UNDESTANDING PORPHYRY COPPER-GOLD DEPOSITS ALONG EASTERN SUNDA MAGMATIC ARC:

An Implication for Future Exploration

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OUTLINE

1. INTRODUCTION
2. REGIONAL GEOLOGY & MINERALIZATION
3. PORPHYRY COPPER-GOLD:

   Eastern Sunda Arc (Randu Kuning, Tasikmadu, Tumpangpitu/Tujuh Bukit, Selodong, Dodo-Elang, Batu Hijau & Hu'u)
4. IMPLICATION FOR EXPLORATION
5. SOME GUIDANCE IN EXPLORATION

1. Introduction:

Metal Prices

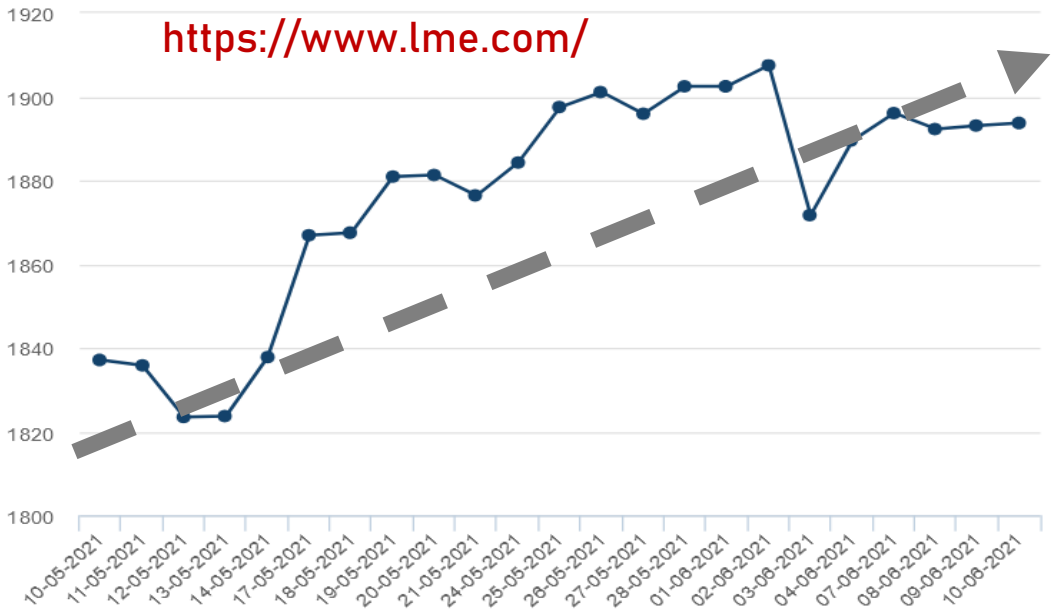
Metal Prices

COPPER	USD 2.95/lb	▲ 11.5 (0.18%)
ZINC	USD 1.00/lb	▲ 14 (0.64%)
LEAD	USD 0.83/lb	▲ 4.4 (0.24%)
GOLD	USD 1,809.30/Oz	▲ 11.1 (0.61%)
SILVER	USD 19.30/Oz	▲ 0.41 (2.12%)
COBALT	USD 12.93/lb	▲ 62.5 (0.22%)
NICKEL	USD 6.13/lb	▼ 34.99 (0.26%)

Thomson Reuters, 16.07.2020

LME GOLD CLOSING PRICES

https://www.lme.com/



s in Pound (lb) | Tonne (T)

es are updated daily.

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Accessed 11.06.2021

1. Introduction

Mineral Commodity Summaries perJanuary 2021: Gold (metric ton)

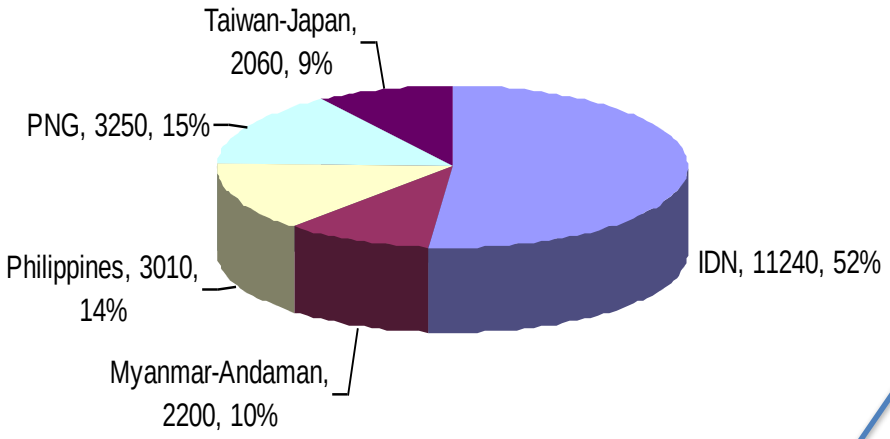
	Mine production		Reserves[8]
	2019	2020[e]	
United States	200	190	3,000
Argentina	60	60	1,600
Australia	325	320	[9]10,000
Brazil	90	80	2,400
Canada	175	170	2,200
China	380	380	2,000
Ghana	142	140	1,000
Indonesia	139	130	2,600
Kazakhstan	107	100	1,000
Mali	61	61	800
Mexico	111	100	1,400
Papua New Guinea	74	70	1,200
Peru	128	120	2,700
Russia	305	300	7,500
South Africa	105	90	2,700
Sudan	90	90	NA
Uzbekistan	93	90	1,800
Other countries	716	750	9,200
World total (rounded)	3,300	3,200	53,000

USGS: https://www.usgs.gov/

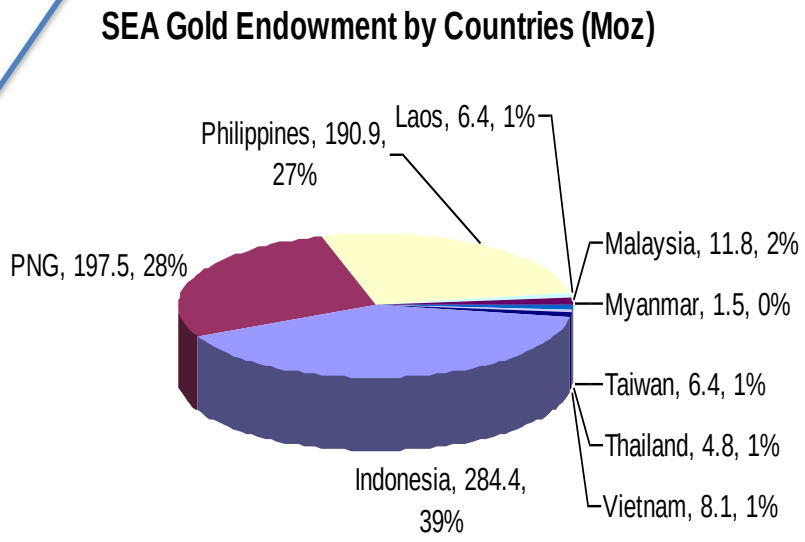
1. Introduction

SE Asian Magmatic Arcs and Endowment

Source: Mitchell & Leach (1991); Carlile & Mitchell (1994); Maryono et al. (2012)



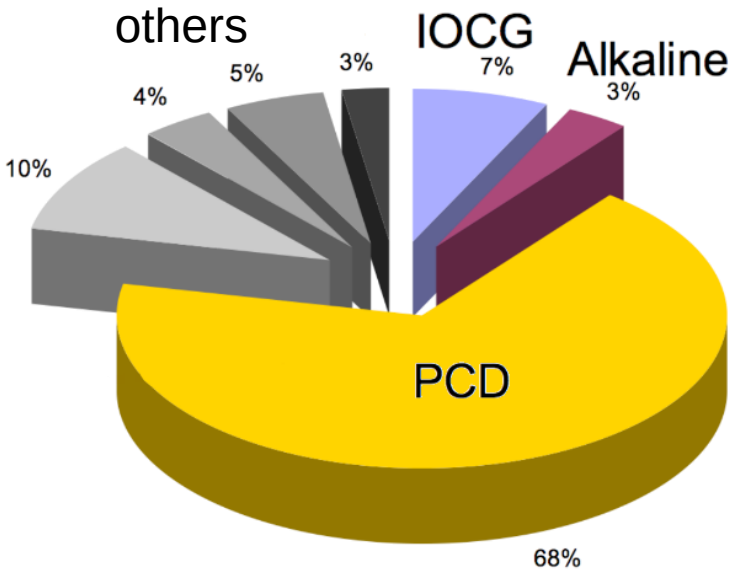
SEA Magmatic Arcs by Countries (km)



Maryono (2016)

1. Introduction

Global Copper Deposit Types

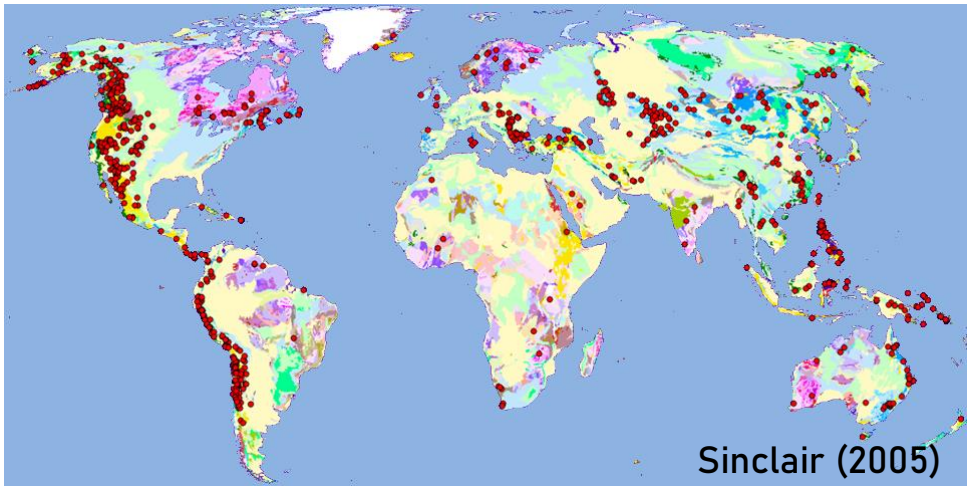


Antoro (2016)

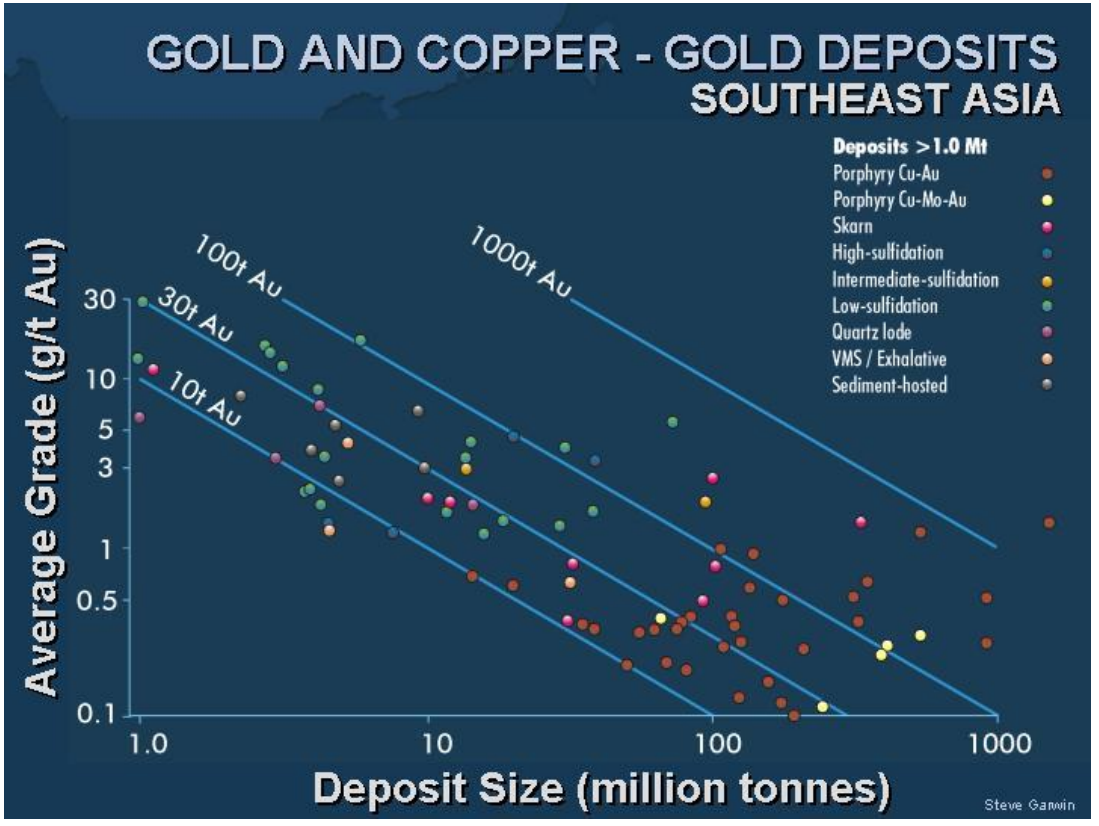
Global copper production by deposit type

PCD – porphyry copper deposits
IOCG – Iron-Oxide Cu-Au

PCD global distribution

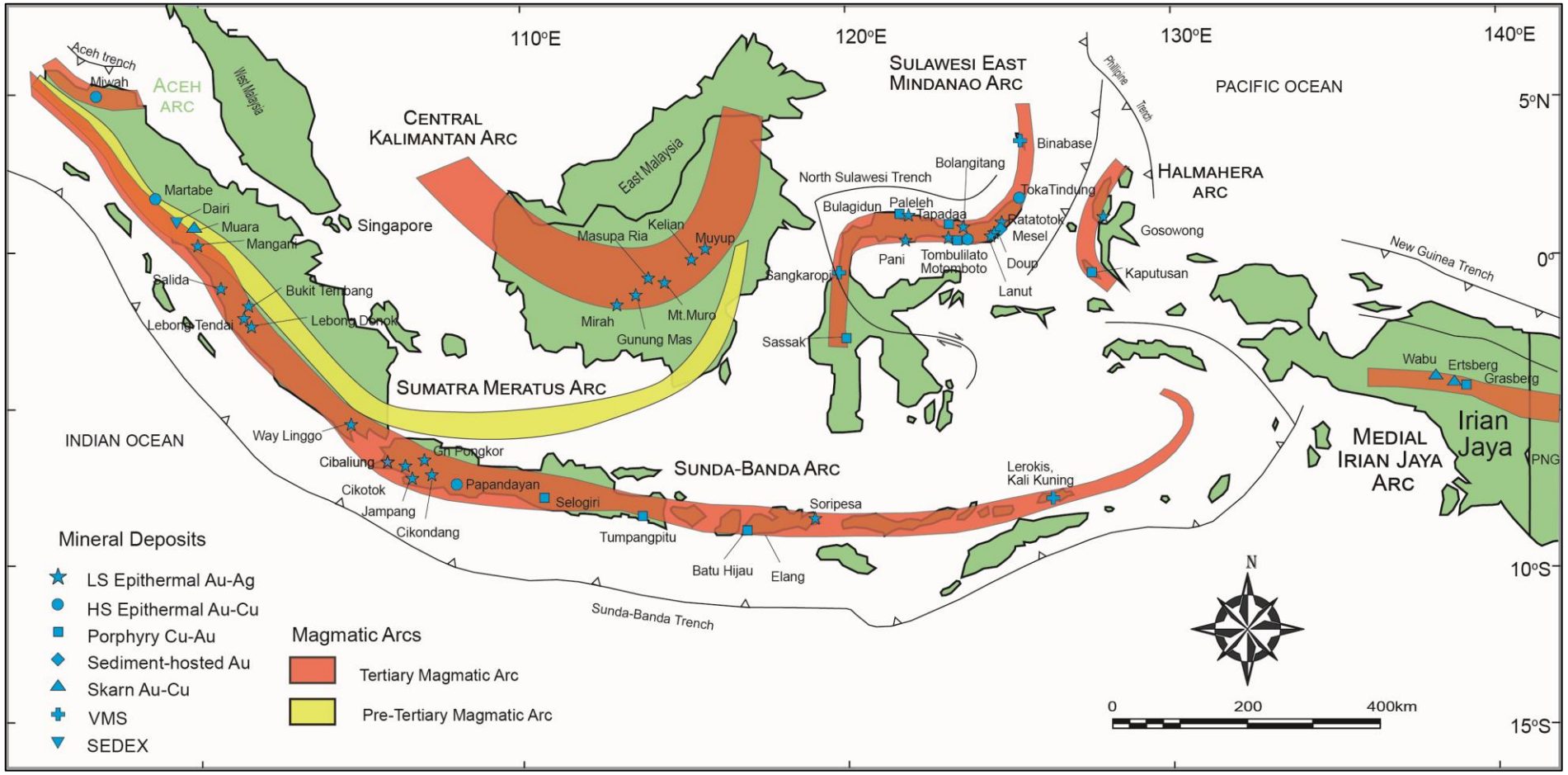


Sinclair (2005)



Garwin (2000)

2. Magmatic Arcs & Mineralization in Indonesia



Carlile and Mitchell (1994)

2. Indonesian Au-Ag-Cu Endowment

(15 Magmatic Arcs)

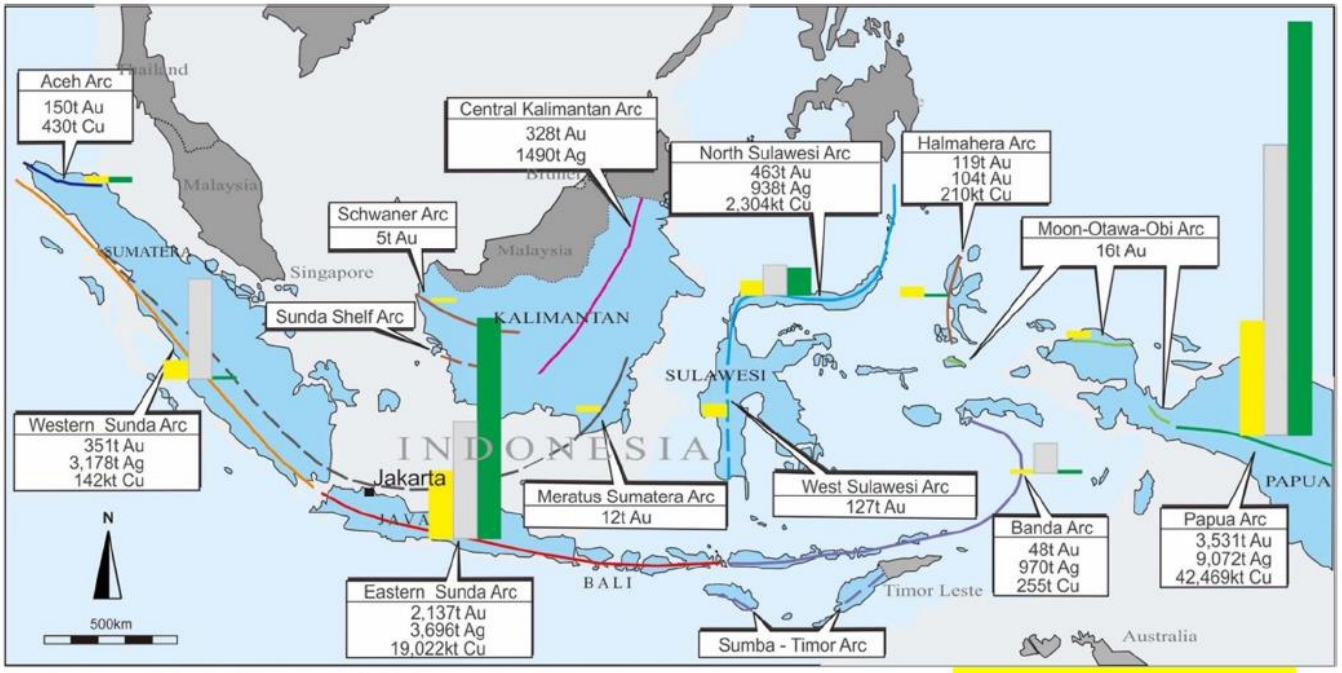
Au-Ag-Cu Endowment

(IAGI-MGEI, 2015)

Au: 7.311 ton,
Ag: 19.448 ton,
Cu: 64.832.000 ton

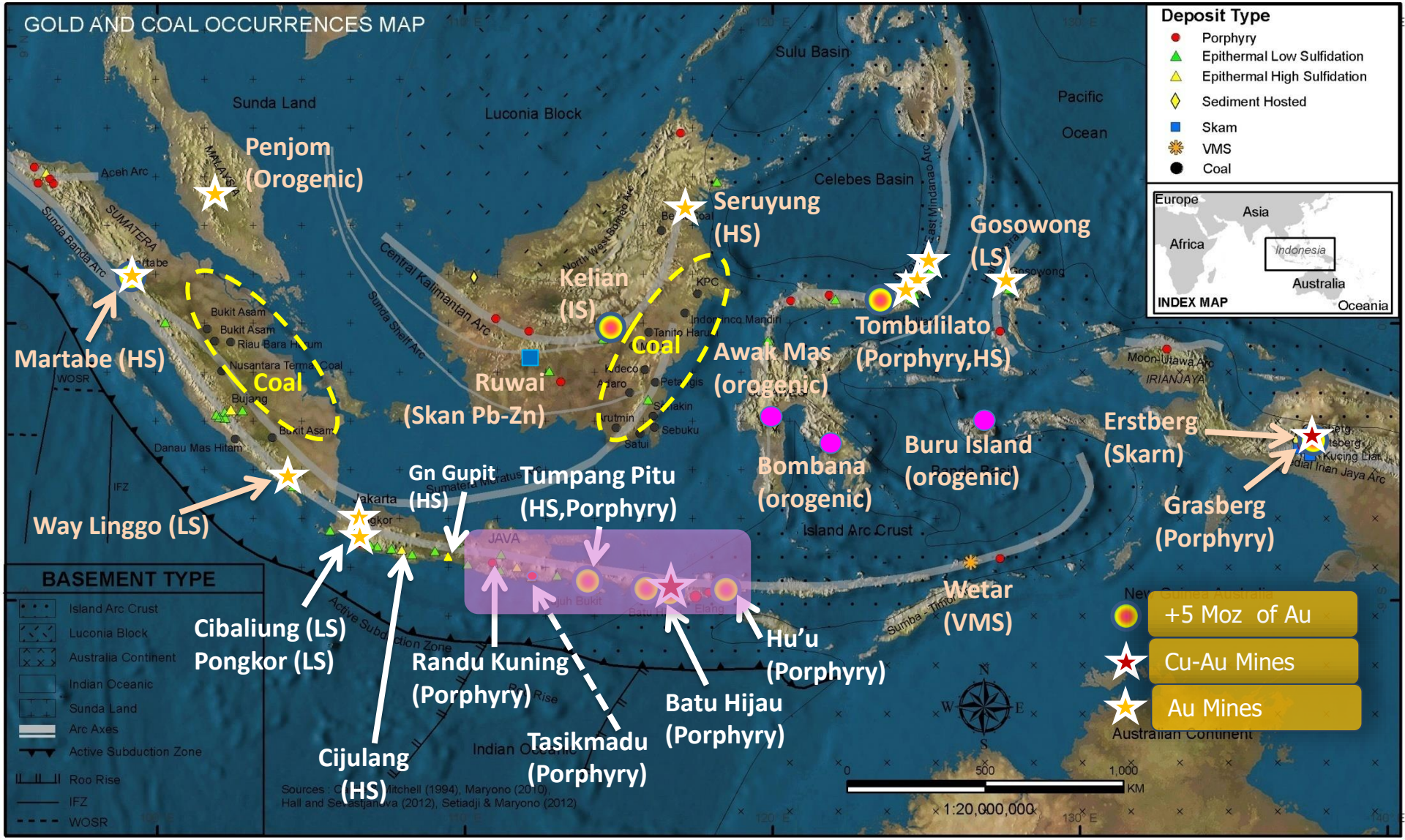
***Sunda-Banda** (Second Biggest):*

- *The longest & largest arc: 4,000 km2*
- *Western Sunda arc: 351t Au; 1,178t Ag & 142kt Cu*
- *Eastern Sunda arc: 2,173t Au, 3,686t Ag & 19,022kt Cu*
- *Banda arc: 48t Au; 970t Ag & 255t Cu.*



IAGI-MGEI (2015)

2. Gold, Basemetal & Coal in Indonesia



Source: Mitchell & Leach (1991); Carlile & Mitchell (1994); Maryono et al. (2012)

3

PORPHYRY COPPER-GOLD

Randu Kuning, Wonogiri (Central Java)

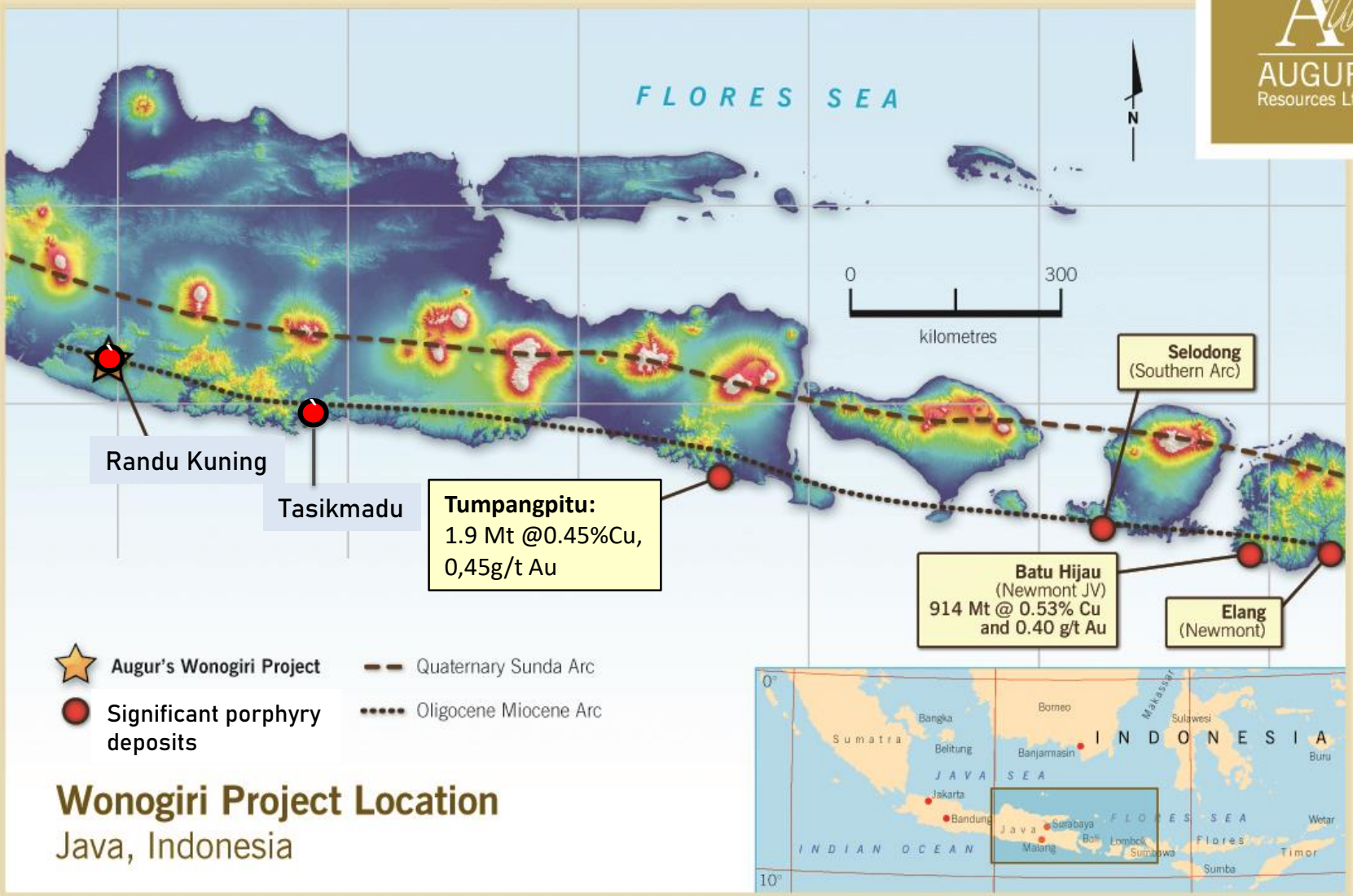
Tasikmadu, Trenggalek (East Java)

Tumpangpitu (East Java)

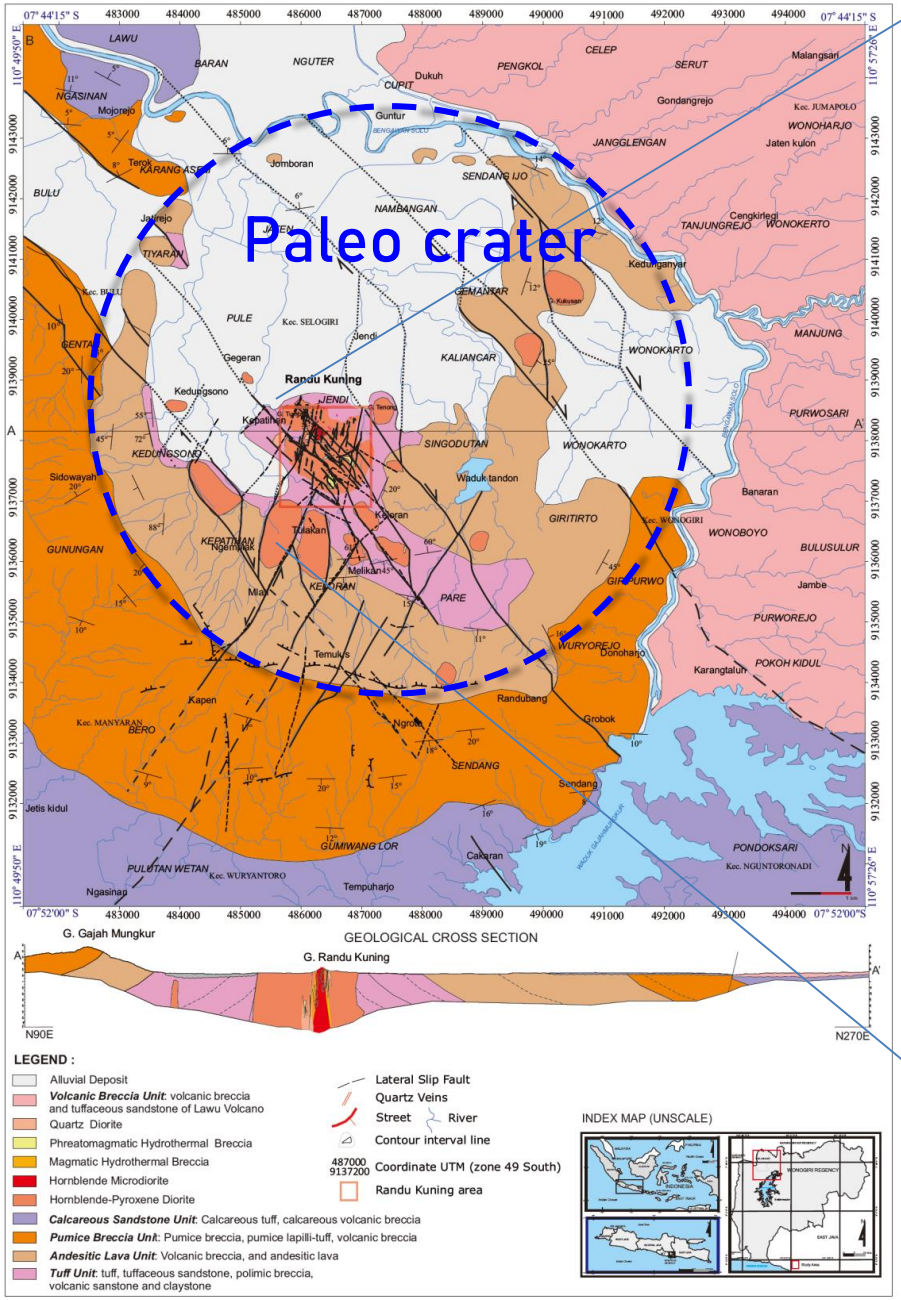
Batu Hijau (Sumbawa Island)

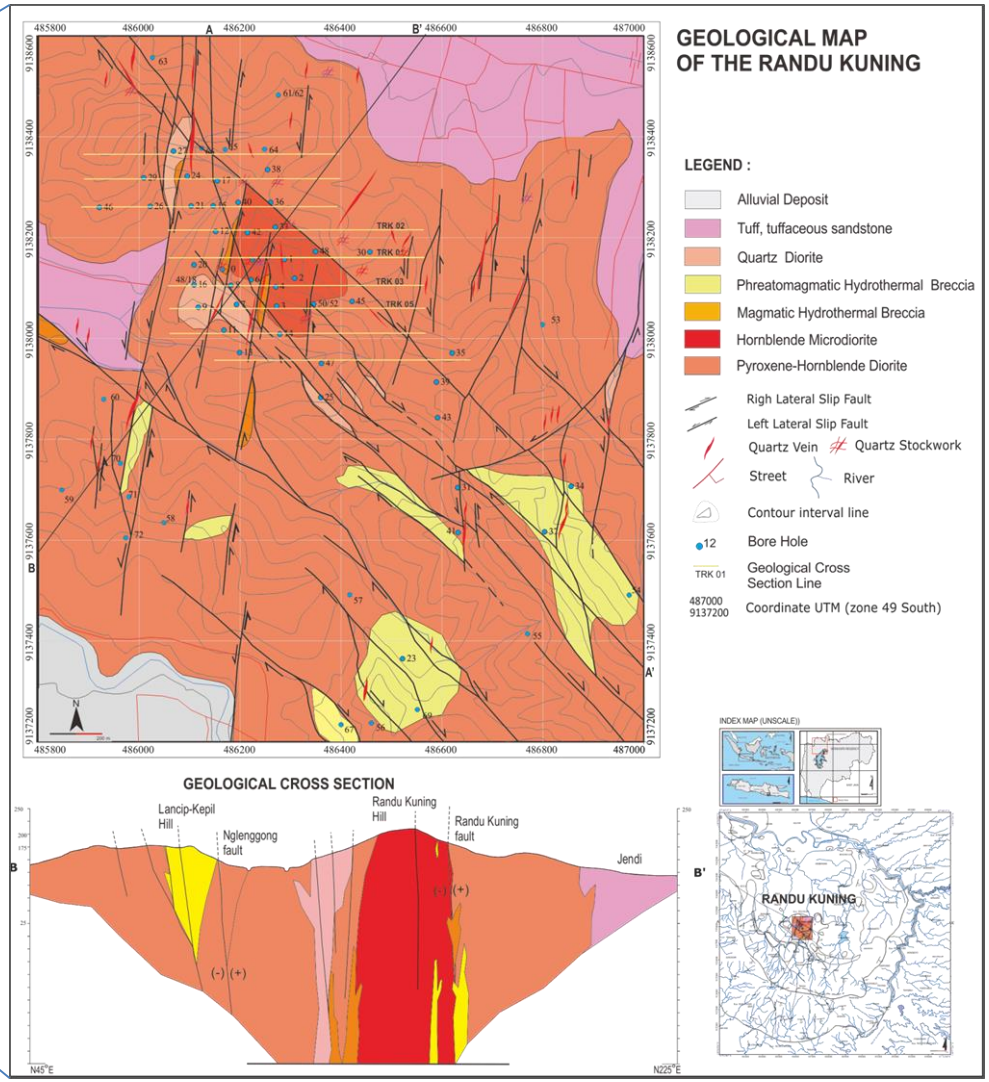
Hu'u (Sumbawa Island)

Randu Kuning, Wonogiri (Central Java)



Randu Kuning, Wonogiri (Central Java)





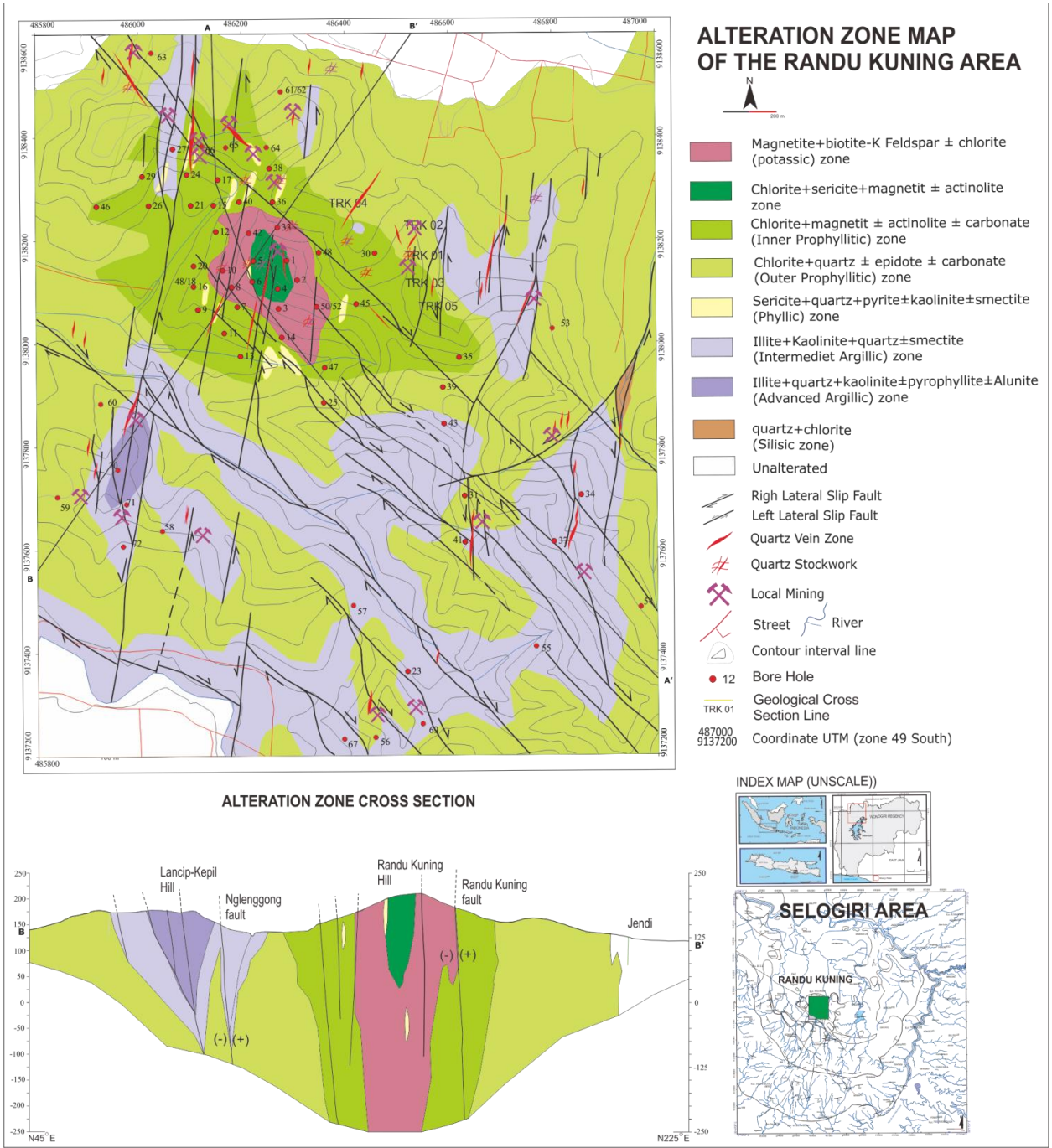
Geological Map of Selogiri area and its vicinity (Geological mapping 2012; modified from Suasta and Sinugroho, 2011 and Hartono, 2010)

Randu Kuning

Hydrothermal Alteration

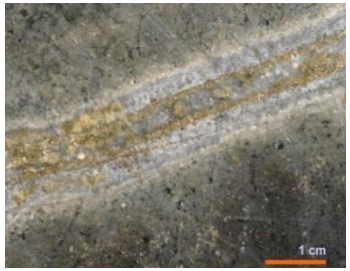
1). Magnetite+biotite±K-feldspar± chlorite (potassic)
2). Chlorite+sericite+ magnetite±actinolite
3). Chlorite+magnetite± actinolite±carbonate (inner propylitic)
4). Chlorite+epidote±carbonate (outer propylitic)
5). Sericite+quartz+pyrite (phyllic)
6). Illite+kaolinite±smectite (intermediet argillic)
7). Illite+kaolinite± pyrophyllite± alunite (advanced argillic)
8). Quatz+chlorite (silicic) zones

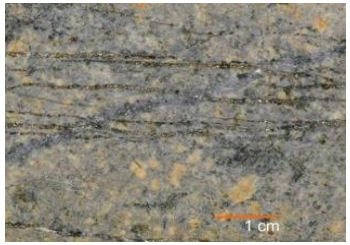
Sutarto et al. (2016)

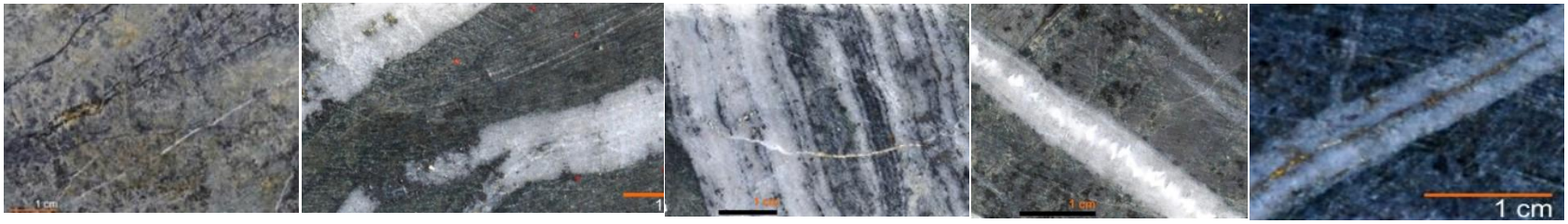


Randu Kuning: Vein/Veinlet System

- At least 7 porphyry vein/veinlet types:
  1. Magnetite±chalcopyrite ±quartz±biotite veinlets
  2. Quartz±magnetite±pyrite±chalcopyrite (A type)veins
  3. Banded/Laminated quartz+magnetite (M type) veins
  4. Quartz±K feldspar±pyrite (B type)veins
  5. Quartz±pyrite±chalcopyrite±bornite (AB type) veins with thin sulphide centre line
  6. Pyrite±chalcopyrite (C type) veinlets
  7. Pyrite+quartz±chalcopyrire±calcite (D type) veins

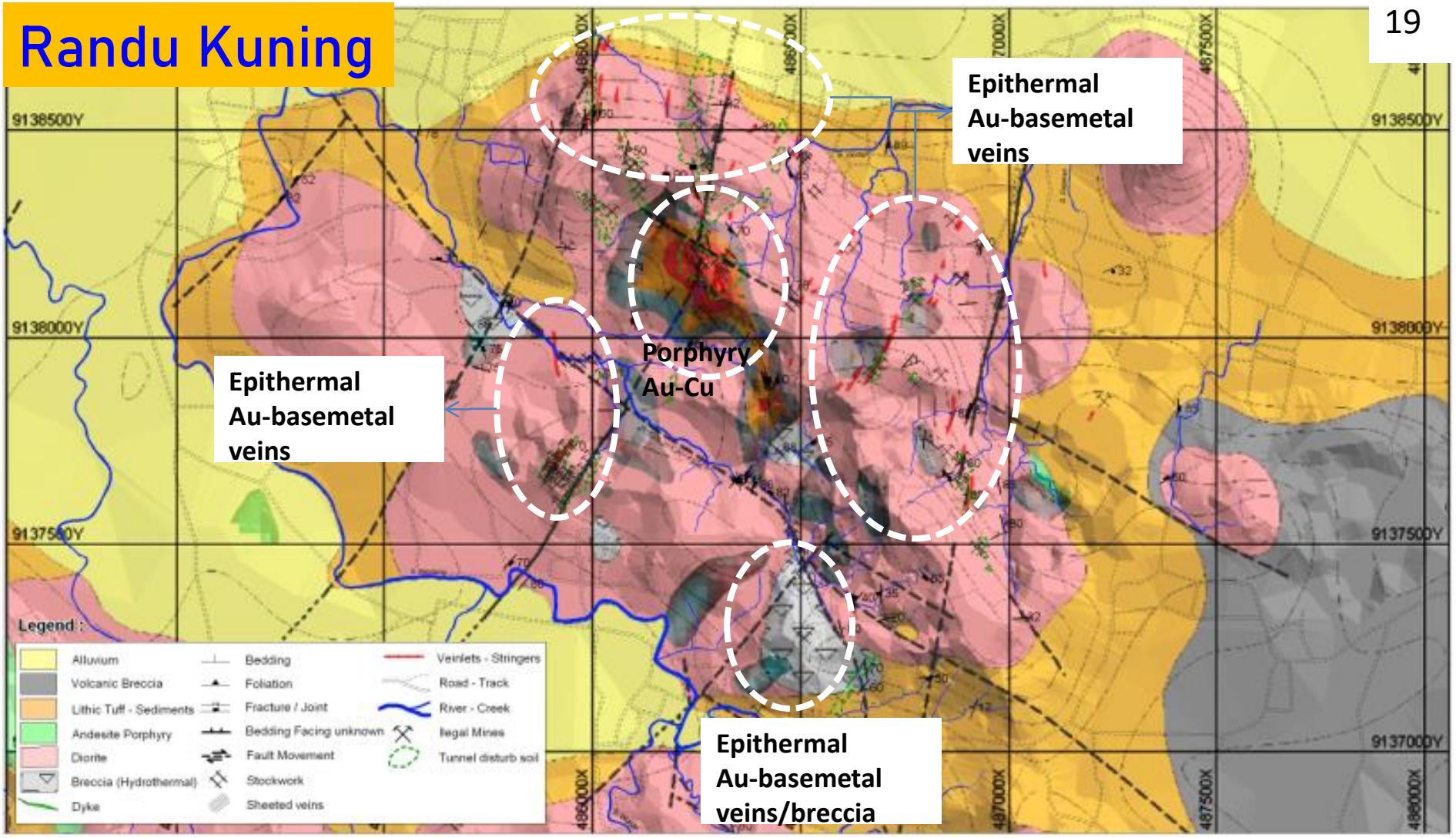






Sutarto et al. (2016)

Randu Kuning



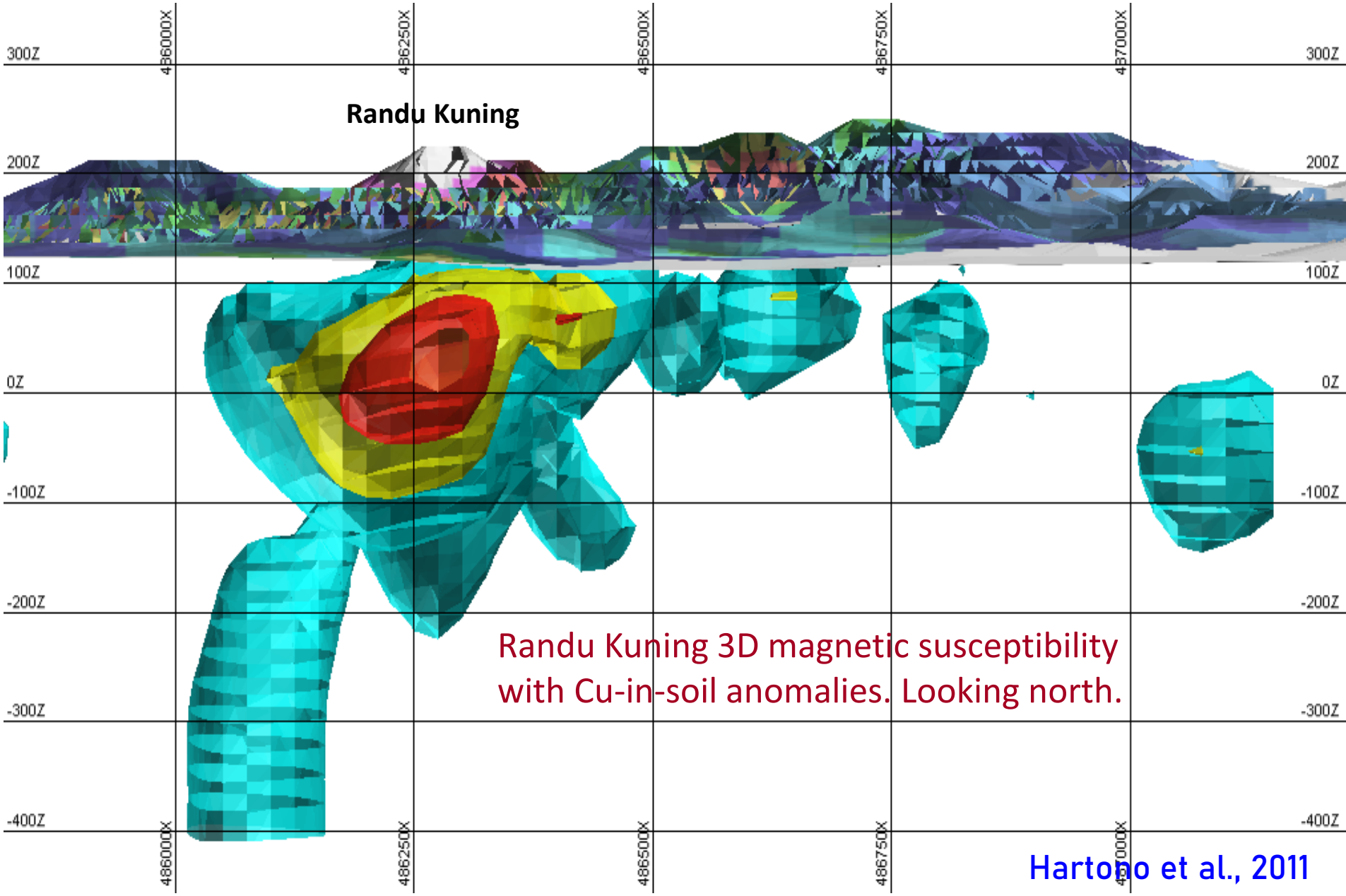
PT OXINDO EXPLORATION

WONOGIRI PROJECT

Geology Interpretation Map

Hartono et al., 2011

Randu Kuning: 3D Inversion Magnetic Modeling

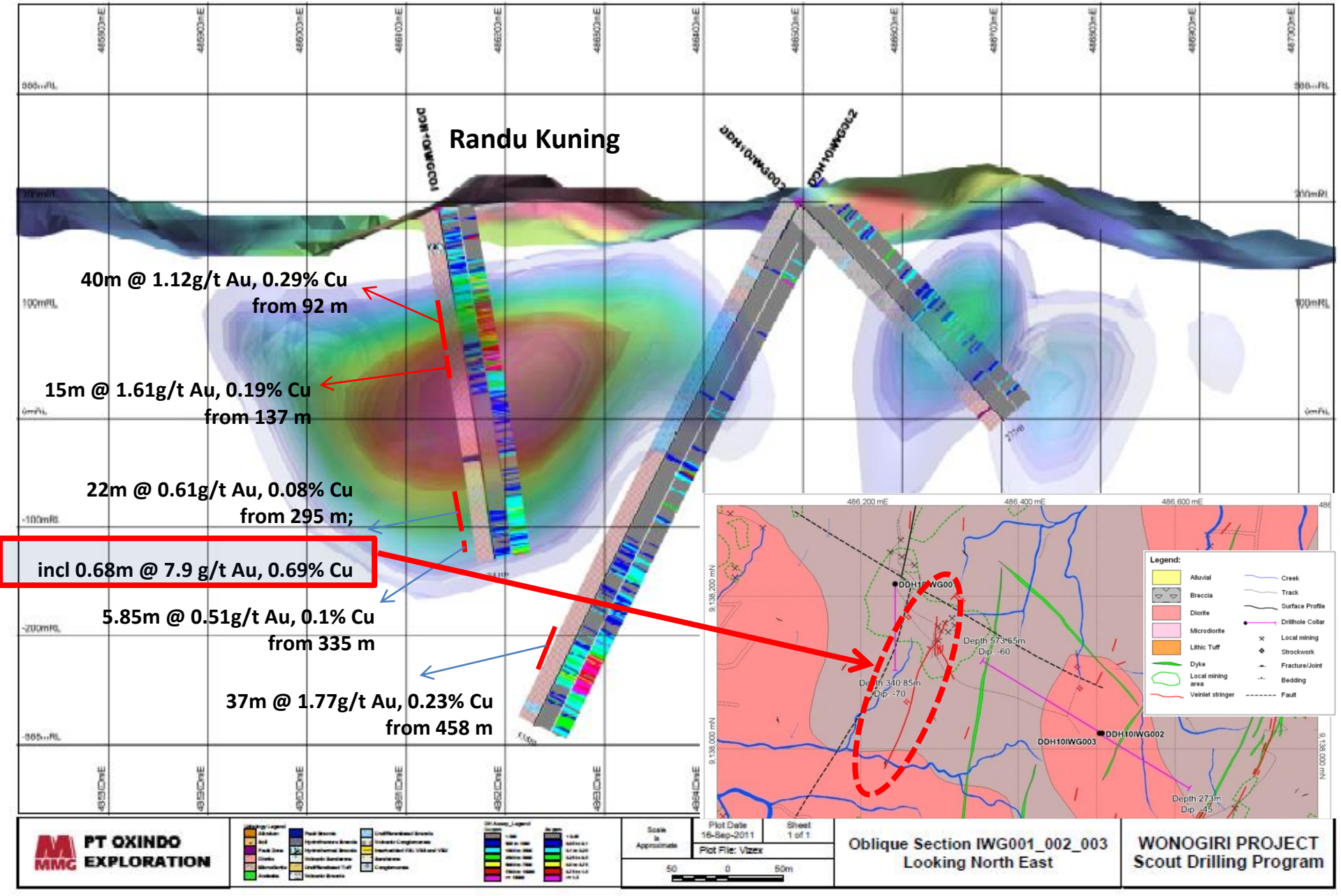


Randu Kuning 3D magnetic susceptibility with Cu-in-soil anomalies. Looking north.

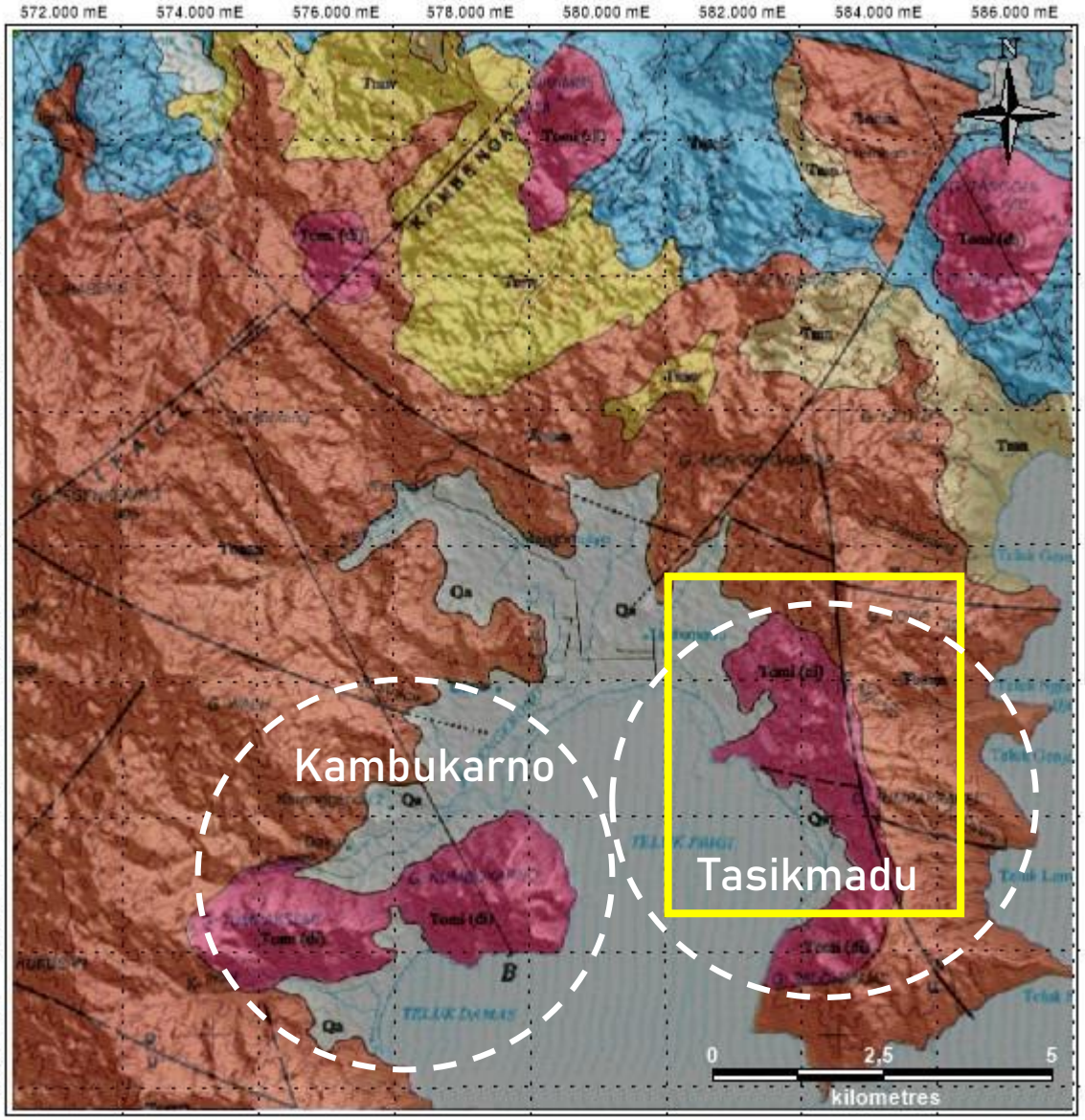
Hartono et al., 2011

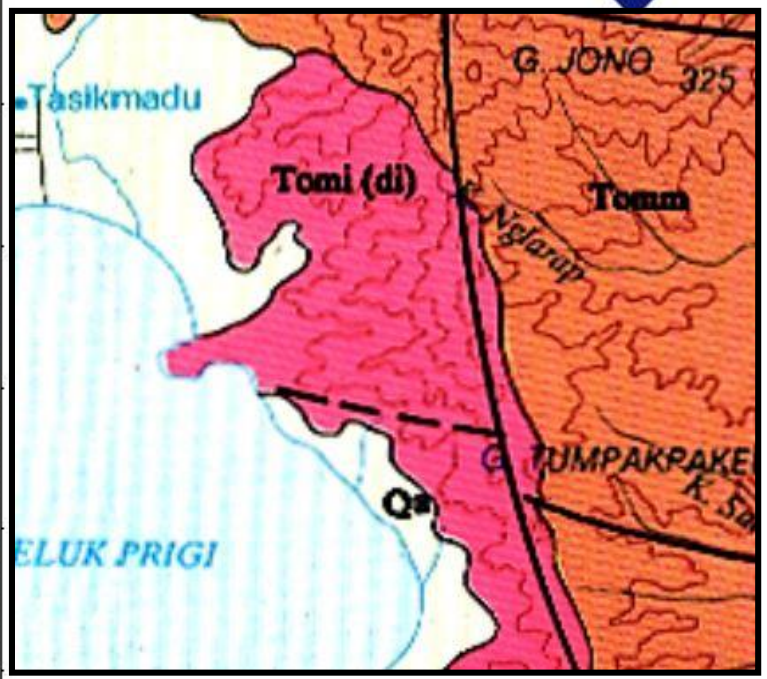
Randu Kuning: Subsurface Ore Mineralization

Hartono et al., 2011



Tasikmadu, Trenggalek



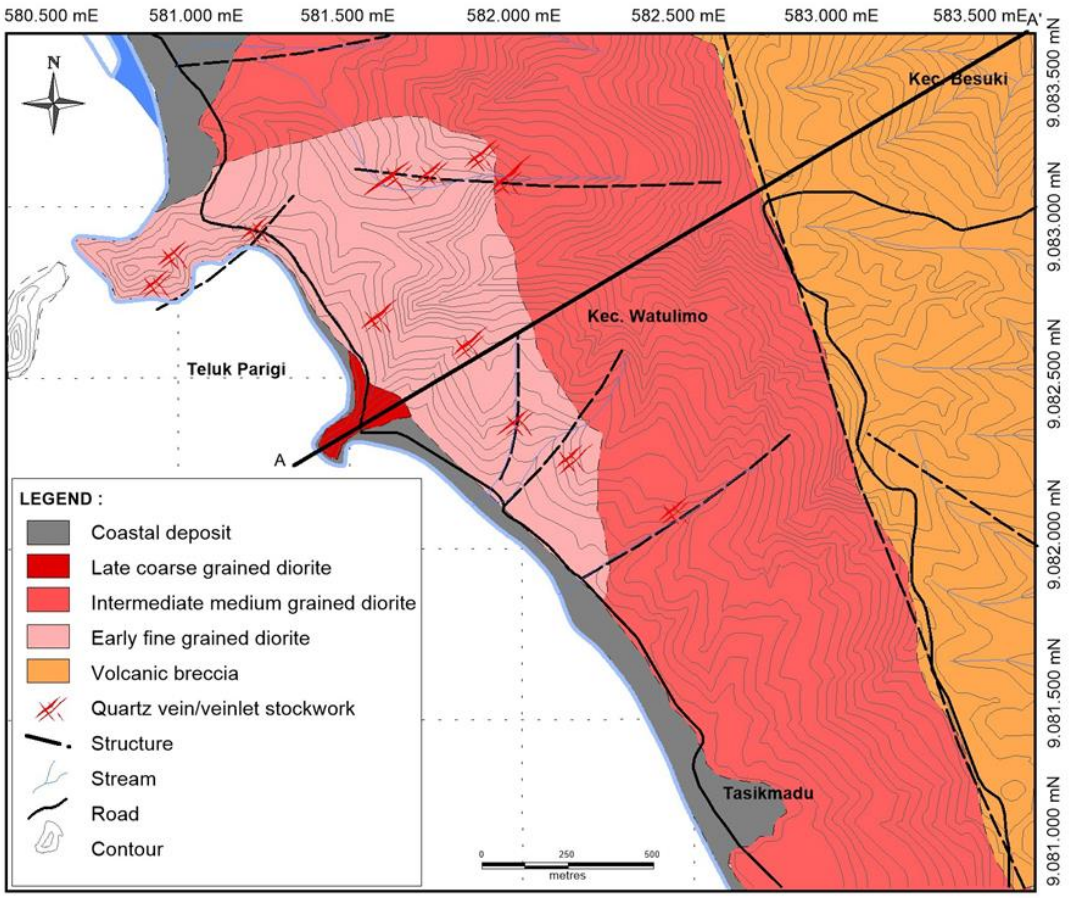


- The study area is occupied by Miocene Mandalika formation (Tomm)
- Tomm was intruded by a series of acidic to intermediate plutonic rocks (Tomi).

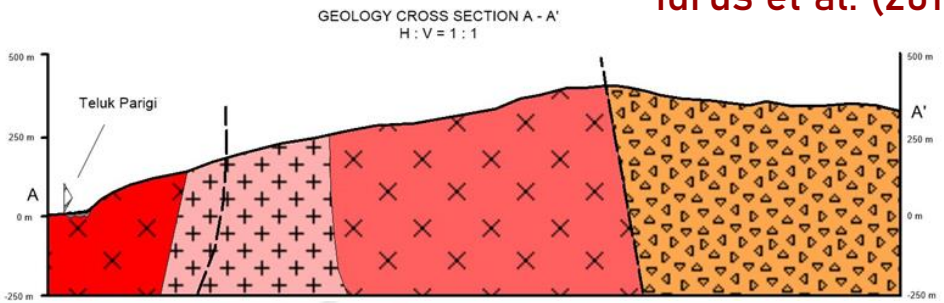
Samodra et al. (1992)

Tasikmadu, Trenggalek

Deposit Geology



Idrus et al. (2019)



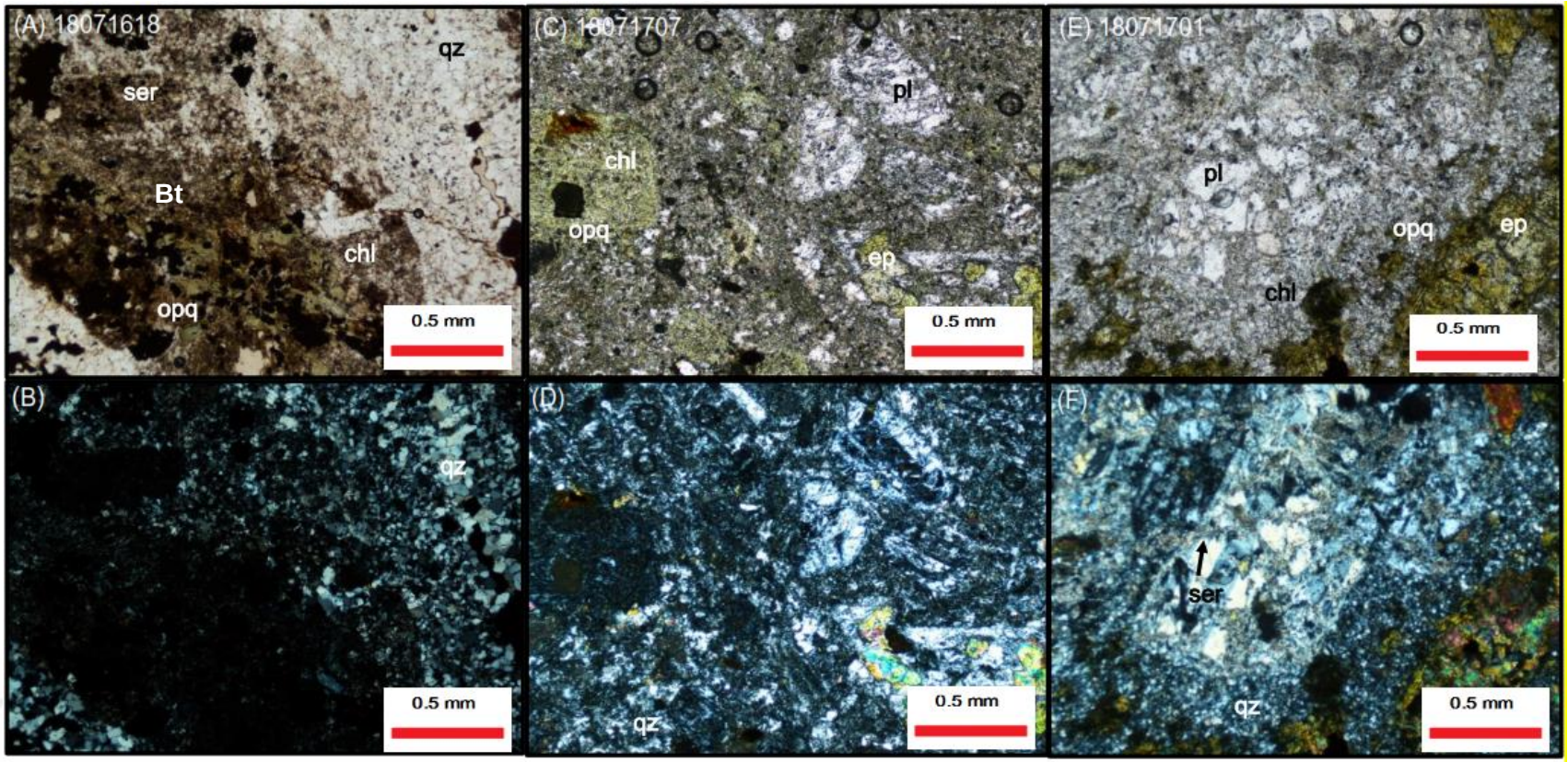
1. **Lithology:** underlain by a series of volcanic units, which from oldest to youngest are volcanic breccia, **at least three phases of intrusive rocks mainly early fine-grained diorite, intermediate medium grained diorite and late coarse-grained diorite porphyries**
2. Causative mineralization intrusion is interpreted to be fine grained diorite porphyry, which is closely associated with of quartz vein/veinlet stockwork occurrences.
3. NNE-SW- and W-E- trending strike-slip faults are interpreted to be causative structure playing an important role controlling the formation of the porphyry copper-gold prospect.

Tasikmadu, Trenggalek

Causative Intrusions

PETROGRAPHY

Early fine-grained diorite | **Intermediate medium grained diorite** | **Late coarse-grained diorite**

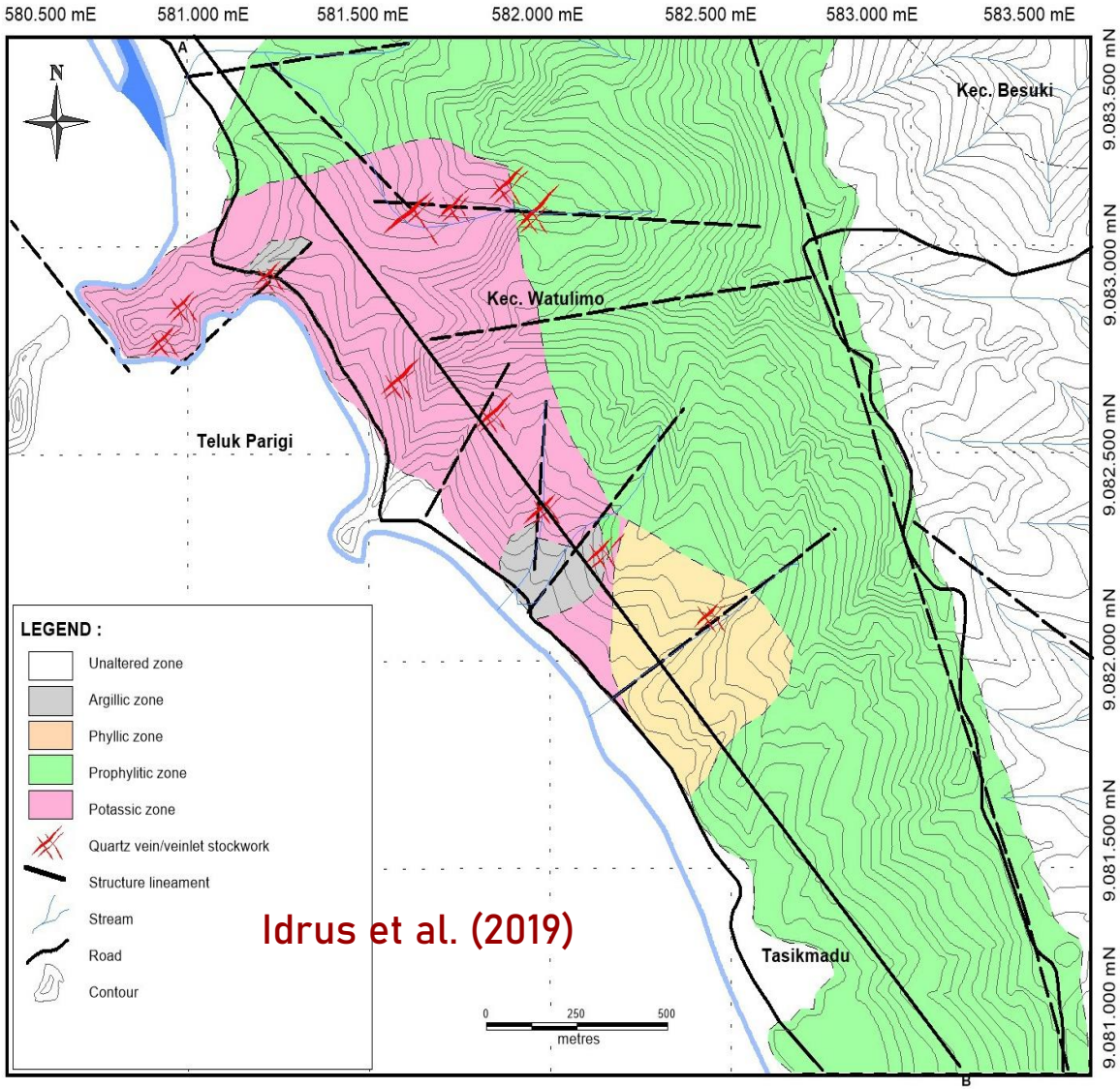


Kaneko et al. (2019)

- The main causative intrusion is interpreted to be fine grained diorite porphyry
- Ore mineralization is gradually depleted to the intermediate medium grained diorite and late coarse grained diorite porphyries, respectively

Tasikmadu, Trenggalek

Hydrothermal Alteration



Idrus et al. (2019)

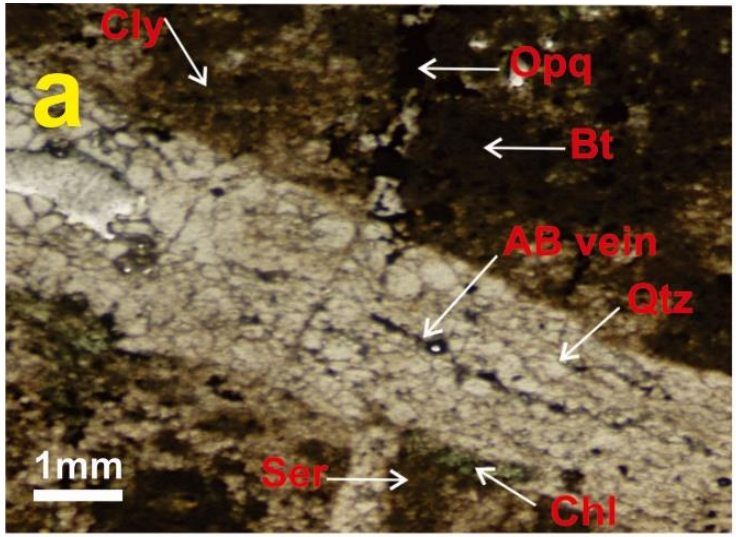
- Four hydrothermal alteration halos developed include **central potassic, proximal phyllic, distal propylitic and superimposed argillic alteration.**
- Central potassic alteration is typified by fine-grained secondary biotite and magnetite, whereas phyllic alteration is typified by sericite-quartz-pyrite±chlorite.
- Ore mineralization is closely associated with potassic alteration and high-dense quartz vein/veinlet stockwork.
- The potassic alteration is spatially and temporally distributed a whole of early fine-grained diorite porphyry.

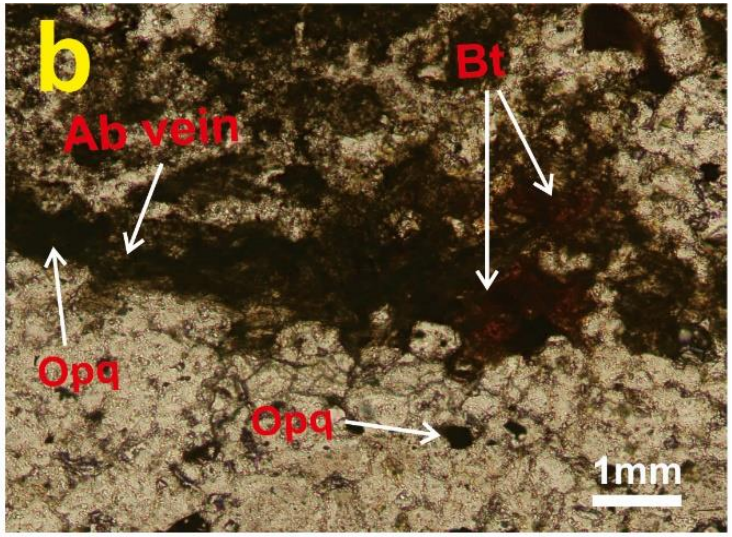
Tasikmadu, Trenggalek

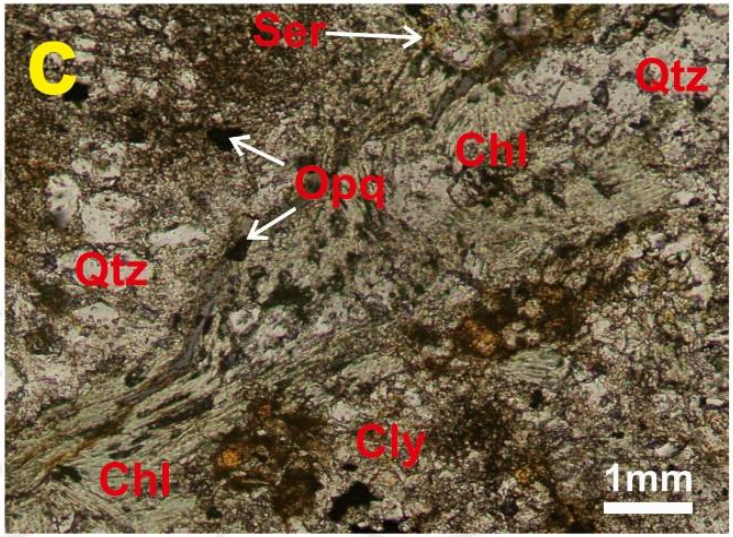
Hydrothermal Alteration

PETROGRAPHY

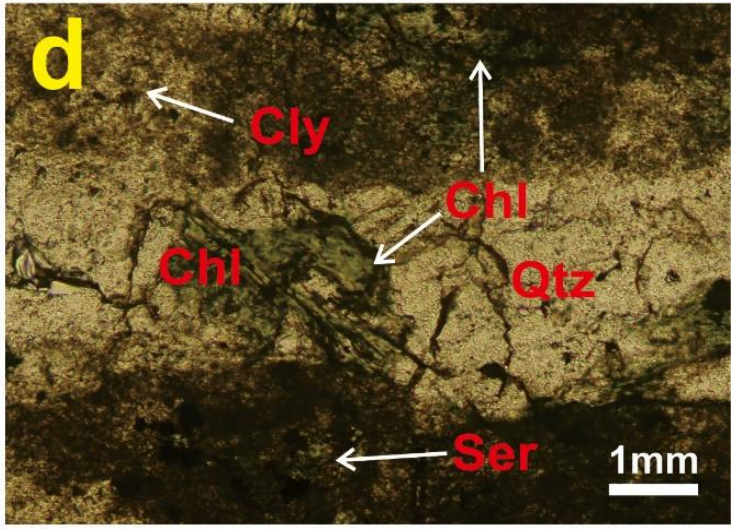
Potassic alteration







Phyllic alteration

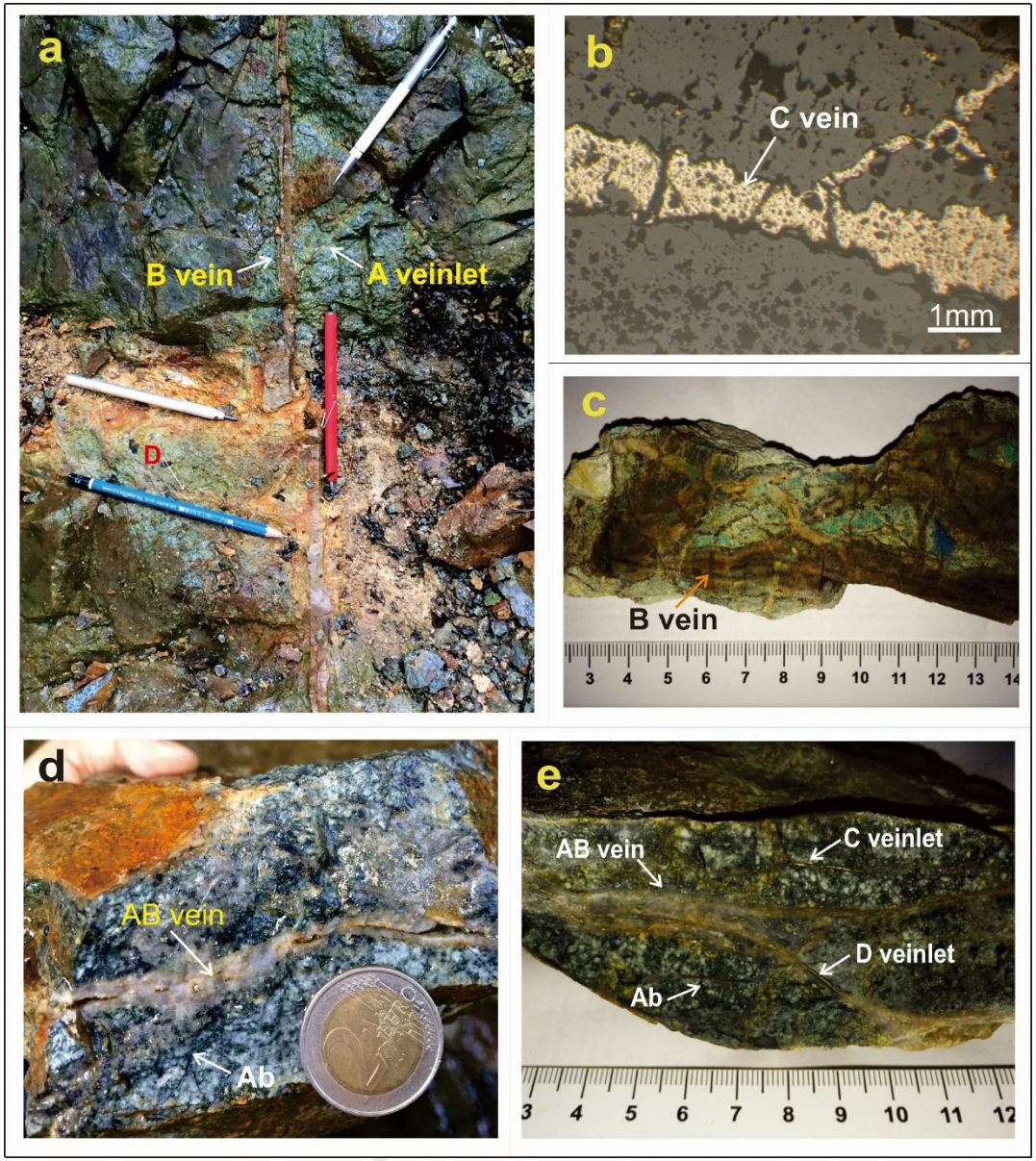


Propylitic alteration

Idrus et al. (2019)

Tasikmadu, Trenggalek

Quartz Vein/Veinlet System



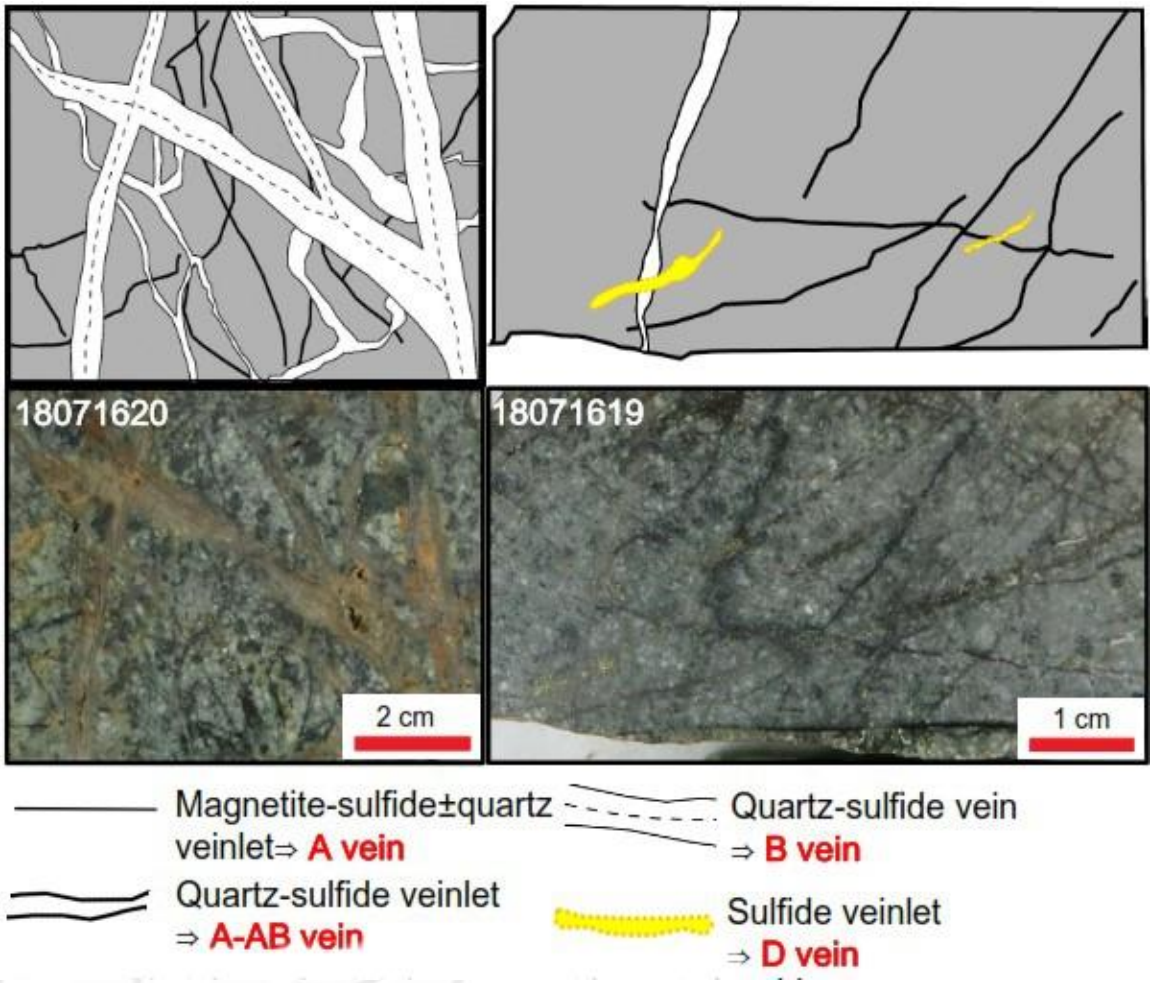
- Ore mineralization is characterized by high-dense mineralized stockwork of quartz vein/veinlet system i.e. Early A, A-AB, center-line AB/B, transitional chalcopyritic C and late pyritic D veins/veinlets of a typical porphyry system.

- The prospect area is mappedly centered by at least 1x1.5 squared km of early potassic alteration zone which is spatially (may be coevally) associated with high-dense mineralized vein/veinlet stockwork zone.

Idrus et al. (2019)

Tasikmadu, Trenggalek

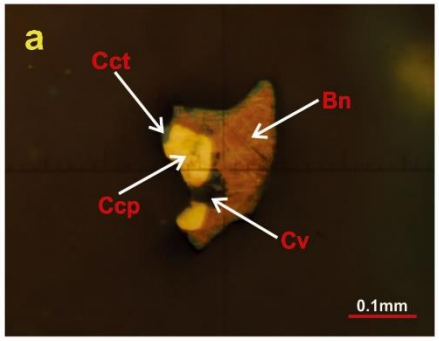
Quartz Vein/Veinlet System

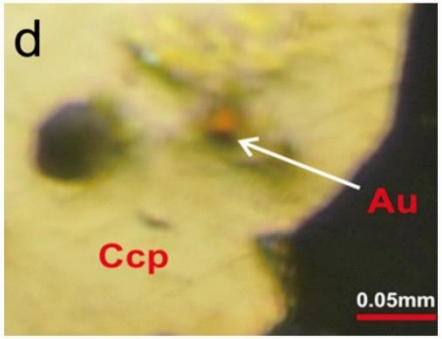


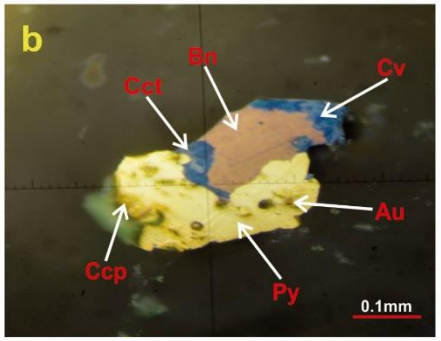
Kaneko et al. (2019)

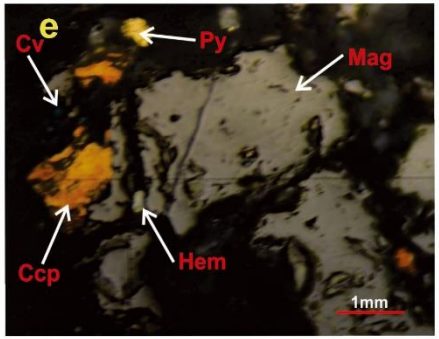
Quartz vein/veinlet system: Early A, A-AB veins/veinlets, center-line AB/B, transitional chalcopyritic C and late pyritic D veins/veinlets

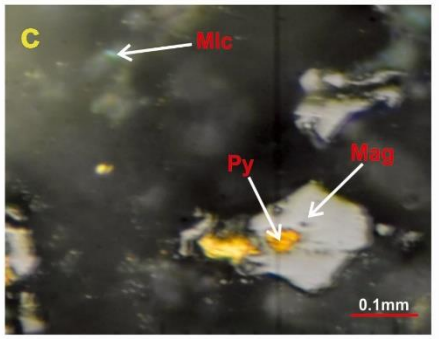
Ore Mineralization

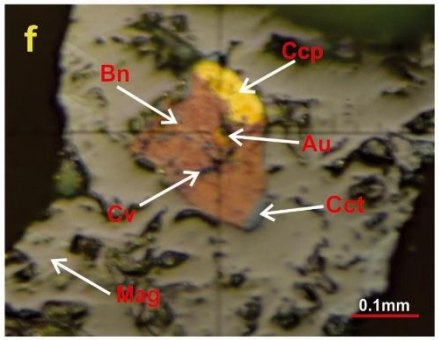












Sample ID	Au	Ag	As	Cu	Pb	Zn	Mo
2.1-A	0.63	0.8	5	0.38	119	137	1
2.1-B	1.89	3	2	0.66	43	77	1
2.2-A	1.54	2.3	3	0.89	35	65	1
2.2-B	0.54	1.9	2	0.52	27	67	1
2.3-A	0.43	10.5	128	0.55	26	36	1
2.3-B	1.48	4.3	18	0.1	12	110	1
2.4-A	5.45	8.4	13	0.1	23	61	1
03-A	7.01	6.3	50	0.1	12	108	1
11-a	0.05	0.3	19	0.02	25	109	1
11-b	0.07	0.3	25	0.08	35	106	1
LAI-02	1.37	2.7	9	0.93	7	81	1
LAI-03	0.52	1.2	3	0.30	4	65	1
LAI-04	1.57	4.3	11	0.1	5	77	1

- High grade of Cu & Au is intimately associated with central potassic altered rocks which have been cross cut by quartz veins/veinlets.
- Copper grade ranges between **0.02 and 0.93 %** at an average of 0.36 % Cu, categorized into medium grade, which may be common in porphyry system in Java Island.
- Gold grade varies from **0.05 to 7.01 g/t** at an average of 1.74 g/t Au. Two samples show an elevated gold grade, i.e. **5.45 and 7.01 g/t Au**.

- **These high gold grades** are not typical of porphyry copper-gold system, and it may imply the presence of the overprinting late LS-epithermal veins in the porphyry system (?).

Idrus et al. (2019)

Fluid characteristics

Fluid inclusion studies suggest that different types of mineralization were occurred in Early Fine-grained diorite.

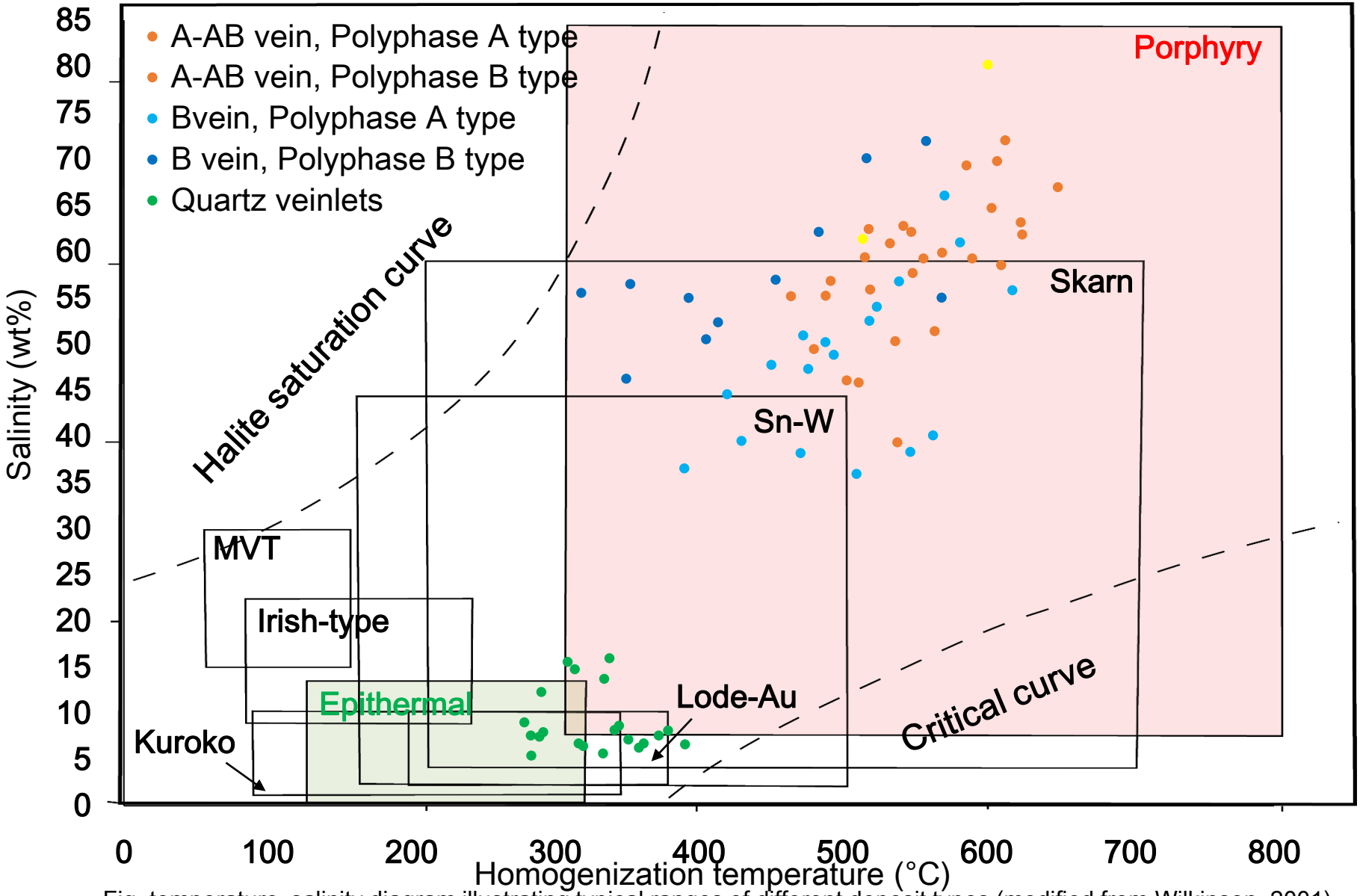


Fig. temperature–salinity diagram illustrating typical ranges of different deposit types (modified from Wilkinson, 2001).

Deposit type and the occurrence of gold

- Early Fine-grained Diorite where show the porphyry-type mineralization has economical potential.
- Au in pyrite occurs as sporadically Au^0, nanoparticle.

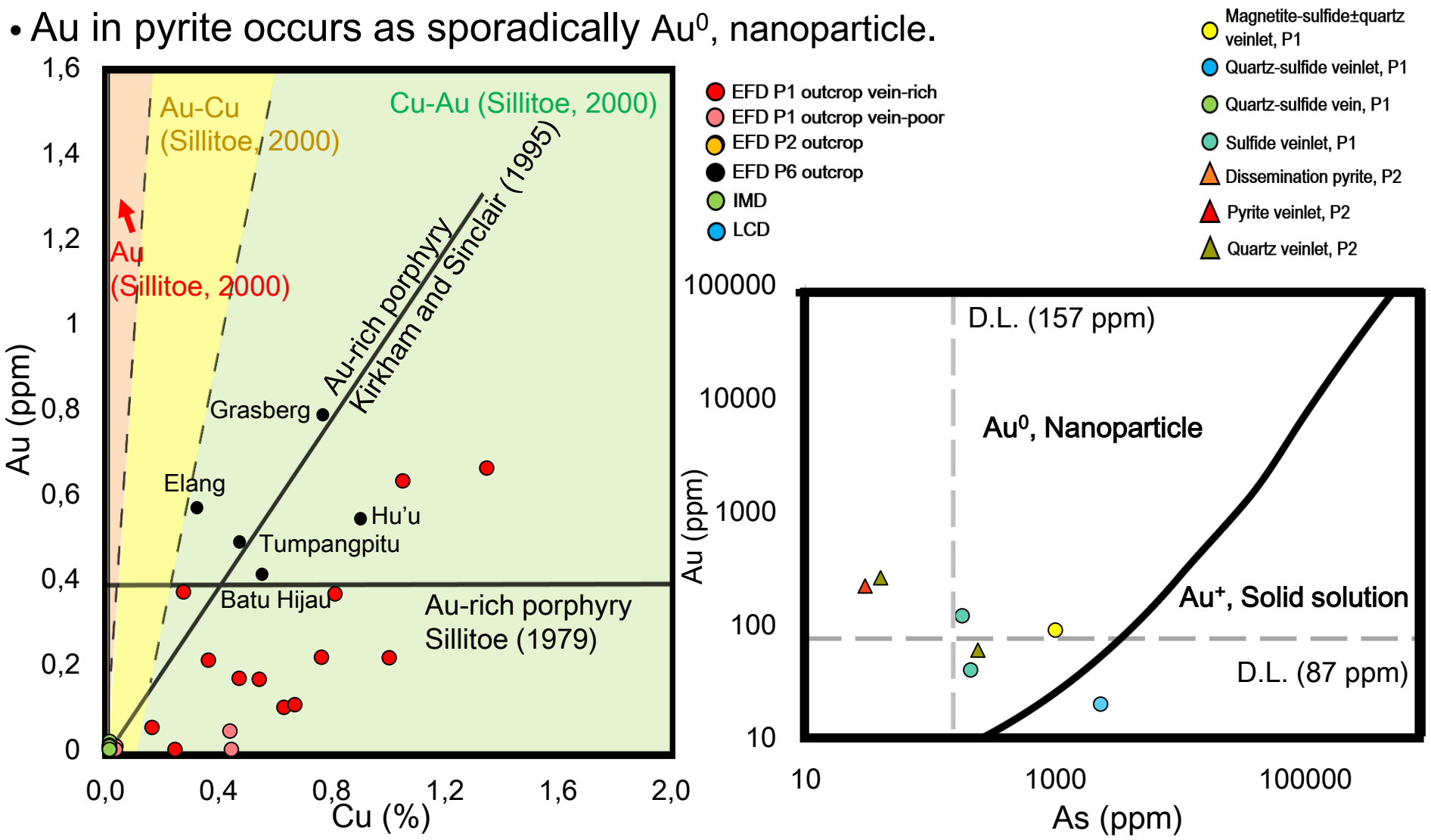
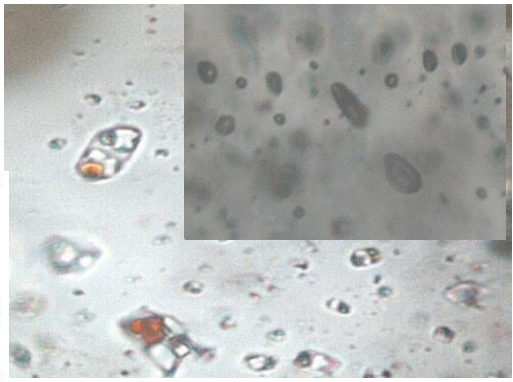
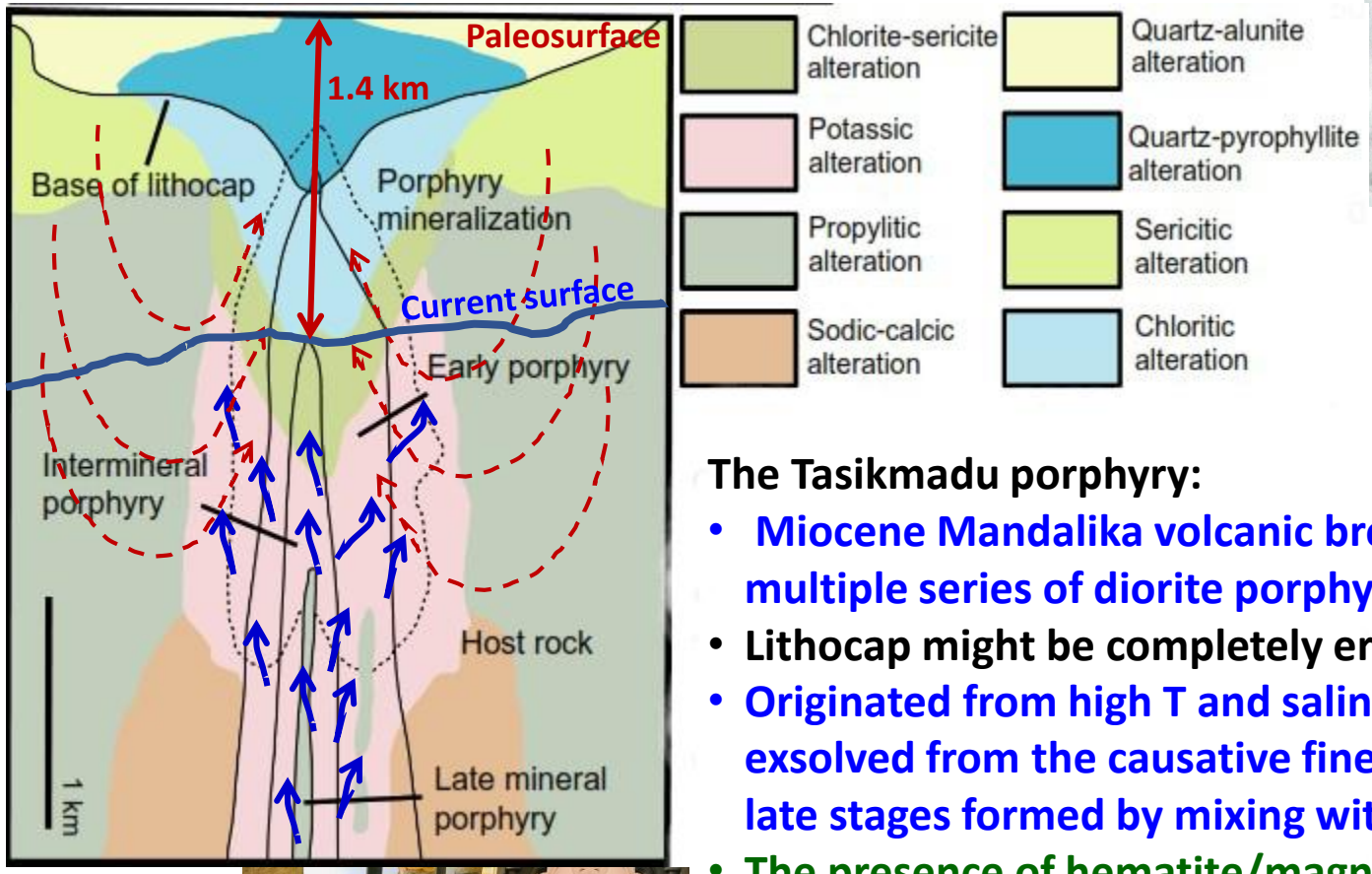


Fig. Copper and Au grade of Tasikmadu intrusions (Kesler et al., 2002; Idrus et al., 2007; Sillitoe, 2010; Hoshke, 2012; Maryono et al., 2018) (left) and Occurrence of Au in pyrite (Keith et al., 2005; 2018) (right).

Tasikmadu: Conceptual Model





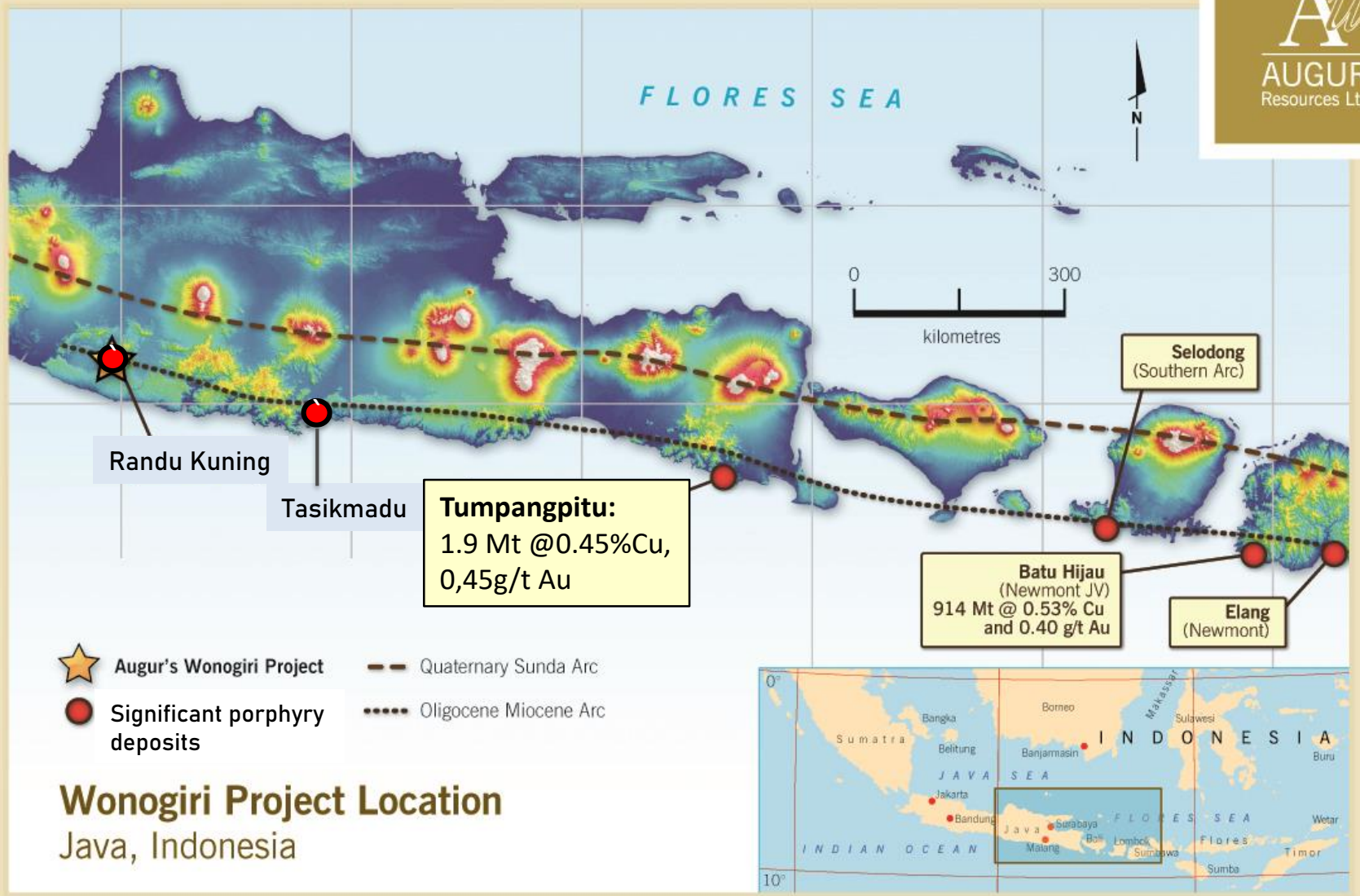
Sillitoe (2010)

The Tasikmadu porphyry:

- Miocene Mandalika volcanic breccia was intruded by multiple series of diorite porphyries
- Lithocap might be completely eroded → ~1.4 km depth
- Originated from high T and saline magmatic fluids exsolved from the causative fine-grained diorite, and late stages formed by mixing with meteoric water
- The presence of hematite/magnetite daughters (S2) is interpreted that the fluid was enriched in metals and being fertile to form the porphyry deposit.
- Abundant L- & V-rich fluid inclusions → boiling condition.
- Classic alteration: potassic, phyllic, propylitic and argillic

MGEI
11th ANNUAL CONVENTION

Tumpangpitu, Banyuwangi (East Java)



Tumpangpitu, East Java

- The Tumpangpitu porphyry and high-intermediate-sulfidation epithermal deposit is the largest deposit in the Tujuh Bukit district, East Java.
- The **porphyry resource** contains **1.9 billion tonnes** @0.45% Cu and 0.45 g/t Au, for 28.1 Moz Au and 19 billion lbs of Cu (Harrison et al., 2018).
- There are an additional 2.1 Moz Au and 72.9 Moz of Ag in **oxidized high-sulfidation** epithermal mineralization (Harrison et al., 2018).

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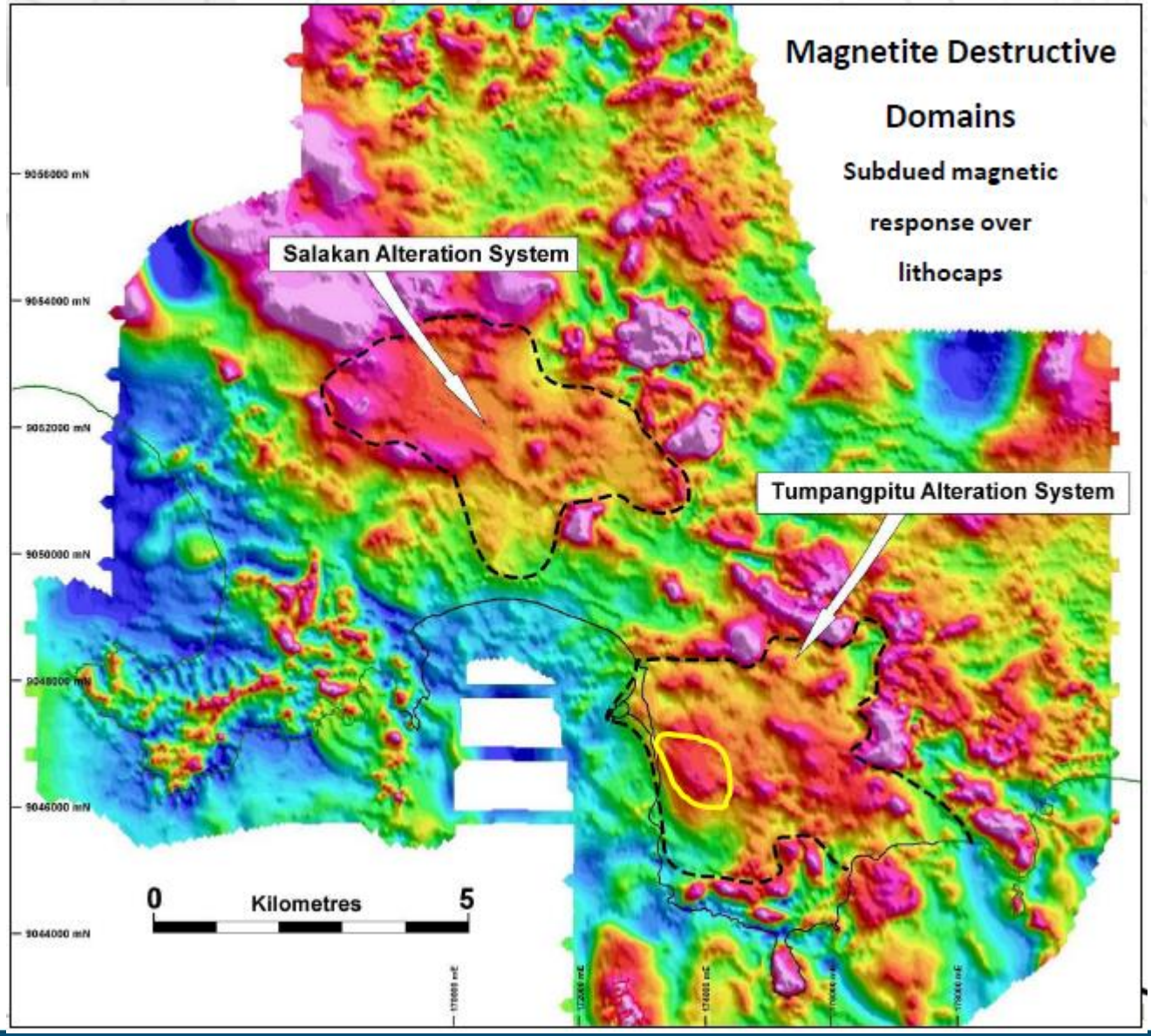
Geophysical Method: Airborne Geomagnetic



Hellman (2012)

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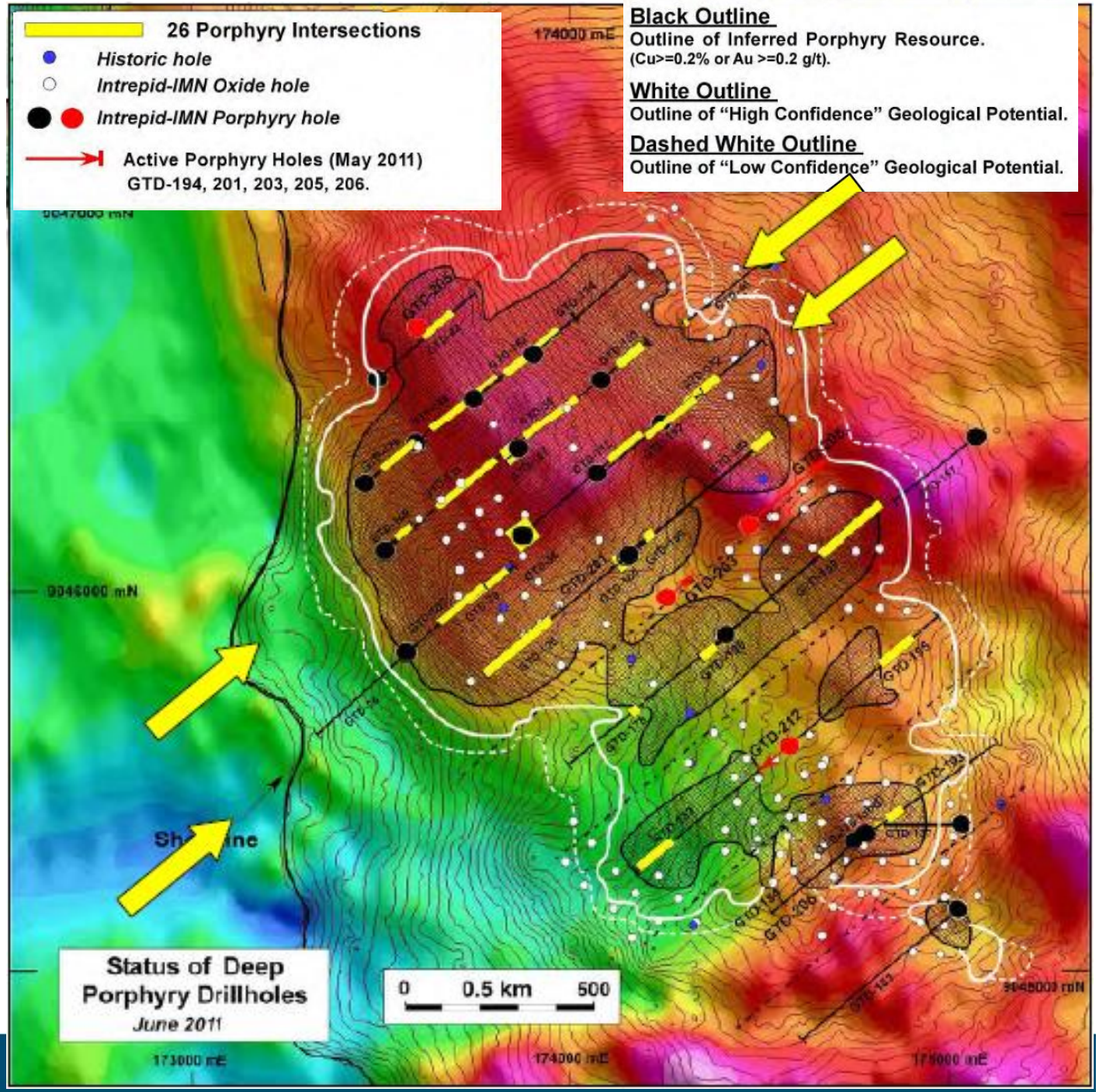
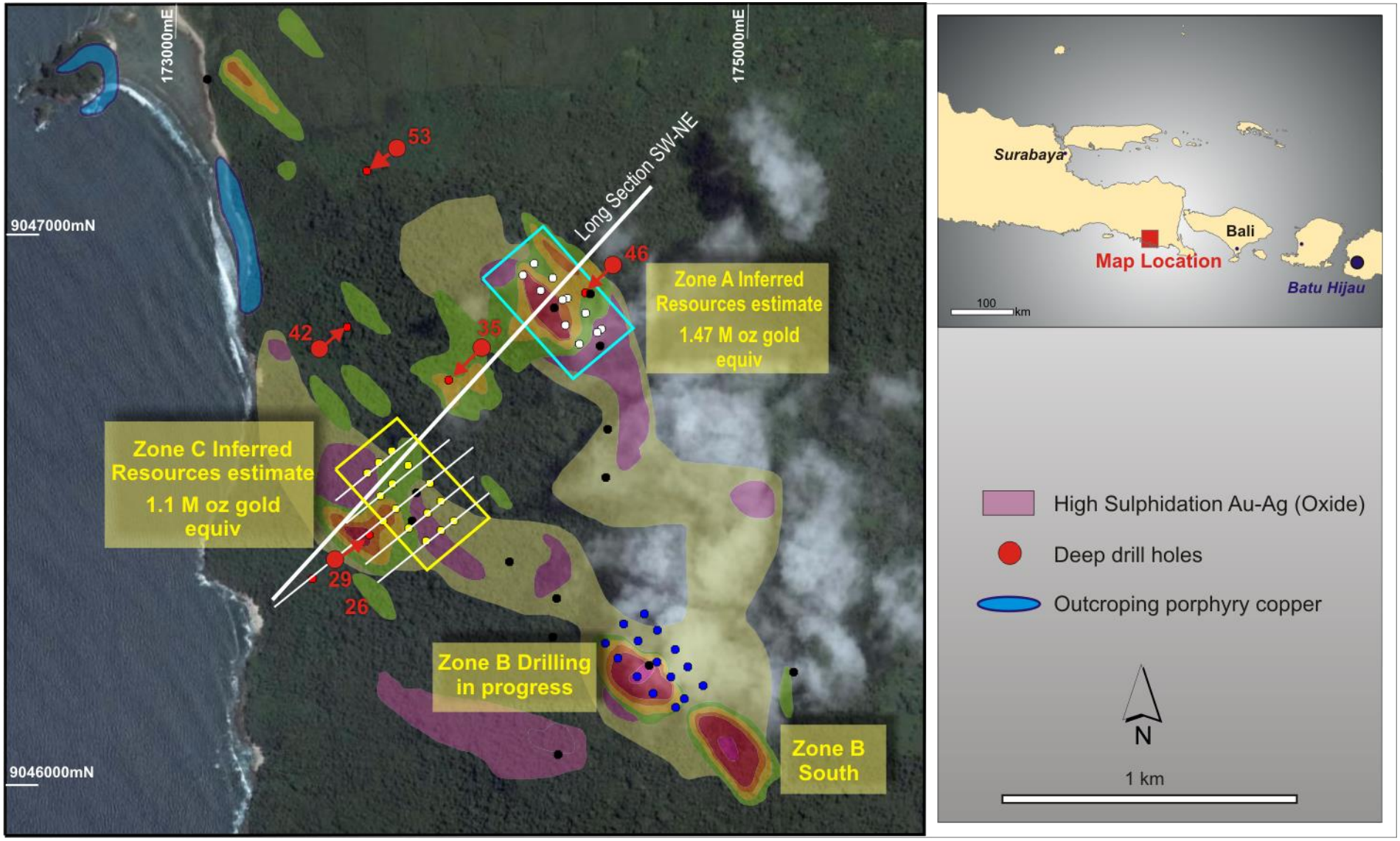


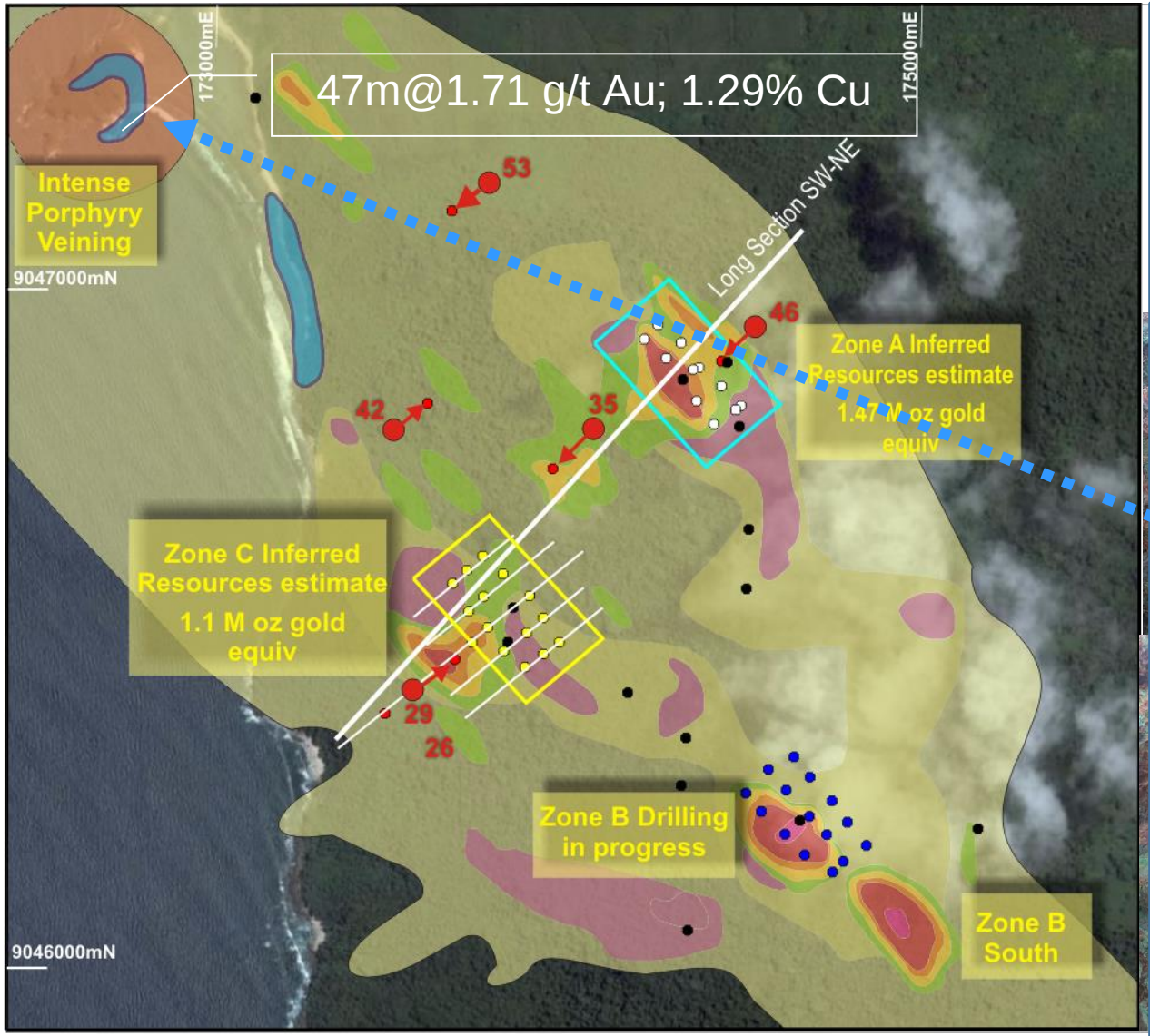
Hellman (2012)

Tumpangpitu, East Java



Maryono (2013)

Tumpangpitu, East Java



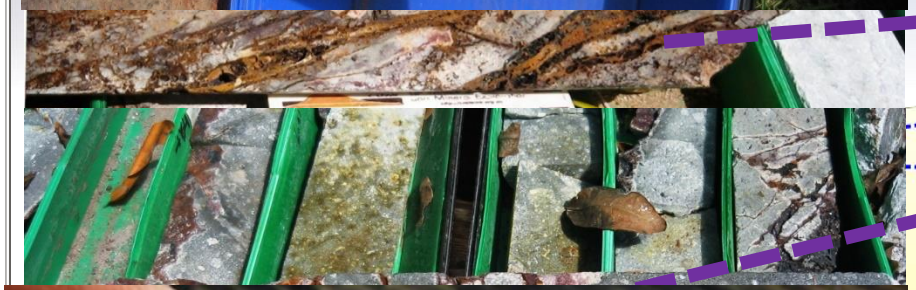
Maryono (2013)

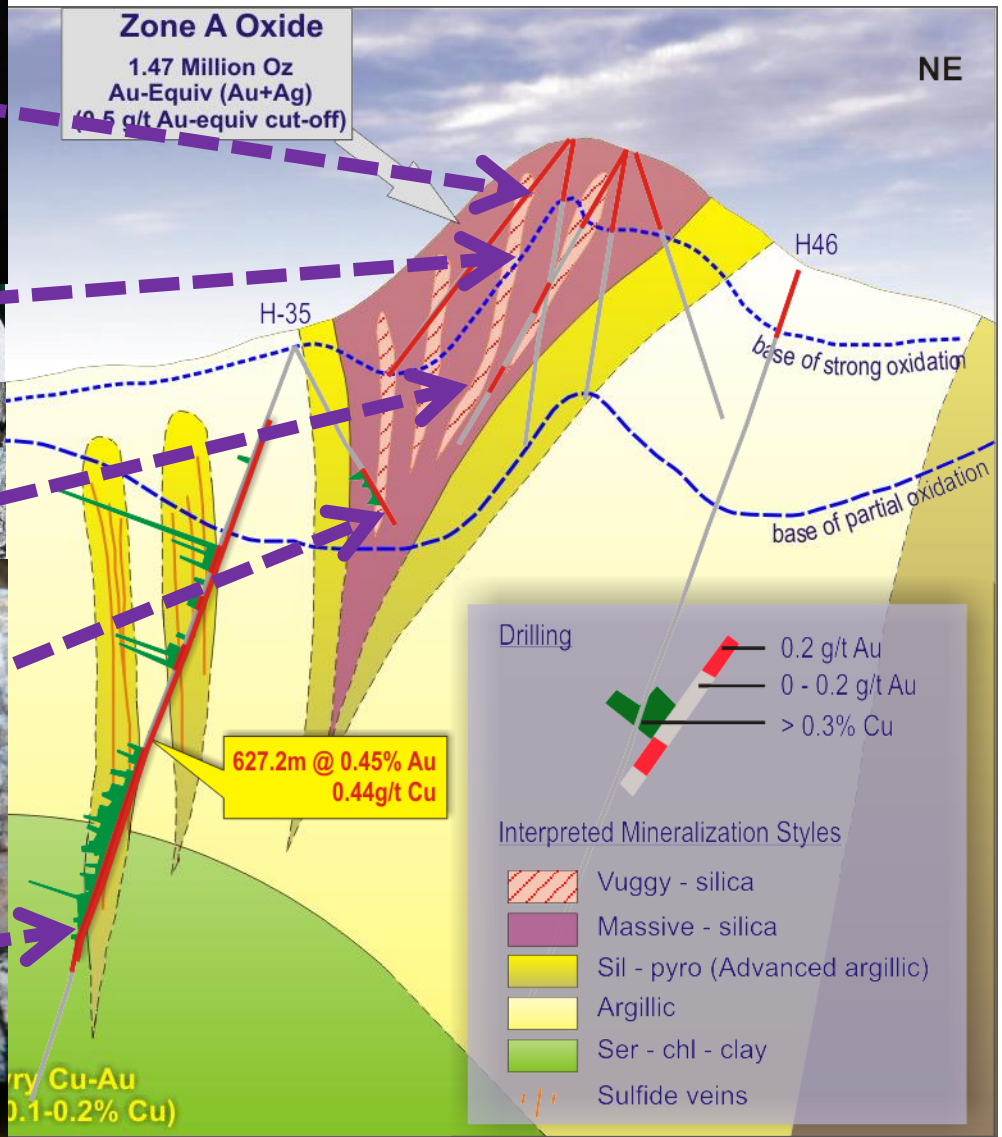
Red Island, Banyuwangi

Courtesy: A. Idrus (2015)

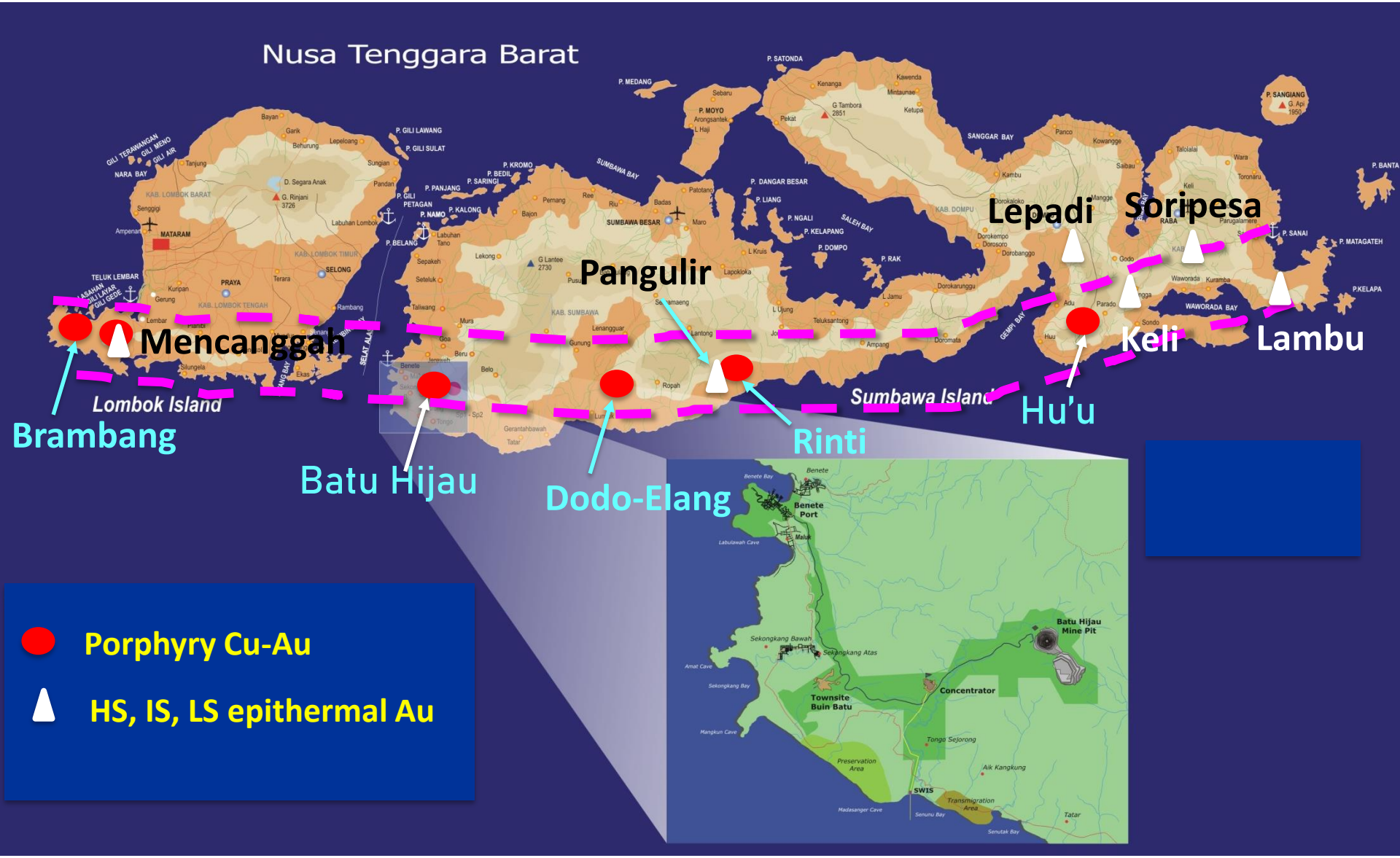
Tumpangpitu, East Java

Maryono (2013)

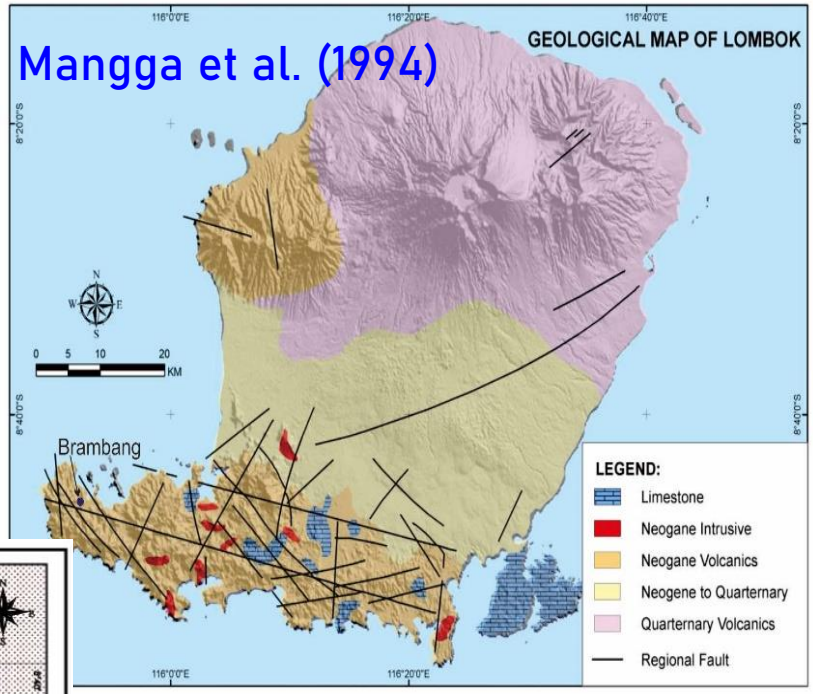


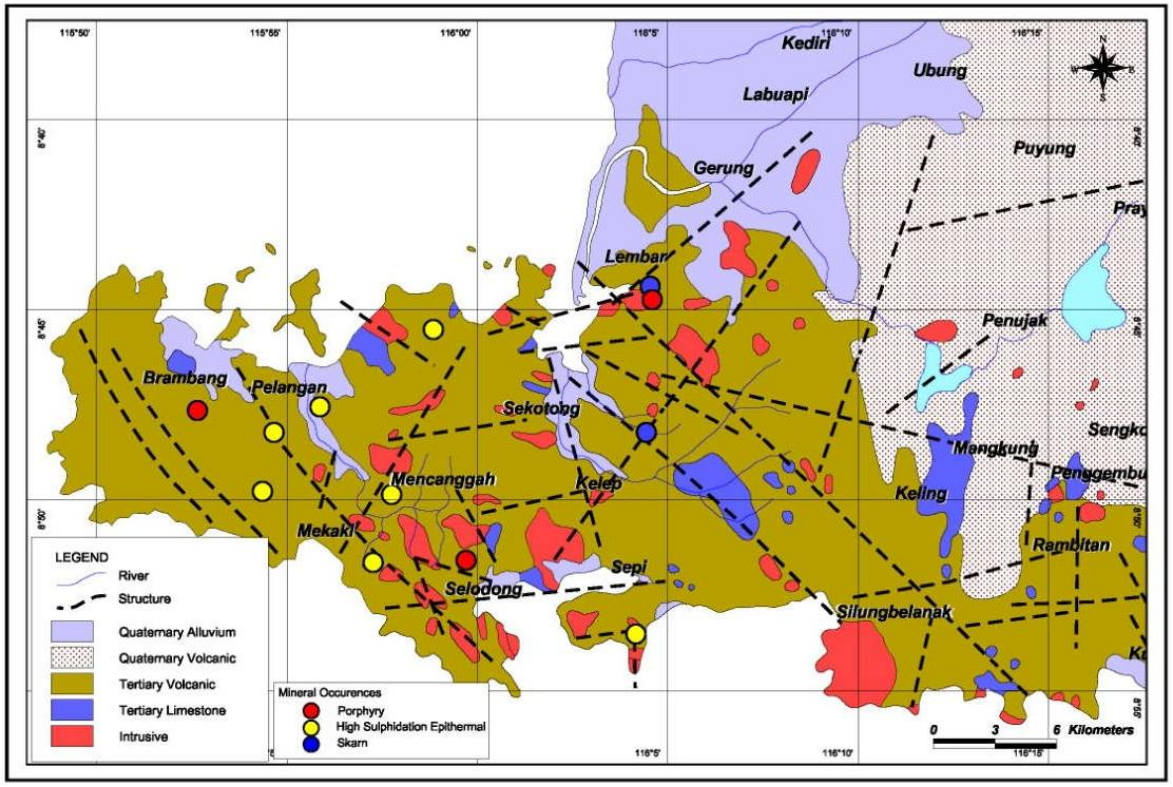


Lombok & Sumbawa Islands: Part of Eastern Sunda arc



Geology & Mineralization of South Lombok Island





Rompo et al. (2012)

Porphyry:
- Brambang
- Selodong
- Lembar

HS Epithermal:
- Mencanggah
- Pelangan

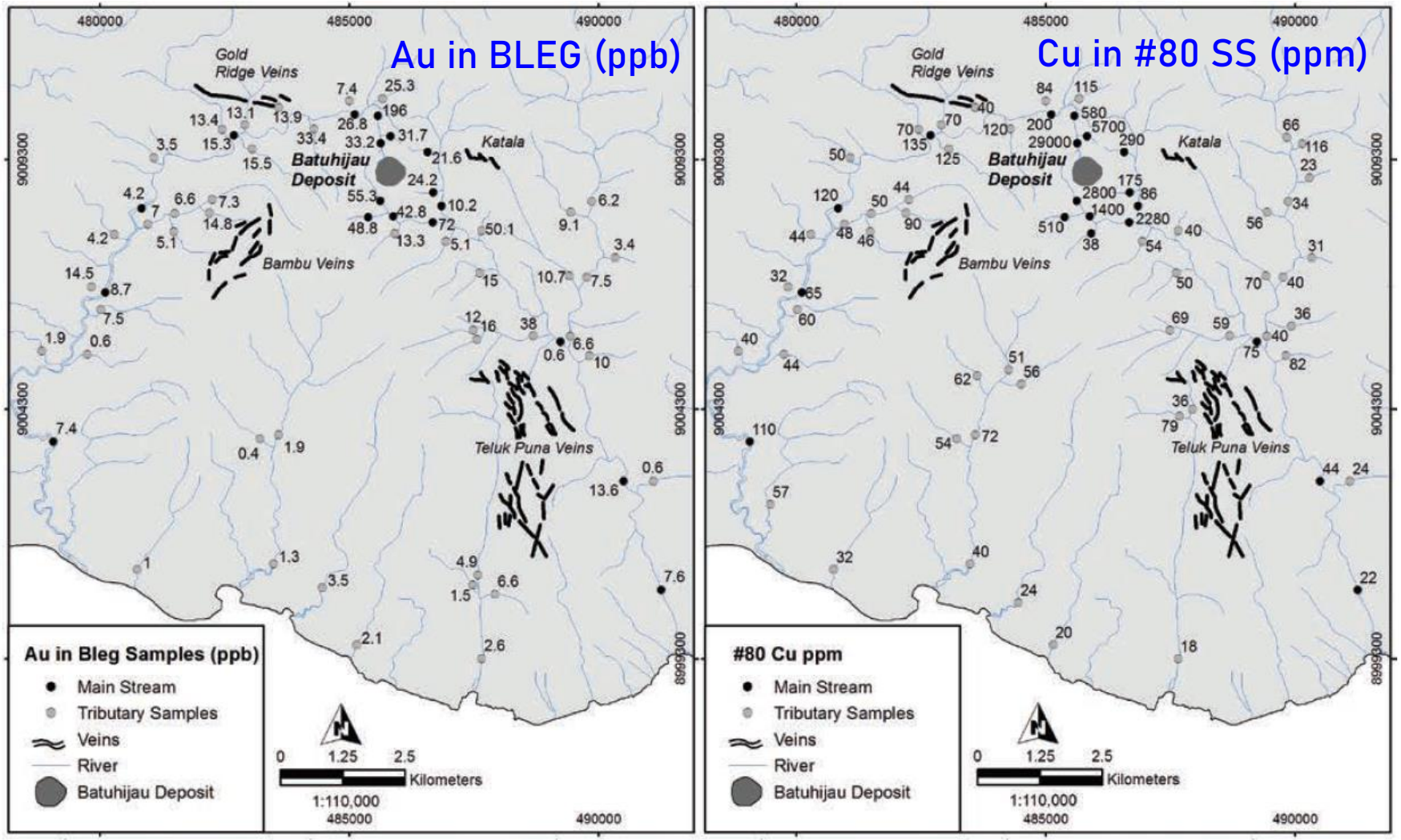
Skarn:
- Lembar
- Near Kelep

Batu Hijau, Sumbawa Island

Source: PT. Newmont Nusa Tenggara

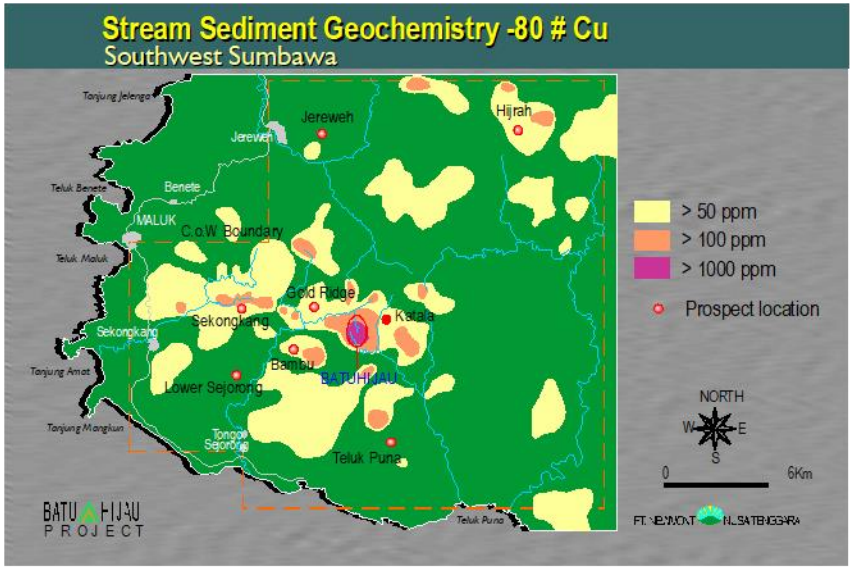
Batu Hijau: BLEG and Stream Sediment Geochemistry

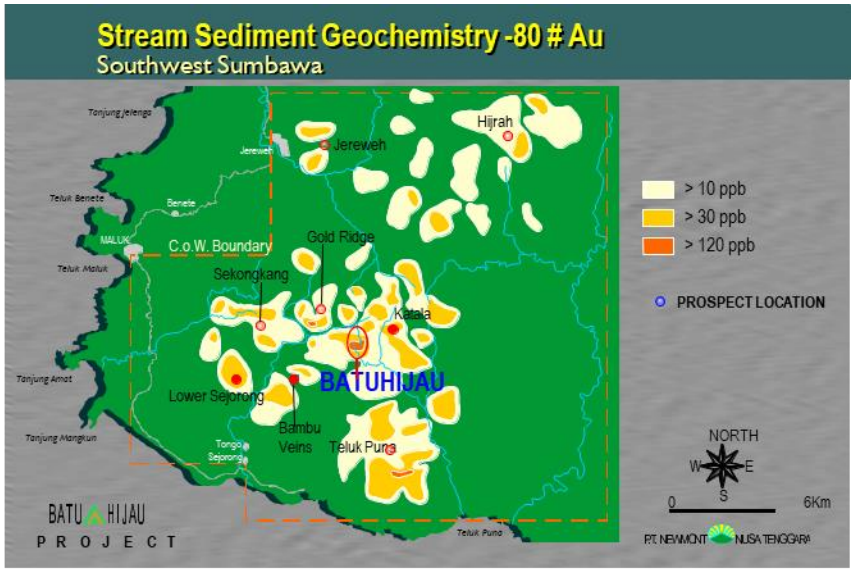
BLEG is one of powerful exploration methods for porphyry discovery

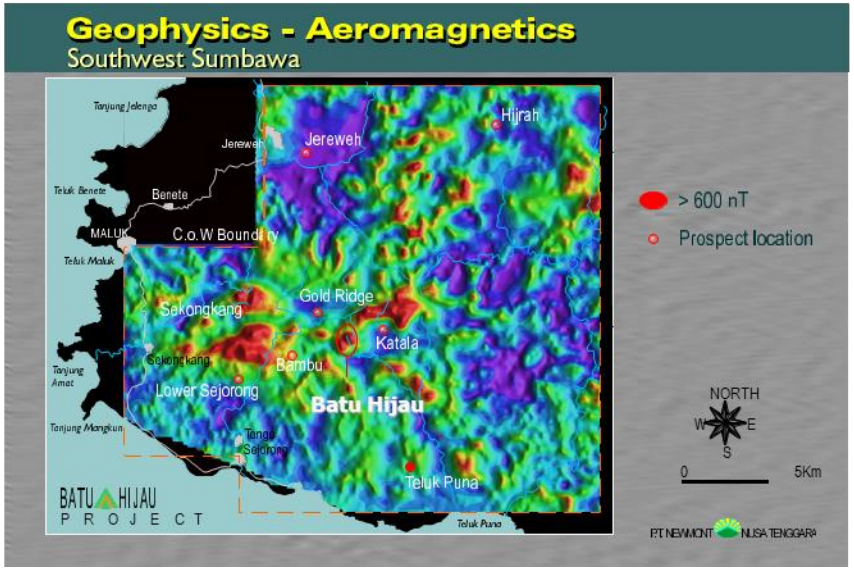


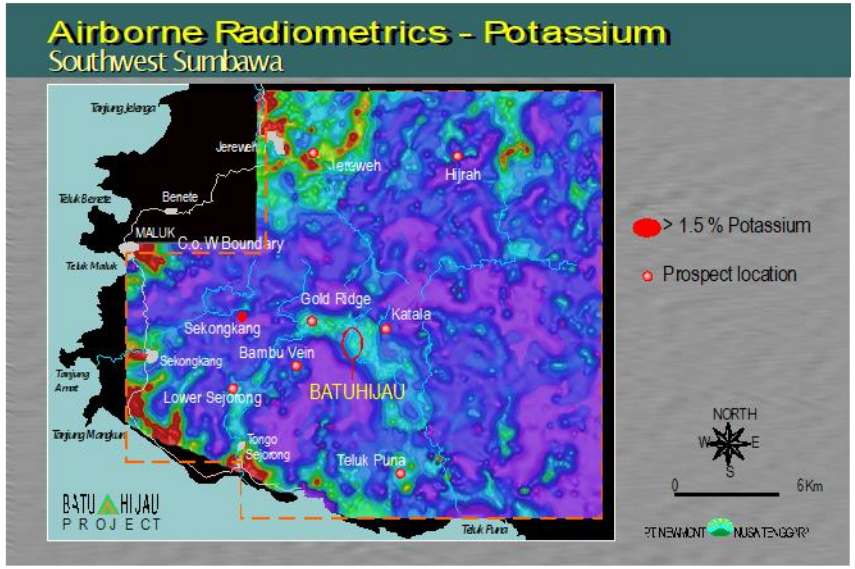
Maryono et al. (2018)

Batu Hijau: SS Geochemistry & Geophysics









Source: PT. Newmont Nusa Tenggara

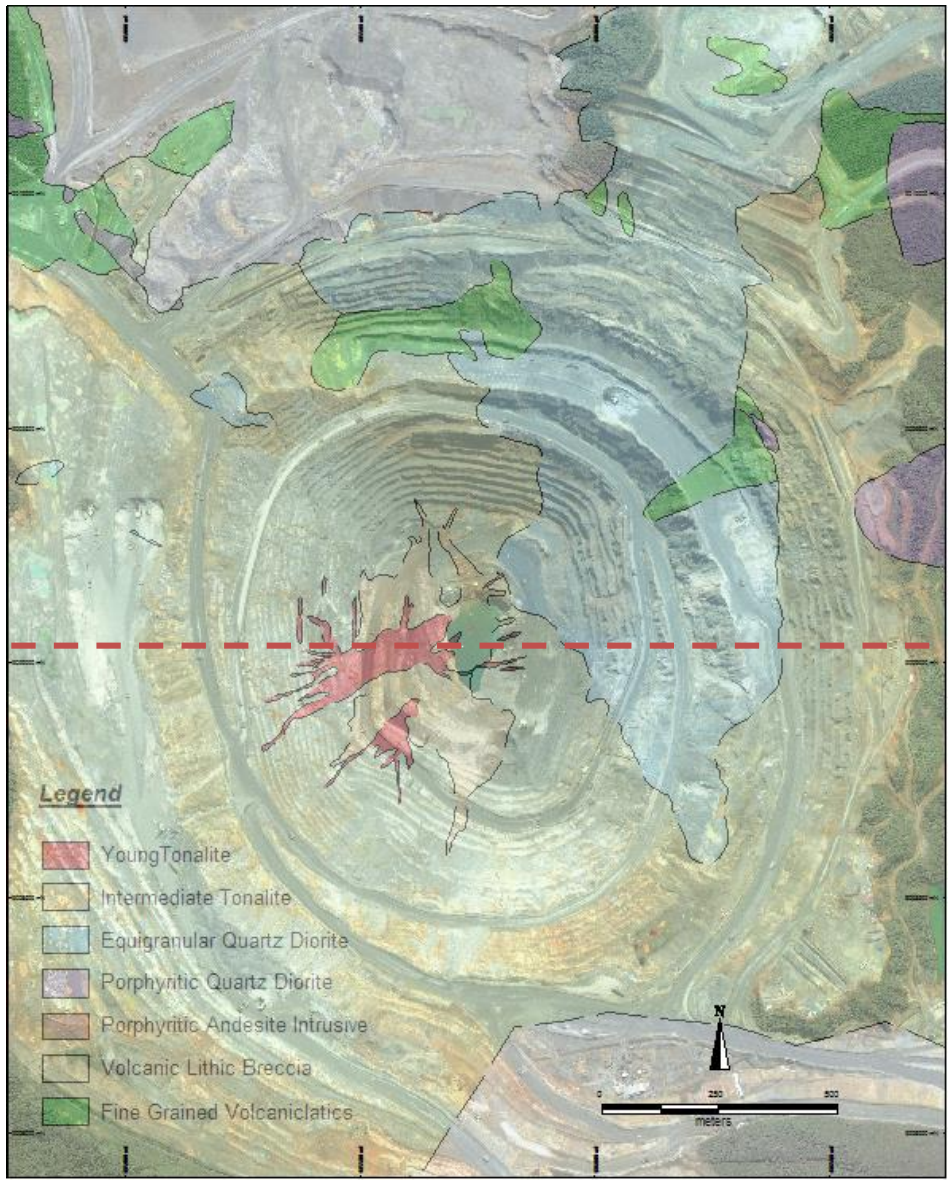
Batu Hijau

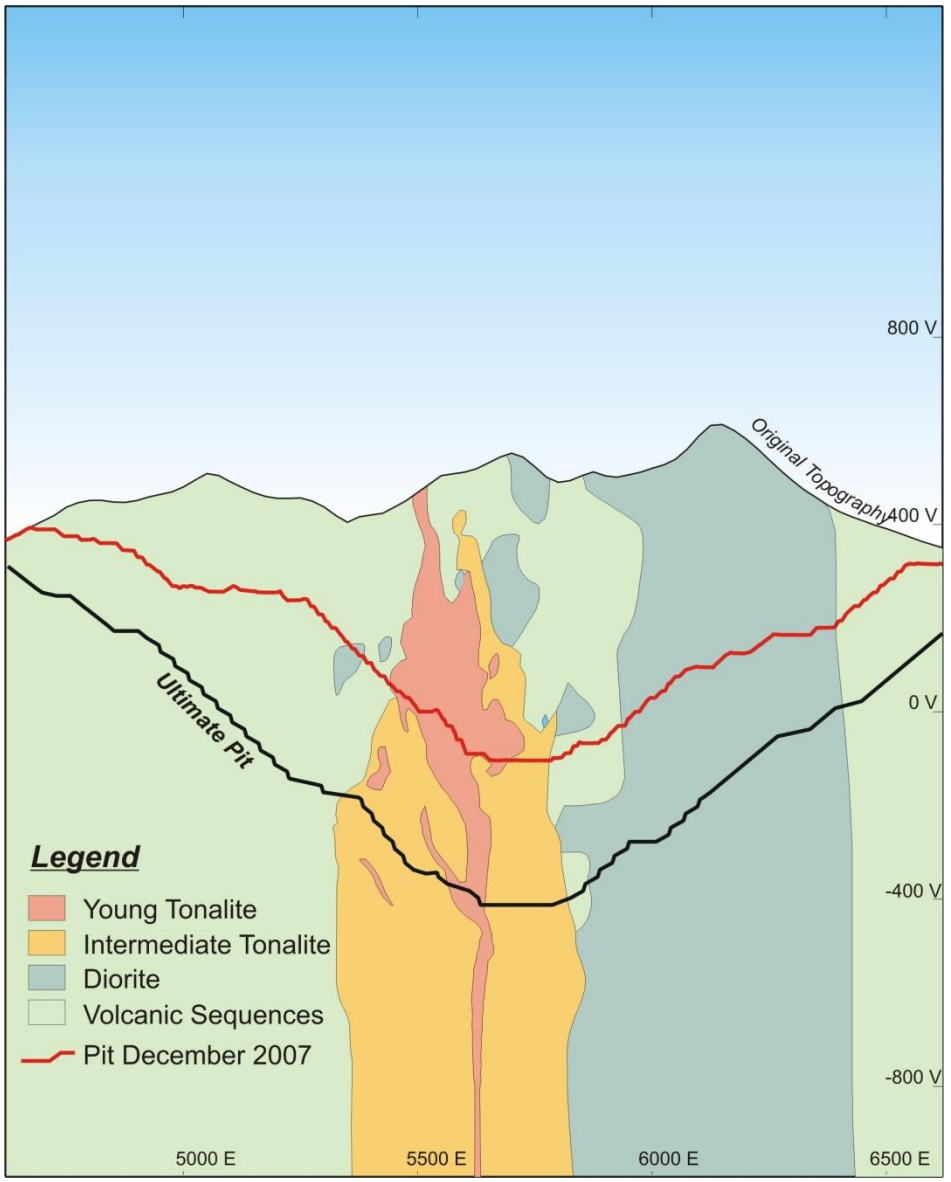
<u>April 1990</u>
Discovery of “Green Creek’ by prospecting. Found outcropping Cu oxides in quartz vein stockwork associated with Tonalite porphyry.

Batu Hijau 1990 (Discovered)

Source: PT. Newmont Nusa Tenggara

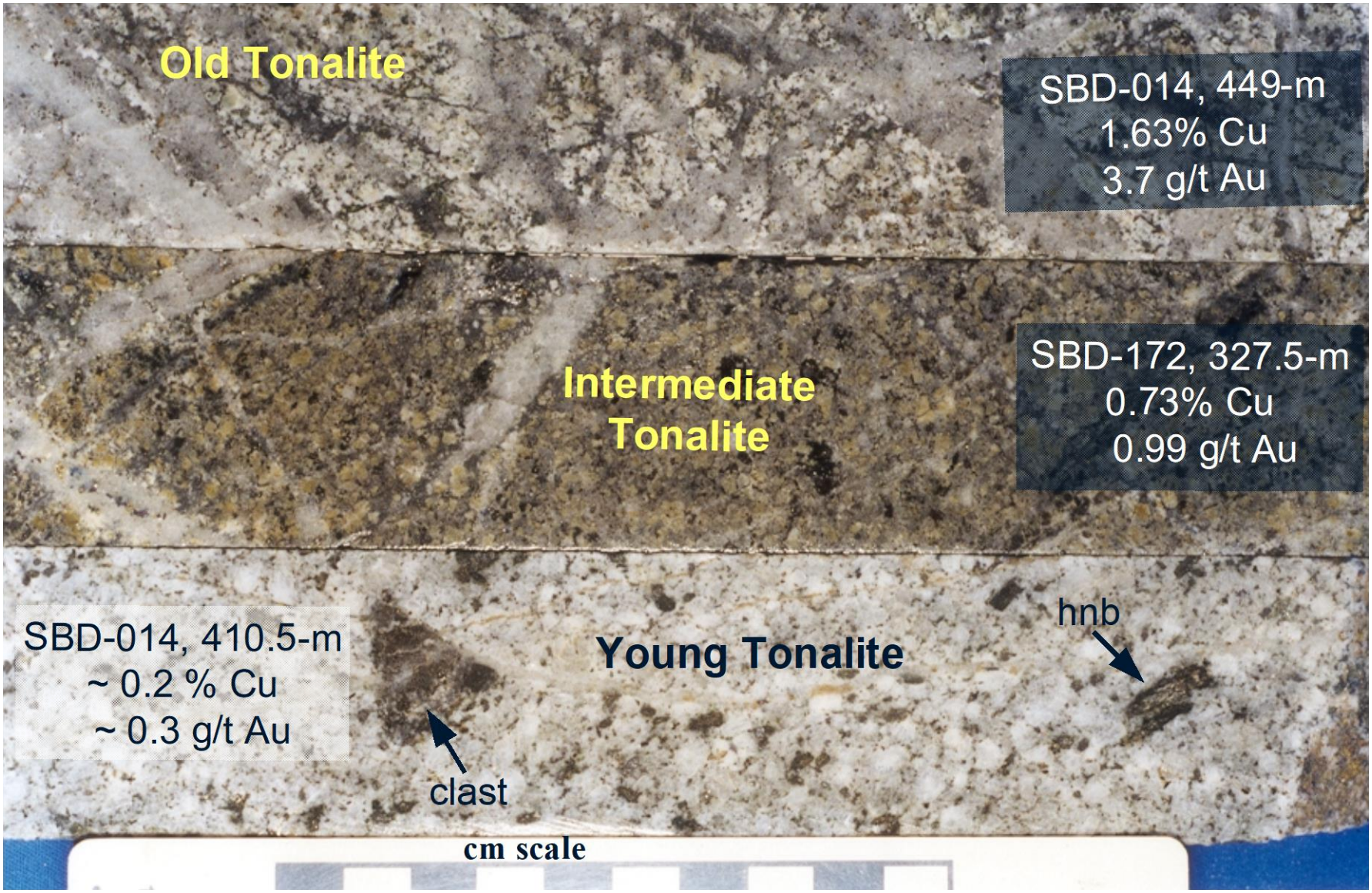
Batu Hijau: Deposit Geology





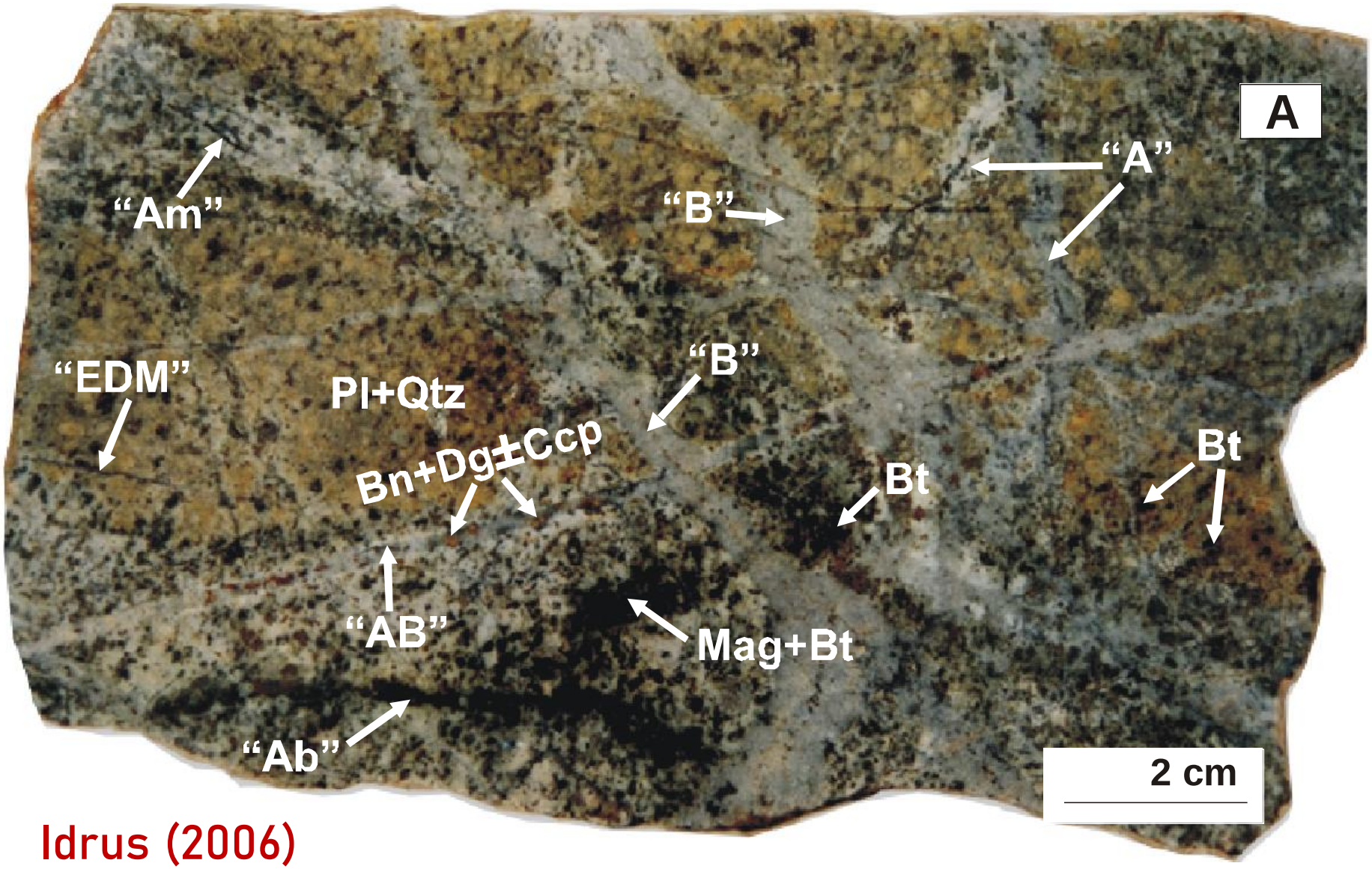
Source: PT. Newmont Nusa Tenggara

Batu Hijau: Causative Tonalite Porphyries



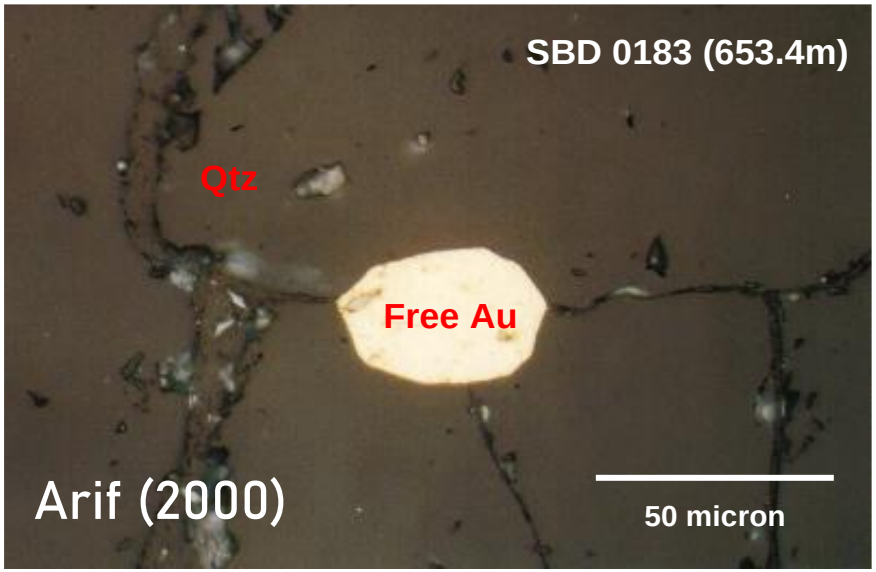
Source: PT. Newmont Nusa Tenggara

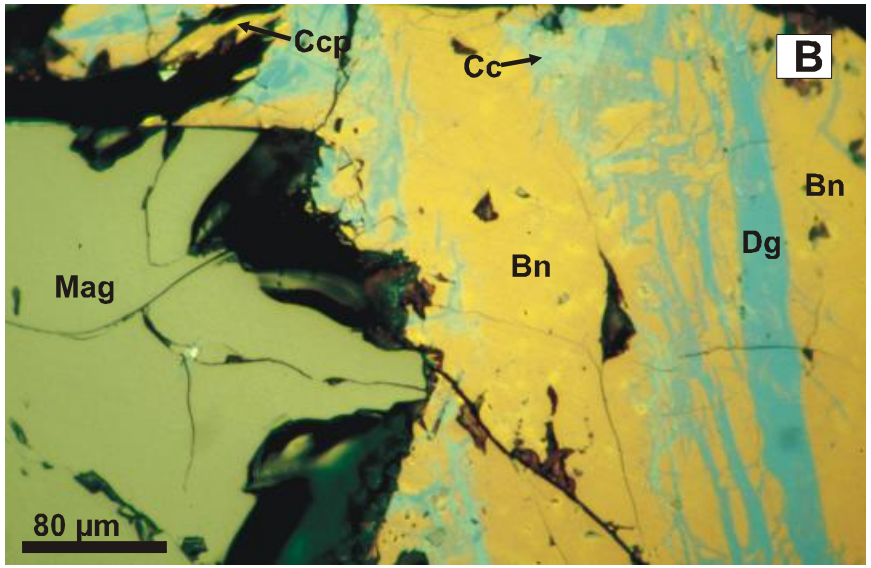
Batu Hijau: Stockwork System

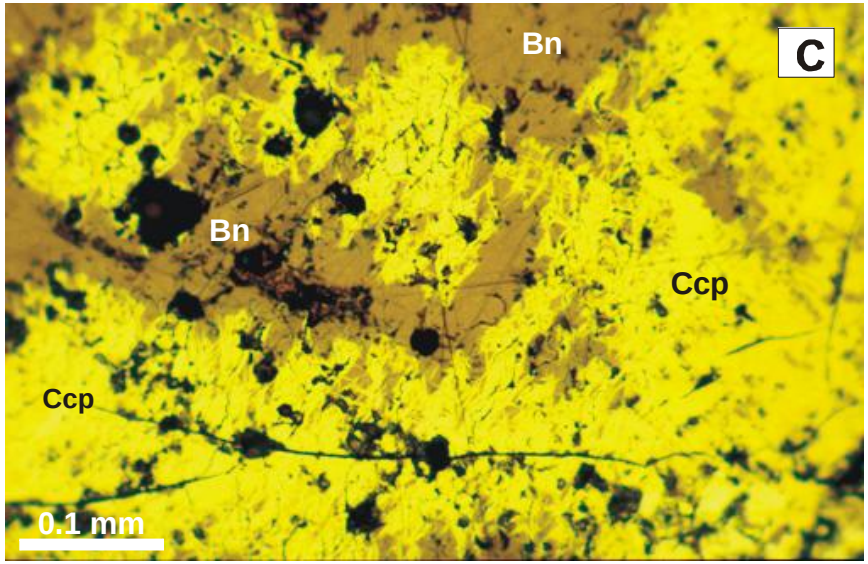


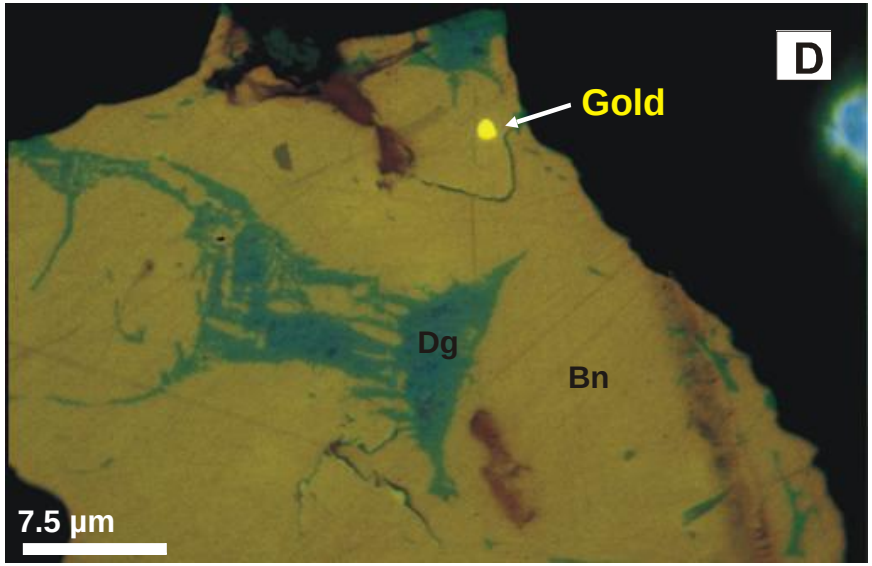
Idrus (2006)

Batu Hijau: Copper & Gold Deportment





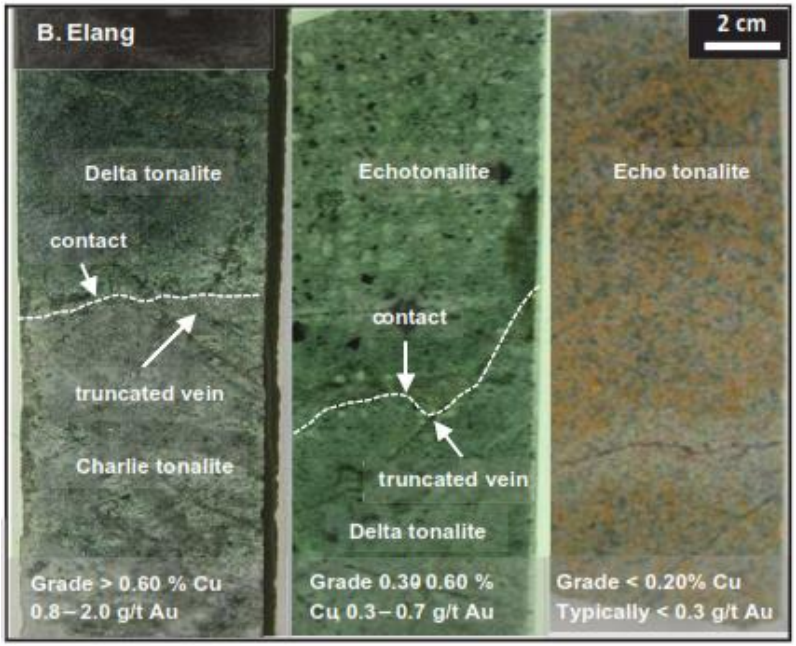




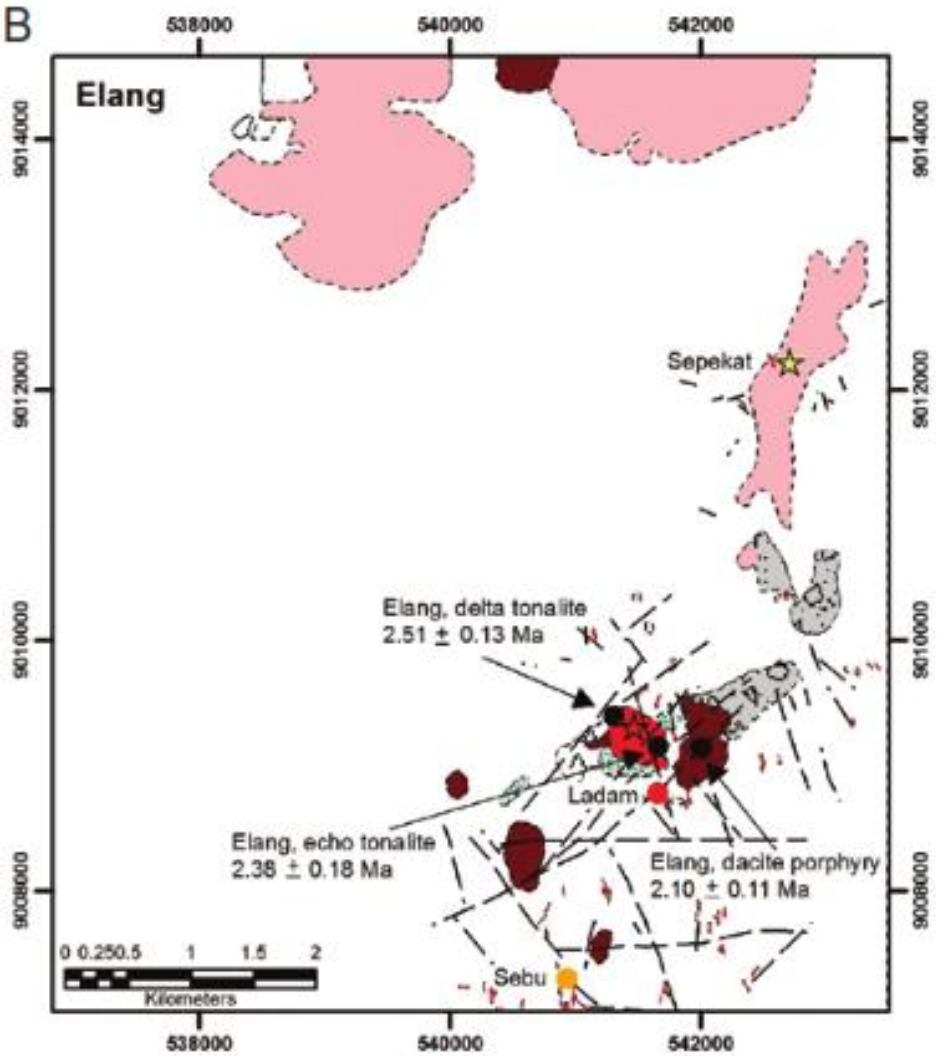
Idrus (2006)

Dodo-Elang: Another World-Class Porphyry

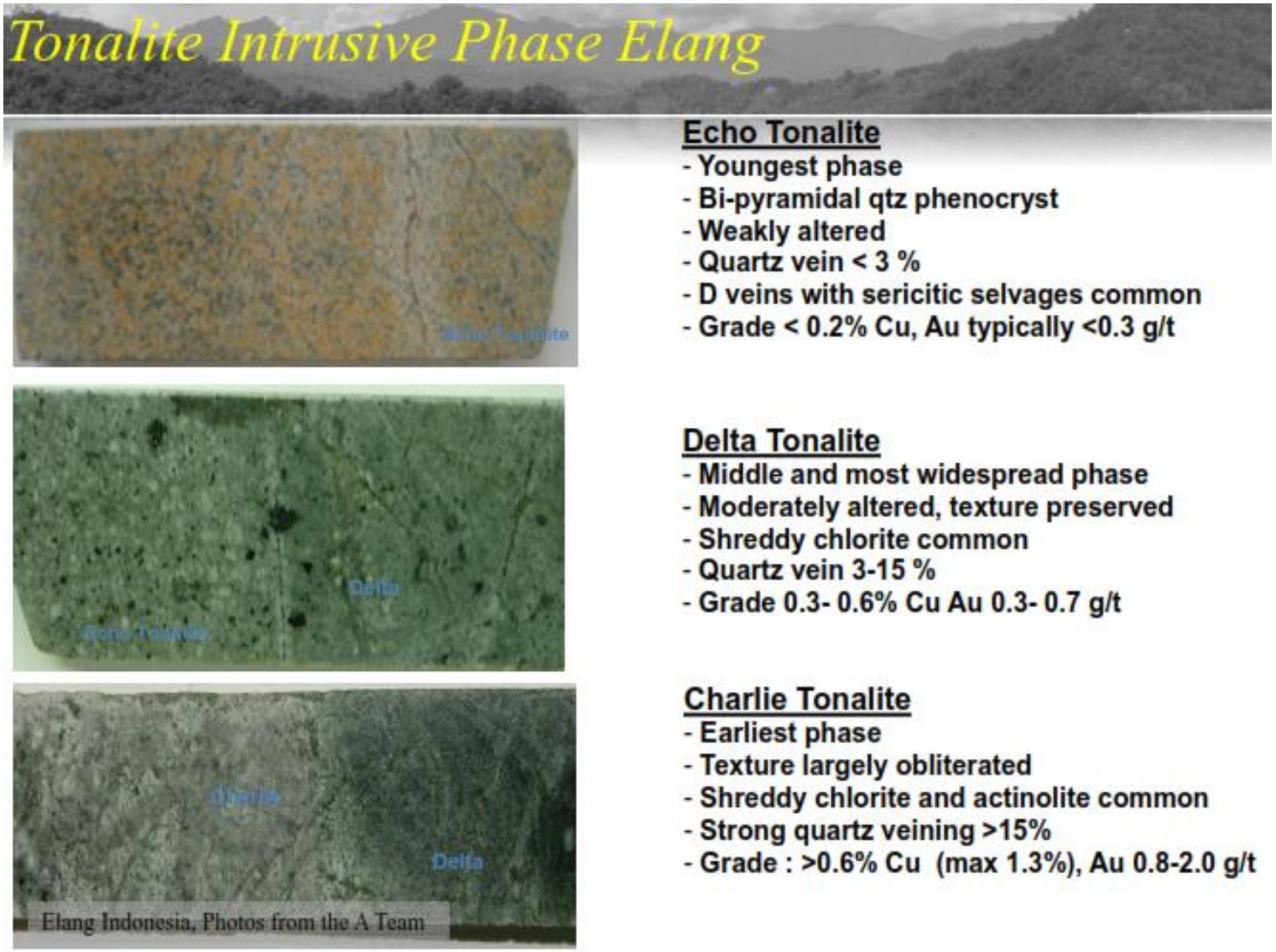
A world-class porphyry resource at Elang (789.1 t Au and 7.4 Mt Cu; Huspeni, 2012) was delineated 15 years after the discovery of the prospect (Maryono et al., 2005).



Maryono et al. (2018)



Dodo-Elang: Tonalite Porphyries



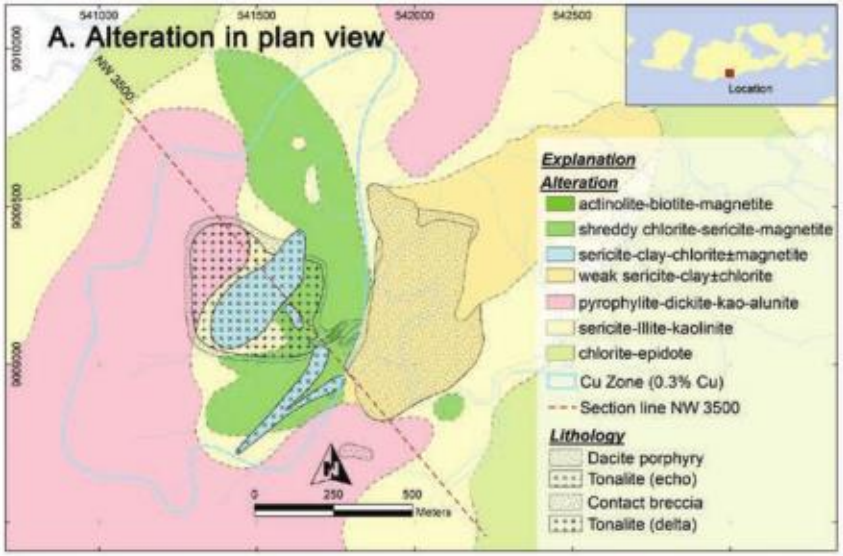
Echo Tonalite
- Youngest phase
- Bi-pyramidal qtz phenocryst
- Weakly altered
- Quartz vein < 3 %
- D veins with sericitic selvages common
- Grade < 0.2% Cu, Au typically <0.3 g/t

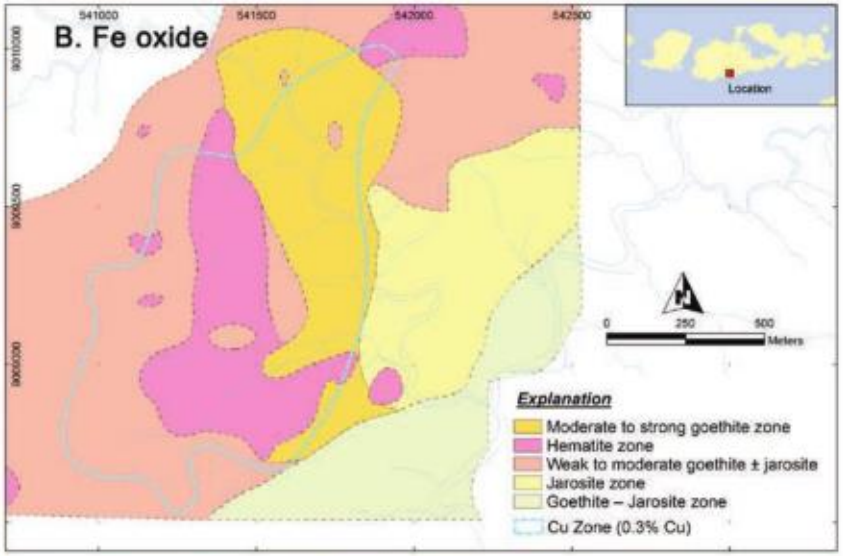
Delta Tonalite
- Middle and most widespread phase
- Moderately altered, texture preserved
- Shreddy chlorite common
- Quartz vein 3-15 %
- Grade 0.3- 0.6% Cu Au 0.3- 0.7 g/t

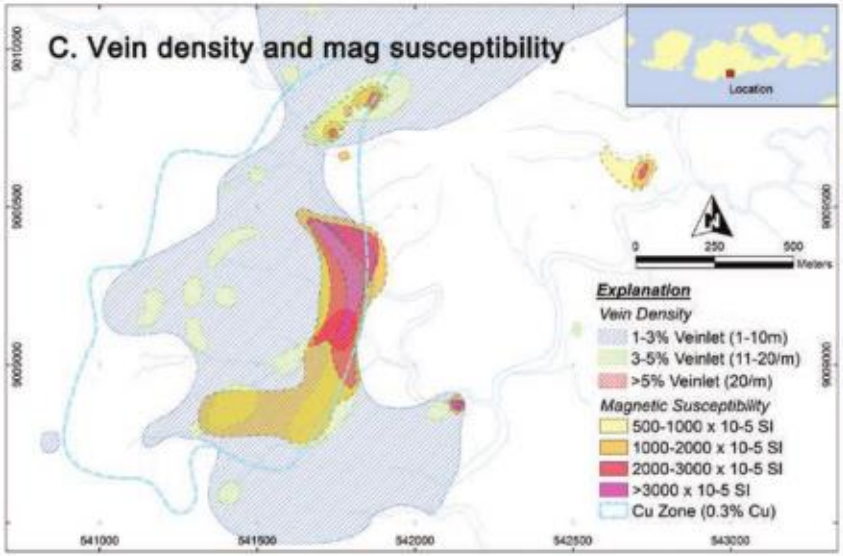
Charlie Tonalite
- Earliest phase
- Texture largely obliterated
- Shreddy chlorite and actinolite common
- Strong quartz veining >15%
- Grade : >0.6% Cu (max 1.3%), Au 0.8-2.0 g/t

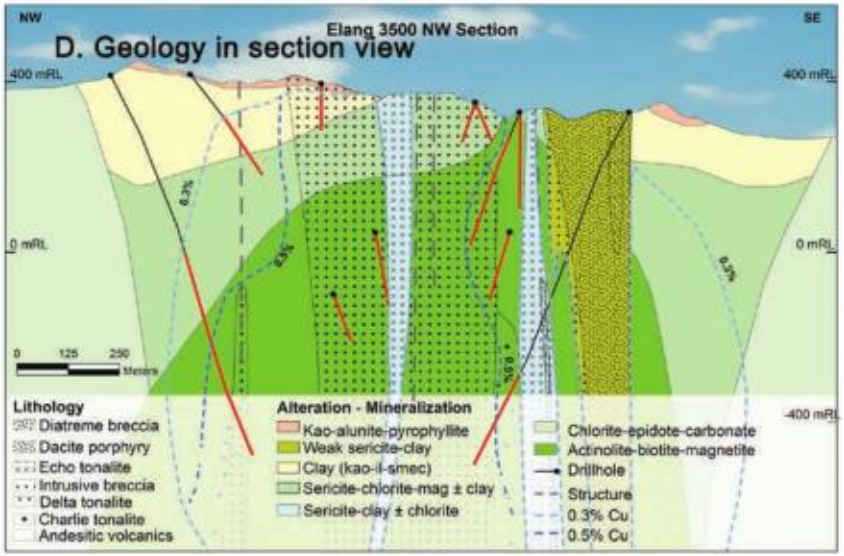
Maryono et al. (2018)

Dodo-Elang: Tonalite Porphyries



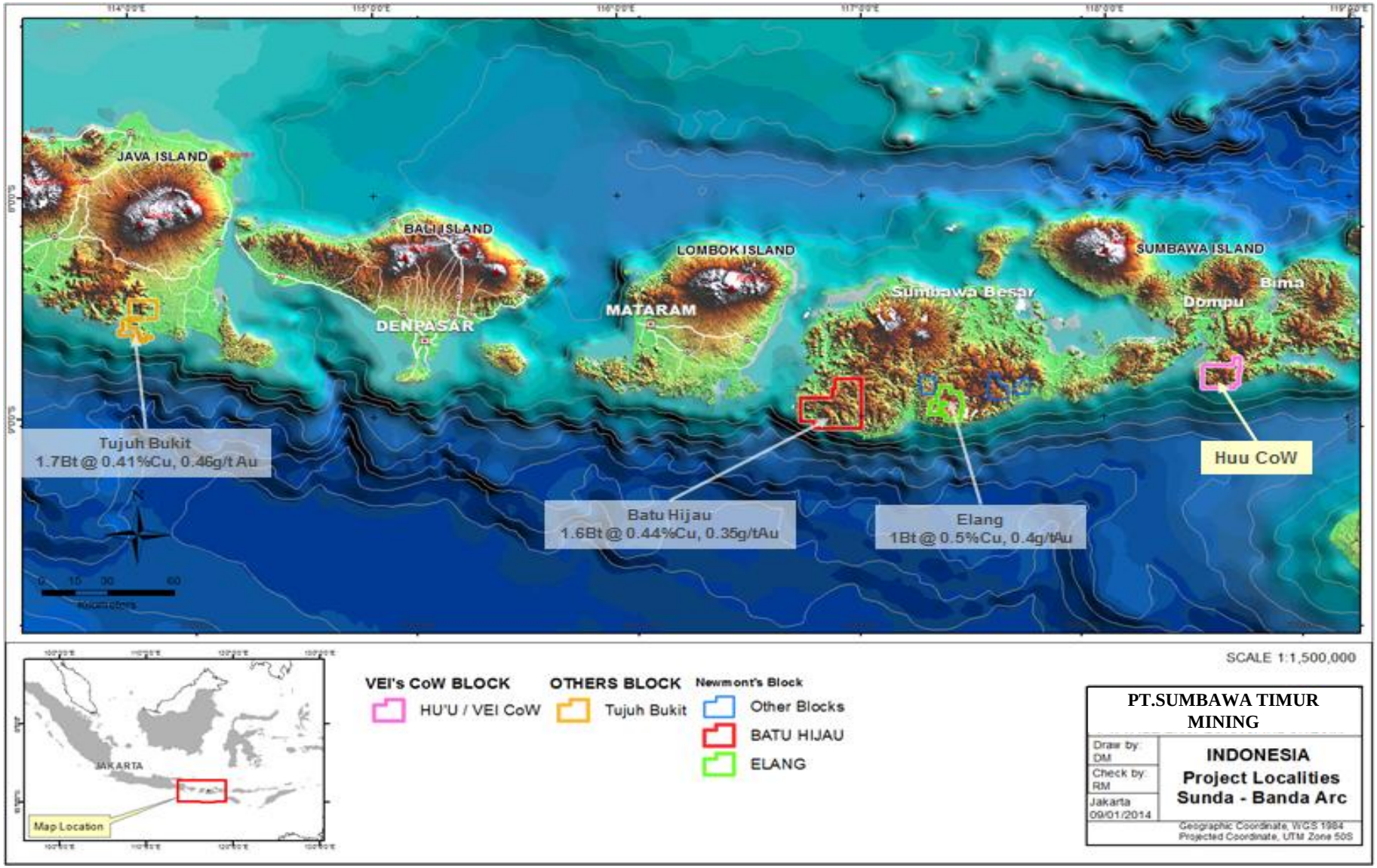






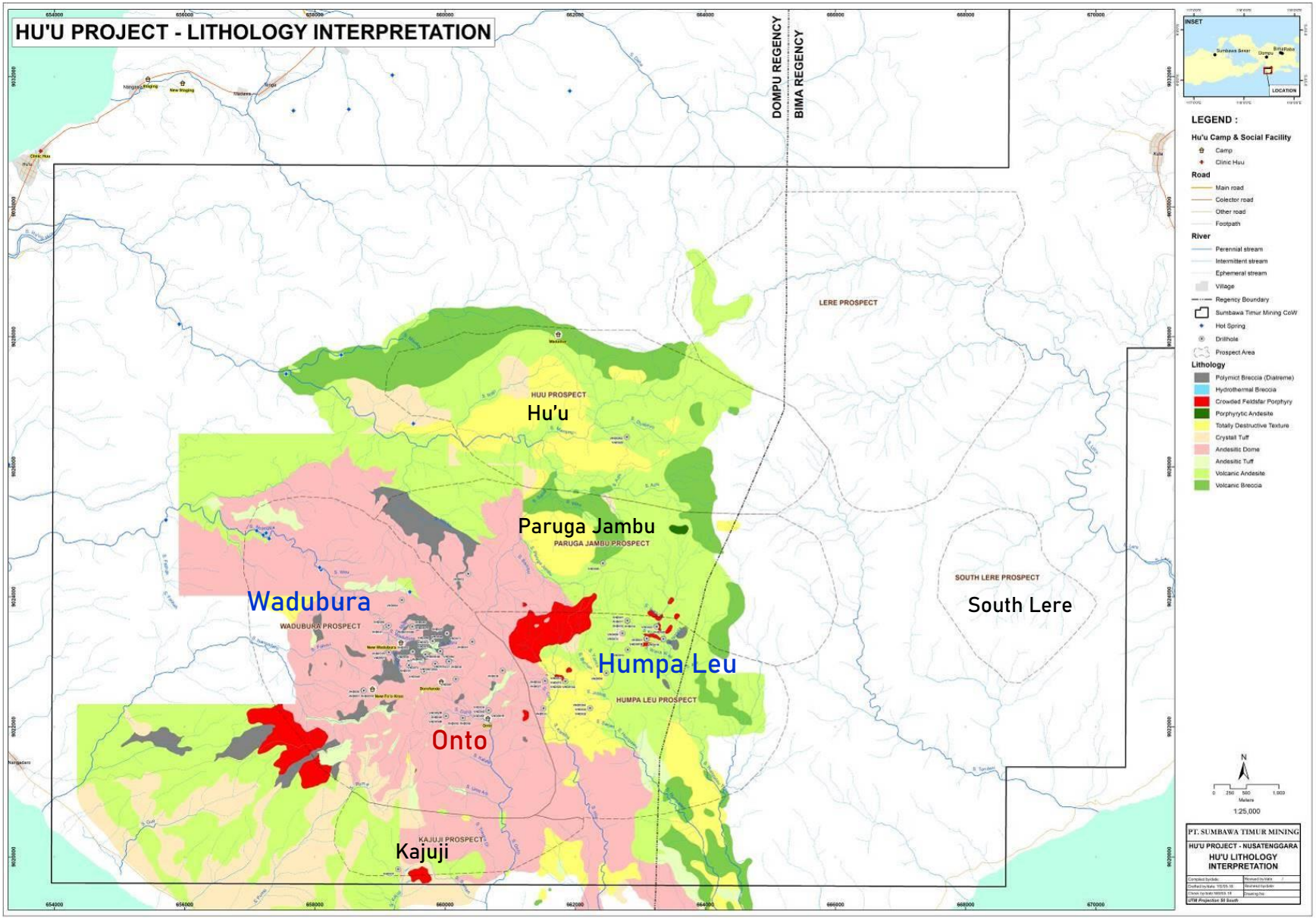
Maryono et al. (2018)

Hu'u (eastern Sumbawa Island)



PT. Sumbawa Timur Mining

Hu'u Prospects: District Geology



PT. Sumbawa Timur Mining

Hu'u Prospects: Lithostratigraphy & Age

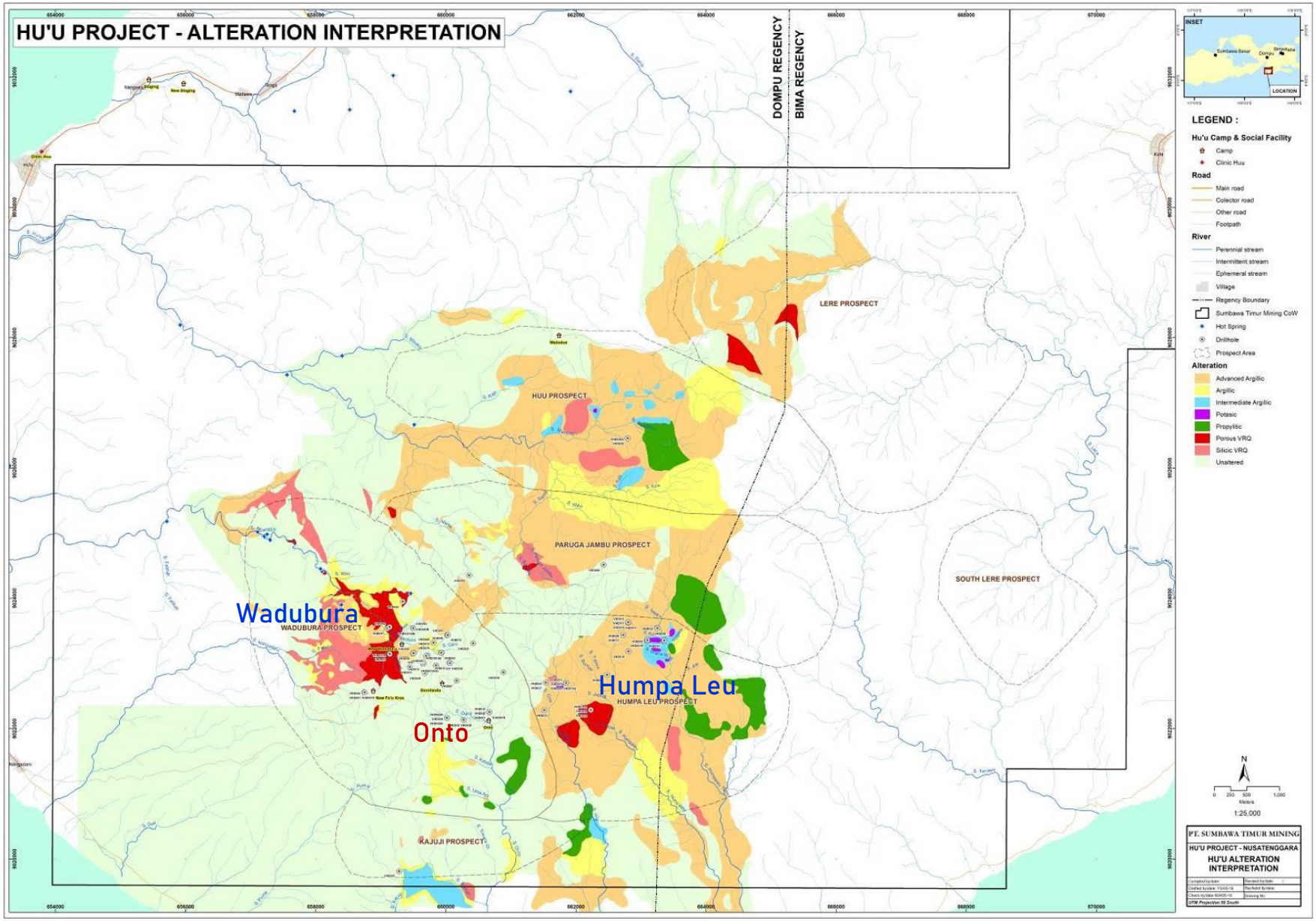
ERA	PERIOD			AGE Ma	LITHOLOGY UNIT	REMARKS	YOUNG INSTRUSIVE UNIT	
CENOZOIC	TERTIARY	HOLOCENE				Limestone at coastal		
		PLEISTOCENE	LATE	0.26		Crystal Tuff		
			MIDDLE			Andesitic Dome	Preathic Breccia	Qz Felds Por
				0.78		Andesitic Tuff		
			EARLY			Pyroclasstic Unit	Multiphase Dio. Por	
						Polemic Breccia		
						Old Andite		

Wadubura-Onto

Sample ID	156901	156902	1569903	156606	156904	
Lith Unit	Andesite Dome	Pyroclastic-USP	Polymic Breccia	USP	EIMP	EP
Average Age (Ma)	0.780 ± 0.063	0.772 ± 0.087	0.716 ± 0.081	0.850 ± 0.046	0.657 ± 0.075	0.526 ± 0.077
Range	1.2 to 0.4	1.2 to 0.2	1.5 to 0.1	1.1 to 0.4	1.4 to 0.3	1.4 to 0.2
Youngest with >1 zircon ages	0.5	0.3	0.3	0.6	0.4	0.3

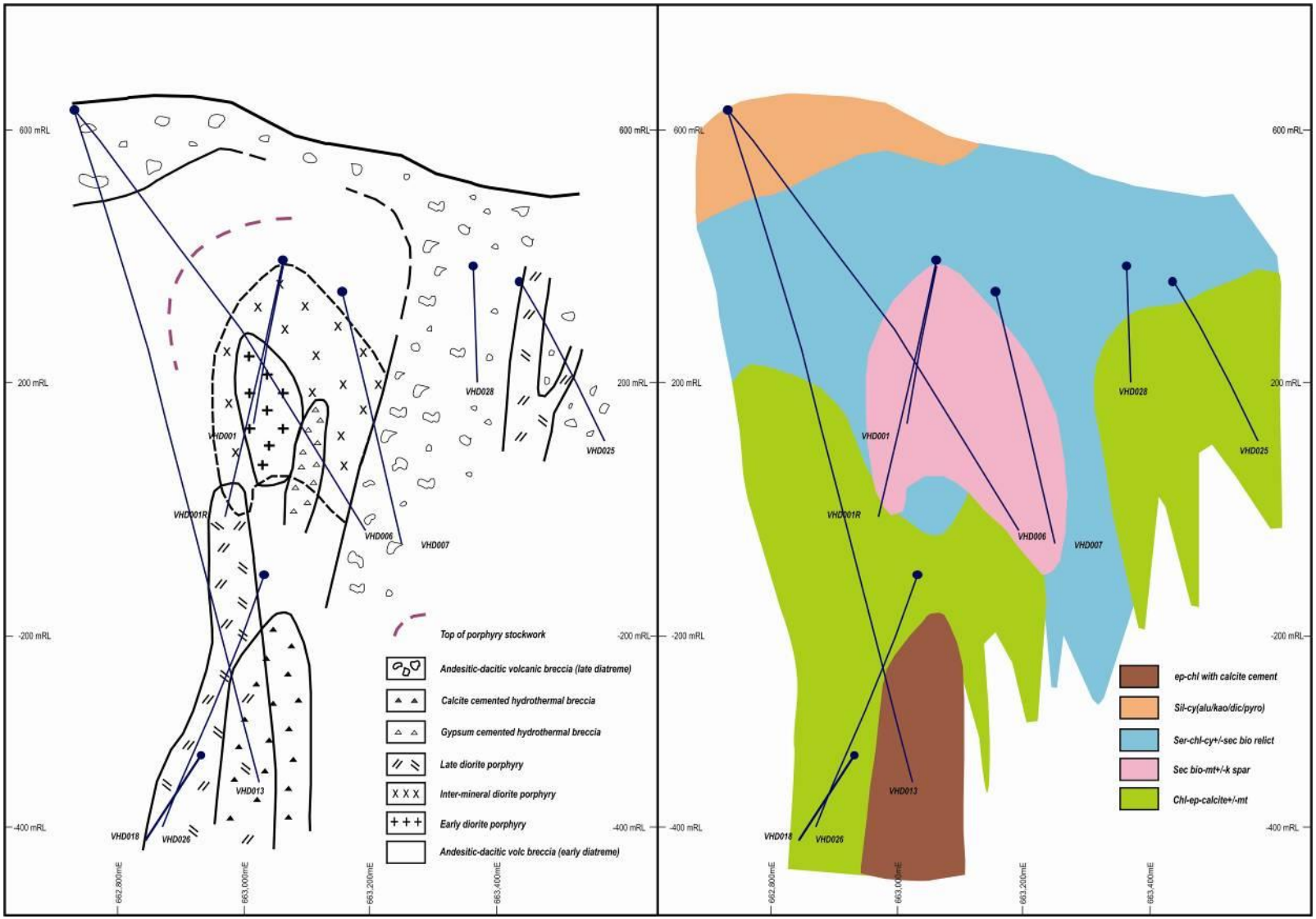
PT. Sumbawa Timur Mining

Hu'u Prospects: Hydrothermal Alteration



PT. Sumbawa Timur Mining

Humpaleu Prospect: Geology & Alteration



PT. Sumbawa Timur Mining

The Onto-Wadubura Cu-Au Porphyry:
One of the World Class Deposits in Hu'u Prospects

- The Onto-Wadubura deposit was discovered in August 2013.
- 64 diamond drill holes (equivalent to 61,000m) have been drilled
- Total Indicated resource of 0.76 billion tonnes (Bt) @0.93% Cu and 0.56 g/t Au.
- Total Inferred resource of 0.96 Bt @0.87% Cu and 0.44 g/t Au.
- This equates to a total resource of 1.7 Bt @0.89% Cu and 0.49 g/t Au.
- In addition to these resources, an exploration target of 0.6-1.7 Bt @0.2-0.7% Cu and 0.1-0.3 g/t Au has been defined surrounding the resource.

Press Release PT. Sumbawa Timur Mining, 19 February 2020

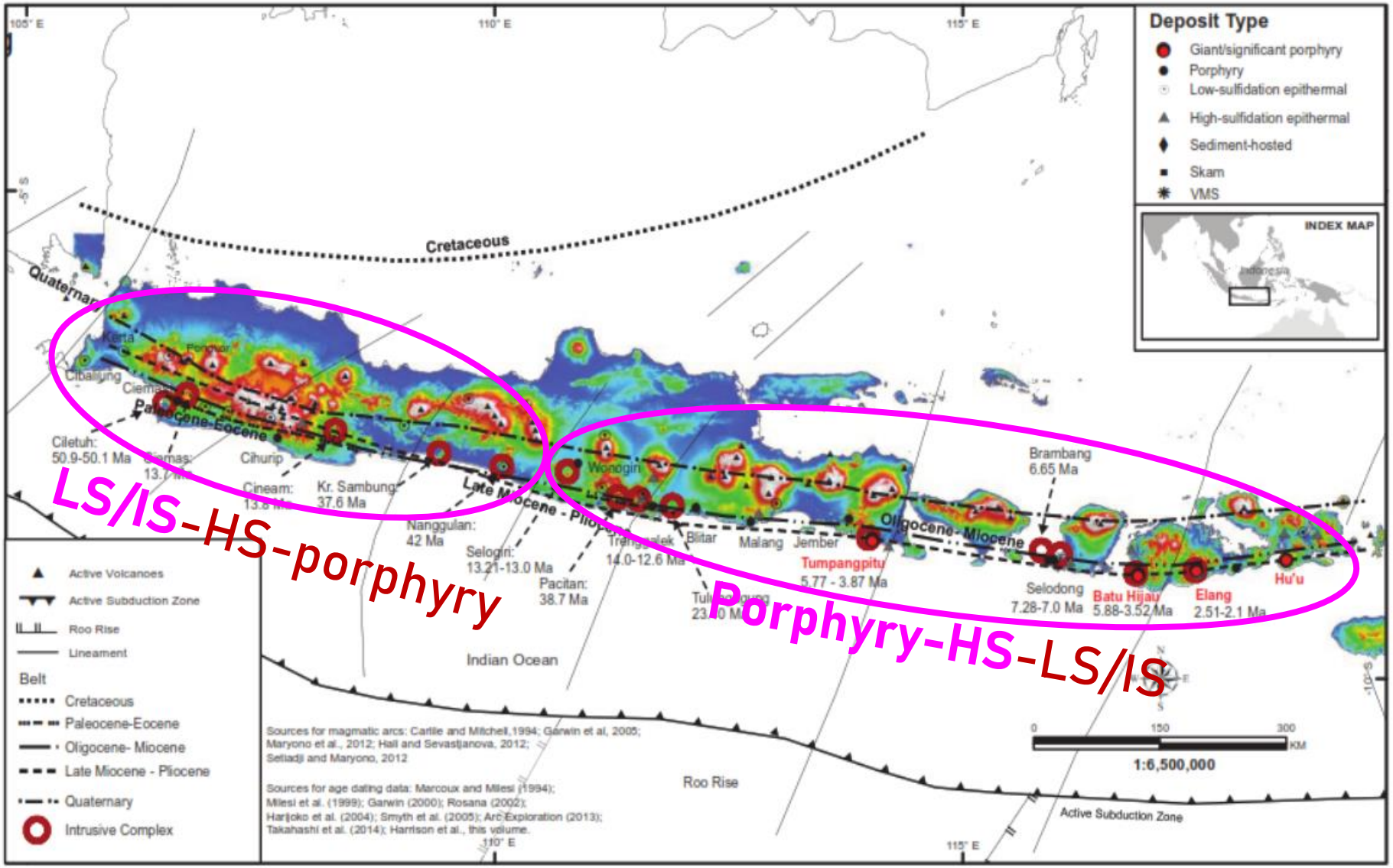
5. Implication for Future Exploration

What is Exploration?

- Exploration is an entire sequence of work ranging from reconnaissance (looking for a prospect) to the evaluation of the prospect and finally to the search for additional ore in a mine (Peters, 1979).

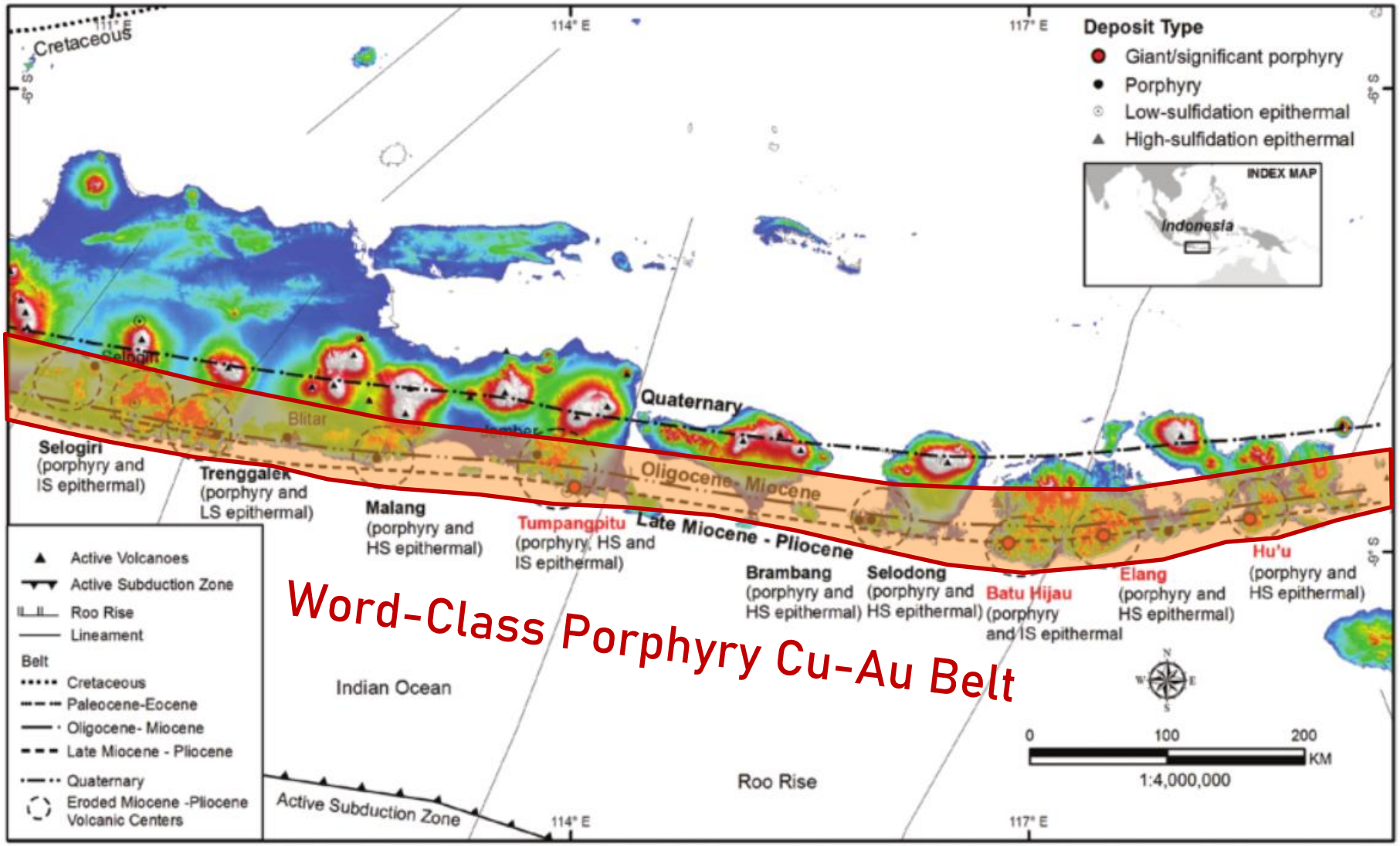
- Exploration Stages (Moon et al., 2006):
  1. Study phase: choice of potential target, supply & demand, commodity price, available markets, exploration cost, draw up budget.
  2. Reconnaissance: remote sensing, selecting areas, initial fieldwork, land acquisition, airborne surveys, geological mapping and prospecting, geochemical and geophysical surveys, and limited drilling
  3. Target testing: detailed geological mapping and detailed geochemical and geophysical surveys, trenching and pitting, drilling
  4. Pre-feasibility: major sampling and test work programs, pilot metallurgical test, business issues.
  5. Feasibility study: confirms and maximizes the value of the preferred technical and business option identified in the prefeasibility study

5. Implication for Future Exploration



Maryono et al. (2018)

5. Implication for Future Exploration



Maryono et al. (2018)

6. Closing Remarks

- Major and world-class copper-gold porphyries and (also) HS epithermal gold prosepects are discovered in central to east parts of eastern Sunda magmatic arc from central Java, Lombok Island to east Sumbawa Island.
- Those may imply that the discovery of other porphyry and HSE prospects along eastern Sunda magmatic arc is still open.

6. Some Guidance…

- Delineation of Pliocene-Pleistocene volcanic complexes with nested multiphase small intrusion centers is a key selection criterion for discovering a fertile district.
- The productive porphyry districts are associated with large lithocaps (>20 km2) and post-mineralization diatreme breccia bodies.
- Mapping the spatial locations and density of mineralized porphyry clasts in the diatreme breccia bodies provided an excellent exploration tool for targeting mineralized porphyry at depth.
- Delineation of the lateral surface extent of lithocaps and understanding their internal alteration zoning is crucial, as they may be used as a proxy for the size of the underlying mineralized porphyry intrusions.
- Geochemical and geophysical surveys have been successfully employed in the discovery of porphyry deposits.

Maryono et al. (2018)