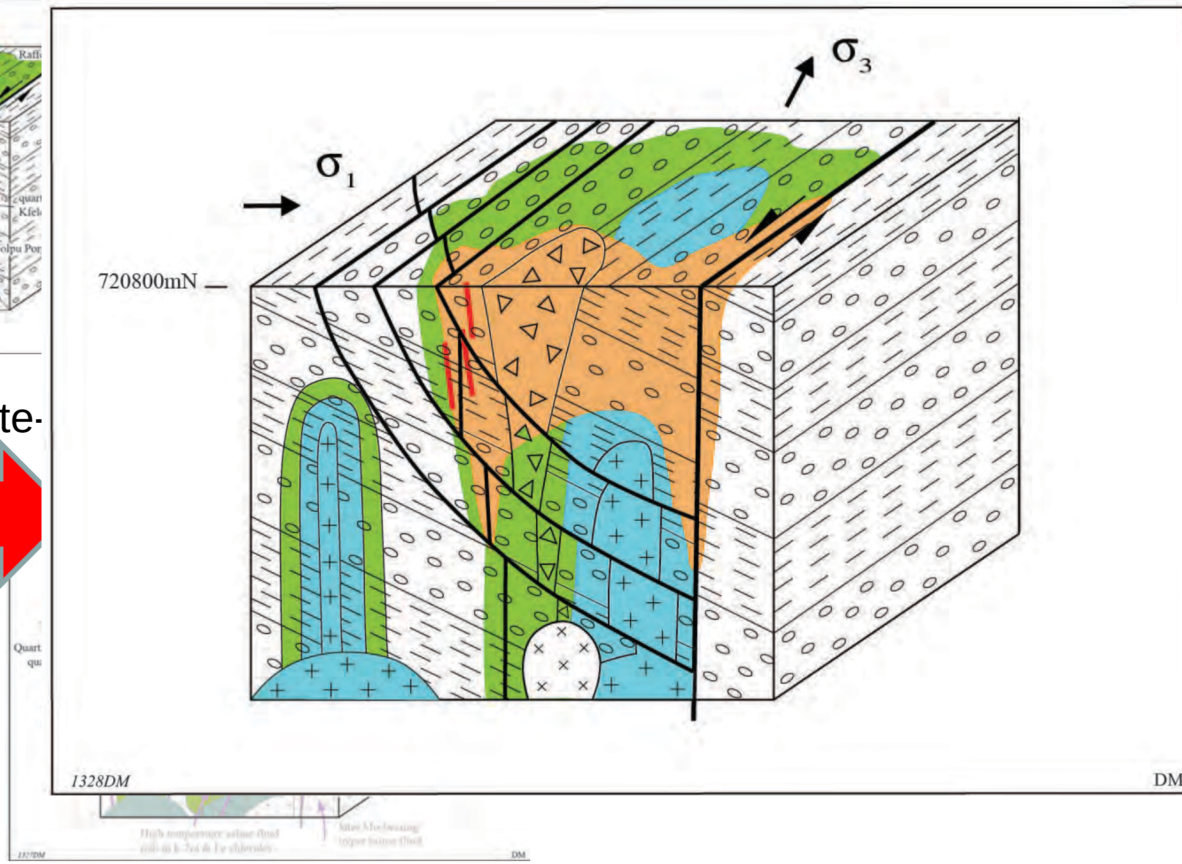
WAFI-GOLPU JOINT VENTURE

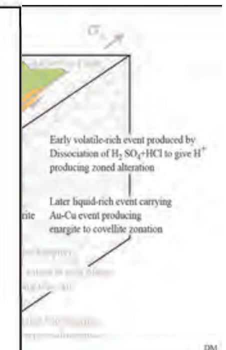
Paragenetic model – post mineral faults

Porphyry intrusion and alteration | **Diatreme emplacement and venting** | **High Sulphidation epithermal overprint**



Quartz-carbonate-



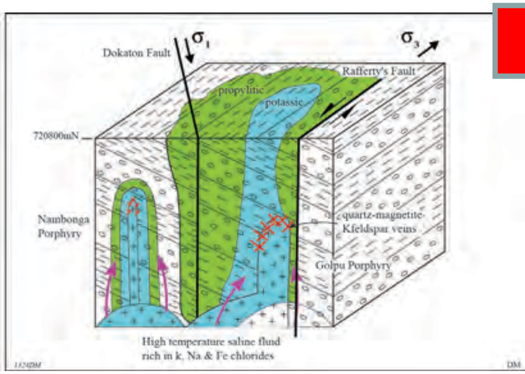


Post mineral thrust faulting during the Pliocene (Cloos *et al*., 2010) off-setting the porphyry mineralisation and diatreme (identified by Reid and Finn).

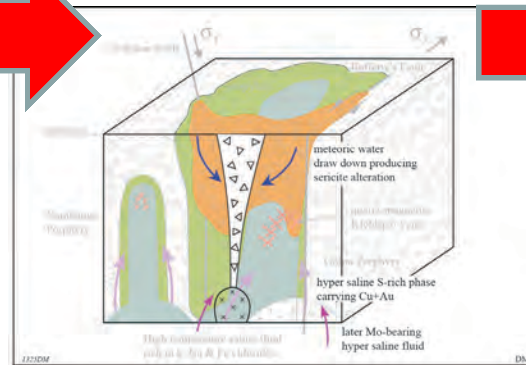
Ref: Menzies et al (2013)

Paragenetic model

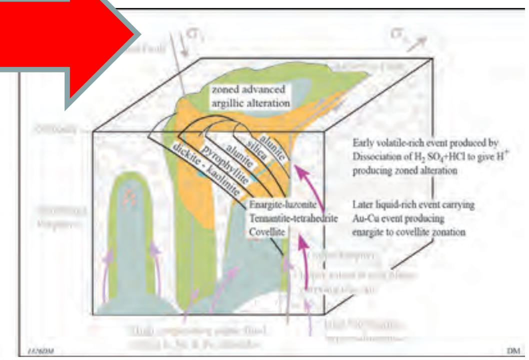
Porphyry intrusion and alteration



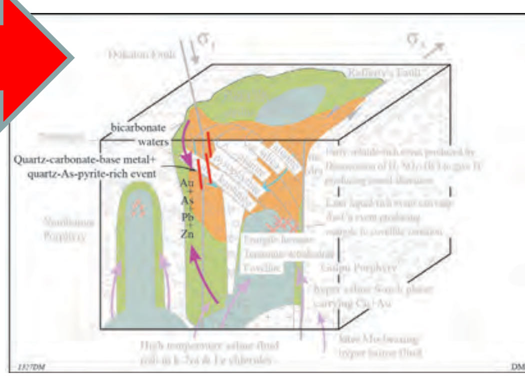
Diatreme emplacement and venting



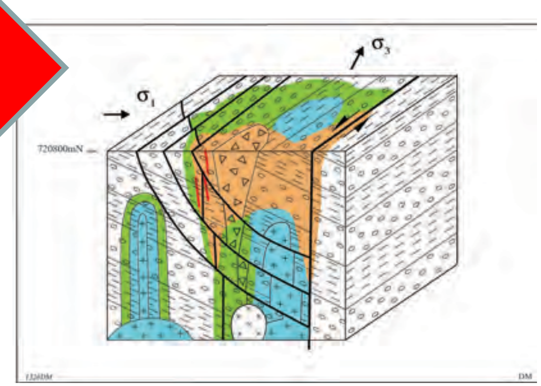
High Sulphidation epithermal overprint



Quartz-carbonate-base metal Au epithermal veins



Post mineral thrust faulting



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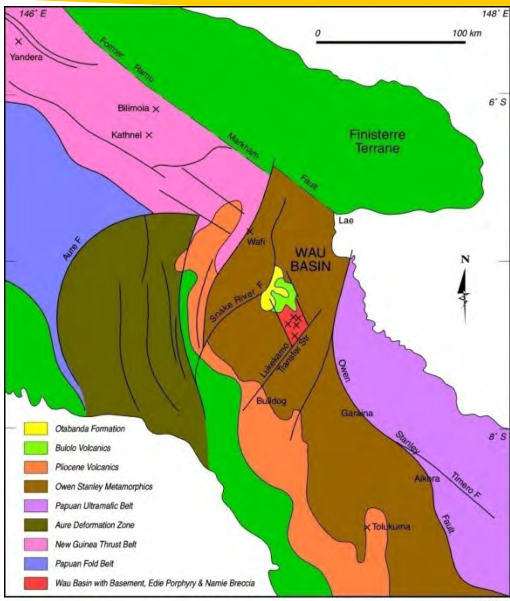
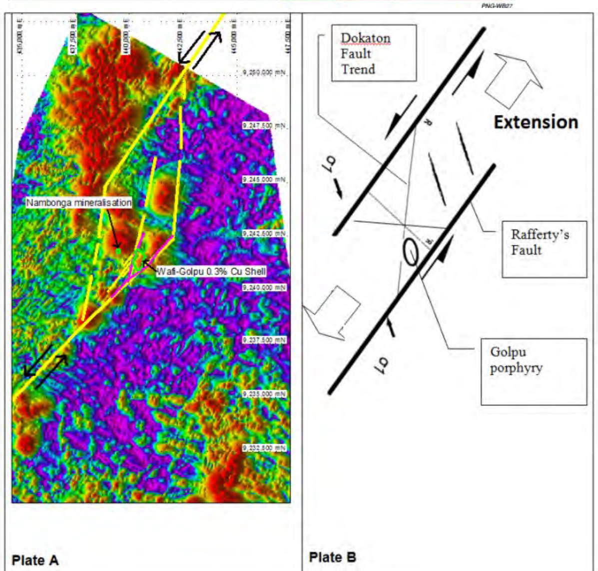
Ref: Menzies et al (2013)

WAFI-GOLPU JOINT VENTURE

Summary





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- Regional boots-on-ground stream sediment and followup work led CRAE to the area.
- The identification zonation of alteration assemblages and regional structure assisted with initial hole targeting.
- Identification of porphyry M and A veins provided vectors to commence and continue discovery hole.
- Wafi- Golpu mineralisation emplacement in extensional zone within a left-stepping sinistral–Wafi Transfer fault.
- Porphyry Cu-Au mineralisation was deposited separate to Mo mineralisation.
- Diatreme vented due to H_2O incursion on magma.
- High Sulphidation overprint depositing Au-Cu-As
- Later Au associated with quartz-carb-base metal veins produced by mixing with bi-carbonate waters
- Post mineral thrust fault during E-W compression
- Surface geochemistry analysis highlights circular peripheral Zn and Mo anomalism over Golpu preserved in advanced argillic alteration.

Questions?

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