Trace Element Geochemistry of Chalcopyrites and Pyrites from Golpu and Nambonga North Porphyry Cu-Au Deposits, Wafi-Golpu Mineral District, Papua New Guinea

STAR 2016:

The Pacific Islands Science, Technology and Resources Conference

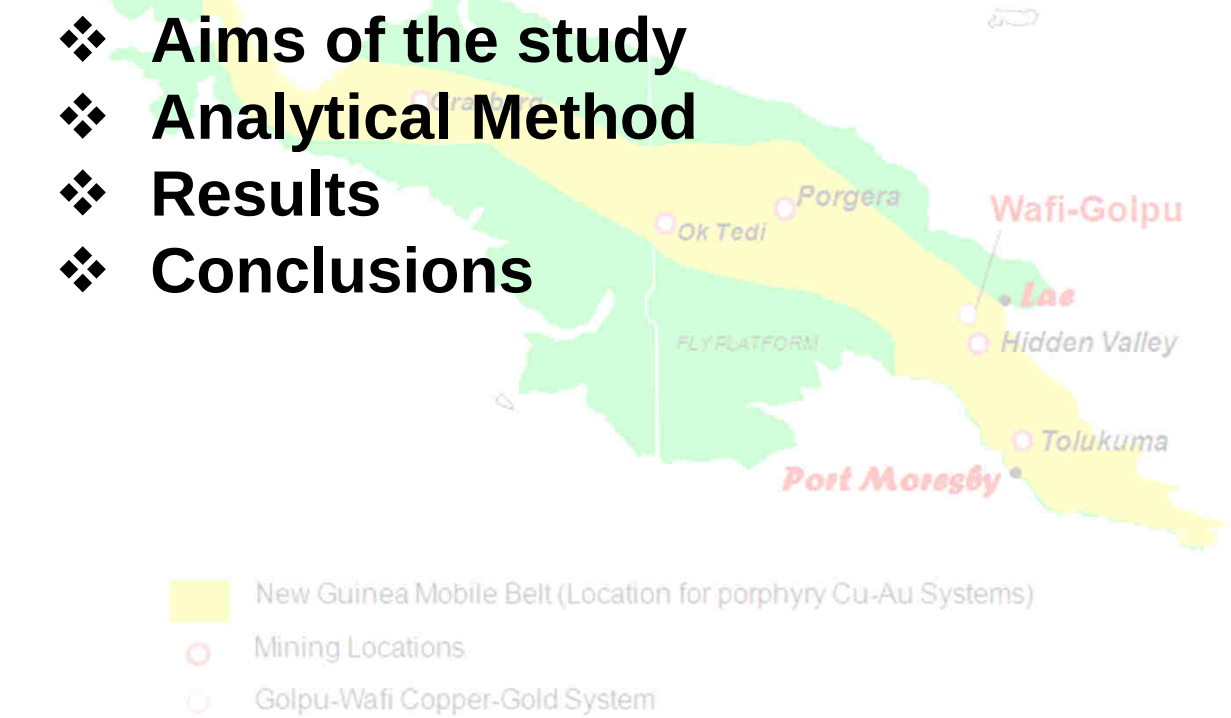
8 June 2016

Tanoa International Hotel, Nadi, FIJI

Moira Lunge – *Geologist (MSc)*
Geological Mapping and Mineral Exploration Branch
Geological Survey Division, Mineral Resources Authority
PAPUA NEW GUINEA

Outline

- Background
- Project Location
- Tectonic Setting
- Aims of the study
- Analytical Method
- Results
- Conclusions



Background

❖ Thesis Title: **"A Mineralogical, Geochemical And Geochronological Study Of The Golpu and Nambonga North Porphyry Copper-Gold Systems, Wafi-Golpu Mineral District, Papua New Guinea"**

❖ **Funded by the European Union under the Mining Sector Support Program "Geomap Project"**

❖ **Study was undertaken in collaboration with the Technical University of Clausthal (TUC), Germany affiliated through the University of Papua New Guinea (PNG)**

Acknowledgements

- **Dr Joseph Espi** *(supervisor, former Earth Science Division lecturer, UPNG)*
- **Professor Bernd** Lehmann *(co-supervisor , TUC, Germany)*
- **Professor Hugh Davies** *(co-supervisor, UPNG)*
- **Mr Leonard Cranfield** *(co-supervisor, former GSD, PNG)*
- **Dr Zhaoshan Chang** (*assessor*, School of Earth and Environmental Sciences, James Cook University)
- Staff of Earth Science Division, UPNG
- Staff of Institute of Mineral Resources, *TUC, Germany*
- ***Dr Fritz Bandelow*** *of the"Geomap Project" and his team*
- *Mineral Resources Authority Management (**Mr Philip Samar and team**)*

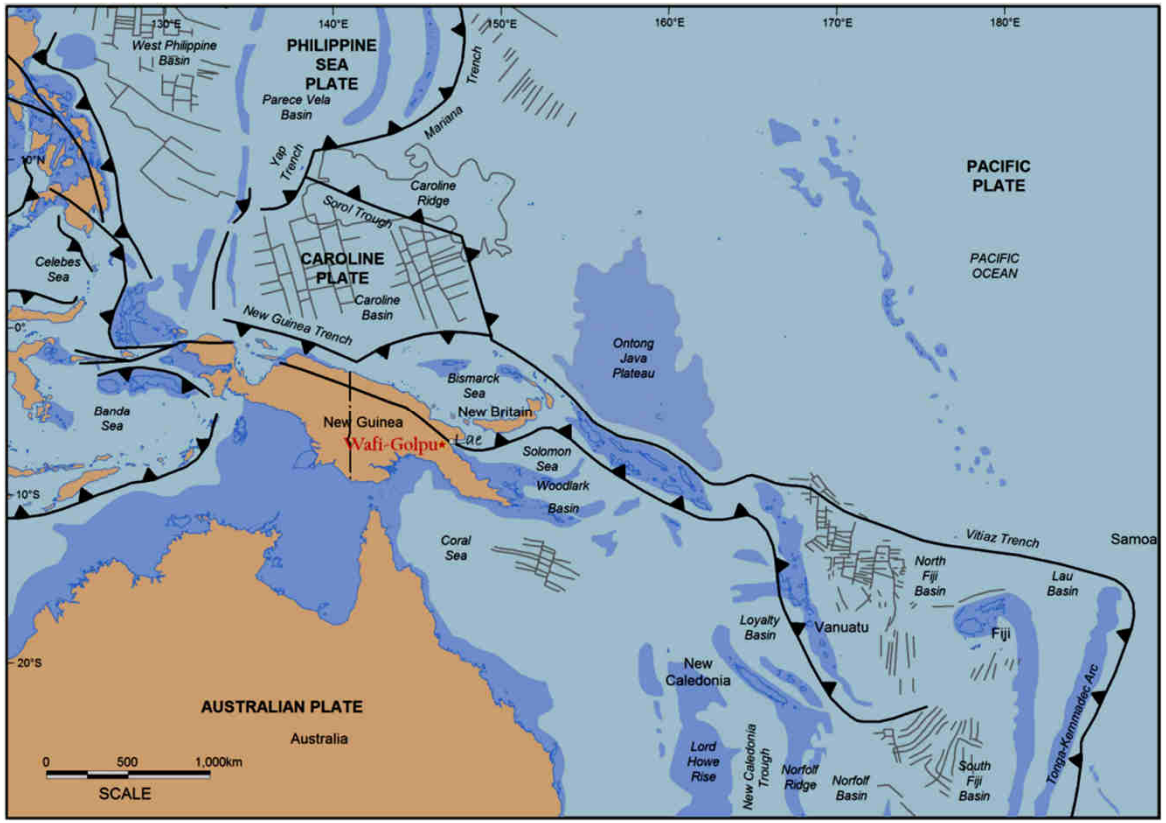
Project Location

- 293 km NNW of Port Moresby and 60 km SW of Lae
- 70 km NNE of Hidden Valley Au mine

Tectonic Setting

- ❖ unique, protracted geotectonic history because of the complexity of the terranes that comprise sialic continental crust, volcanic island-arcs and oceanic micro-plates

- ❖ located between the continental Indo-Australian plate in the south and oceanic Pacific plate in the north and northeast

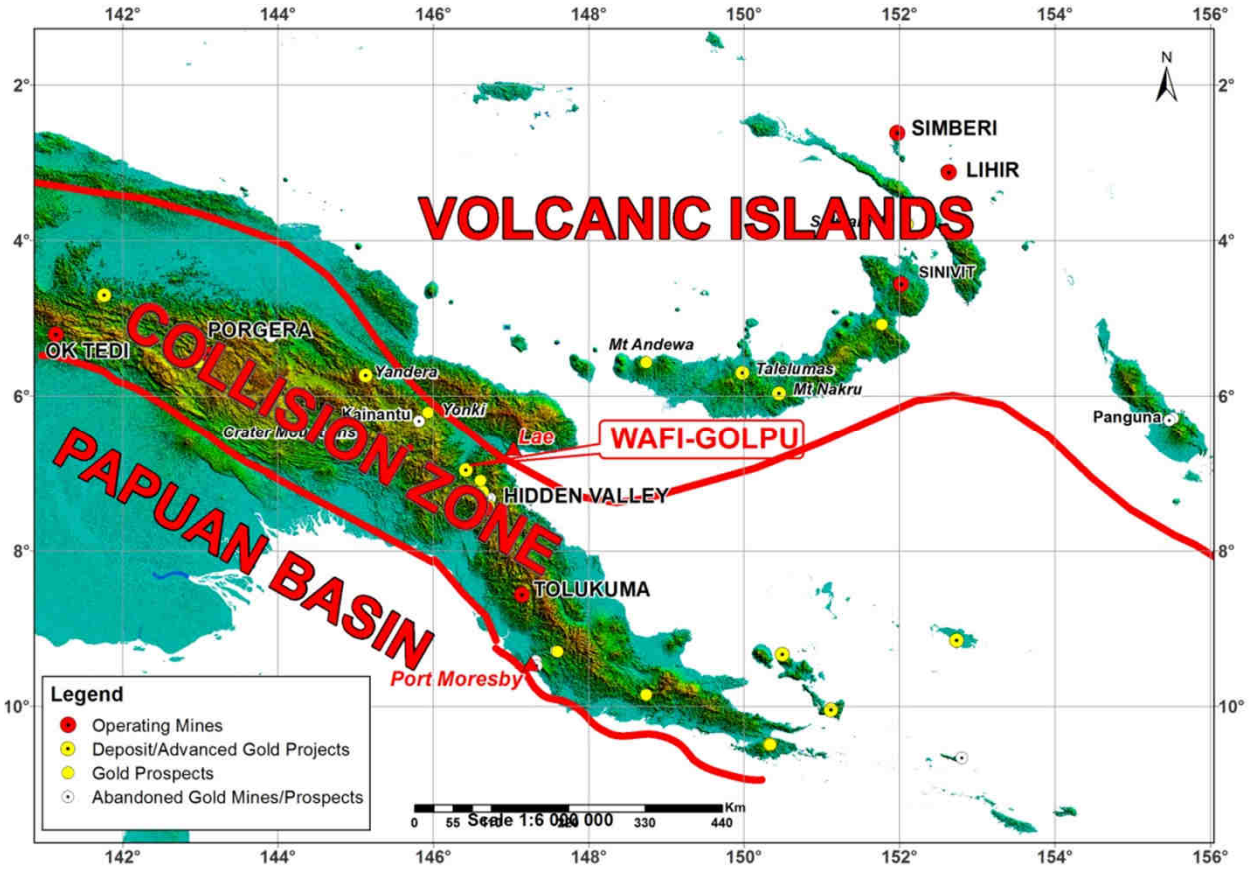


Three main geologic provinces:

1. Australian Craton (Papuan Basin)

2. New Guinea Orogen (Collision Zone)

3. Melanesian Arc (Volcanic Islands)

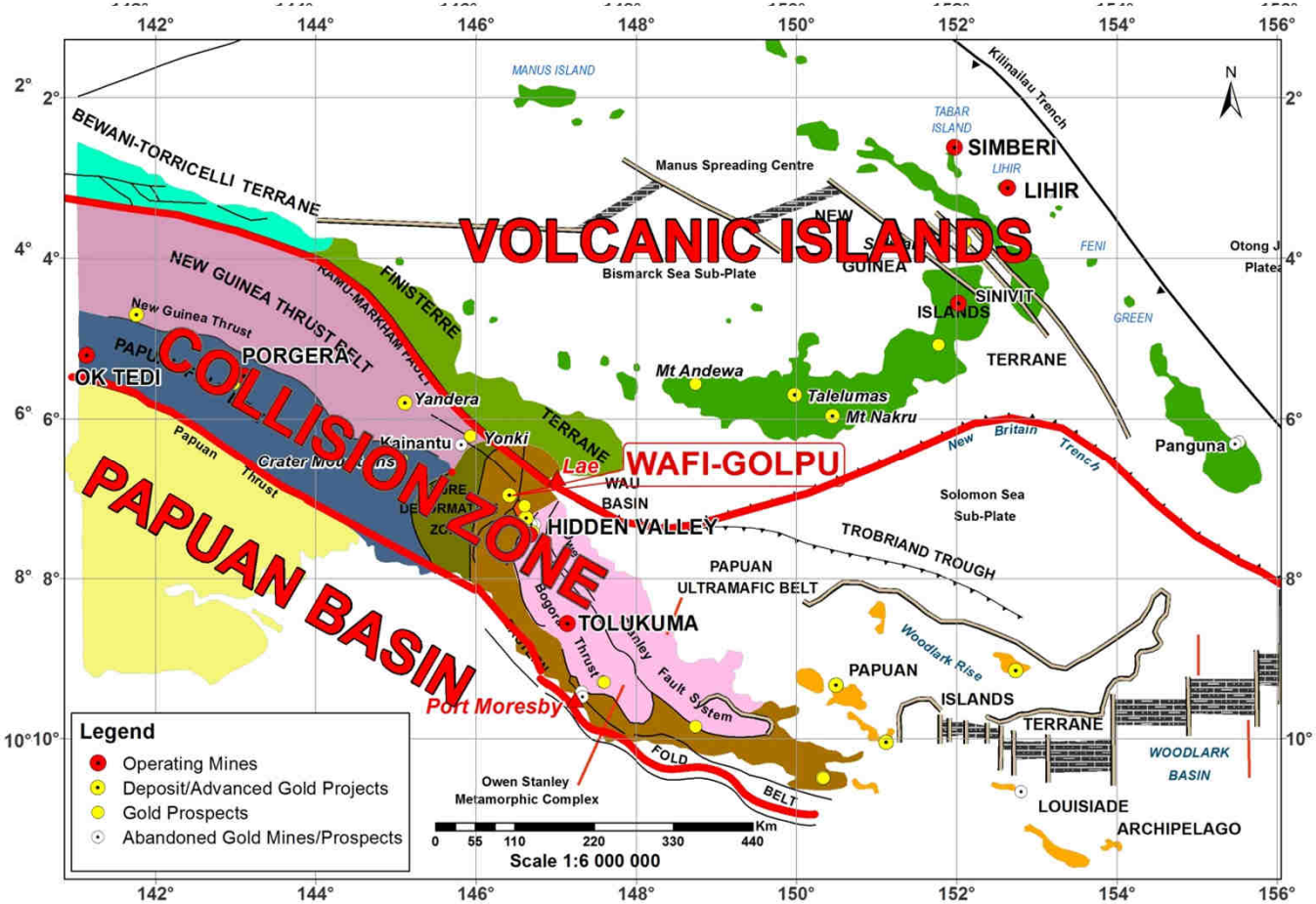


❖ New Guinea Orogenic Belt (Collision Zone)

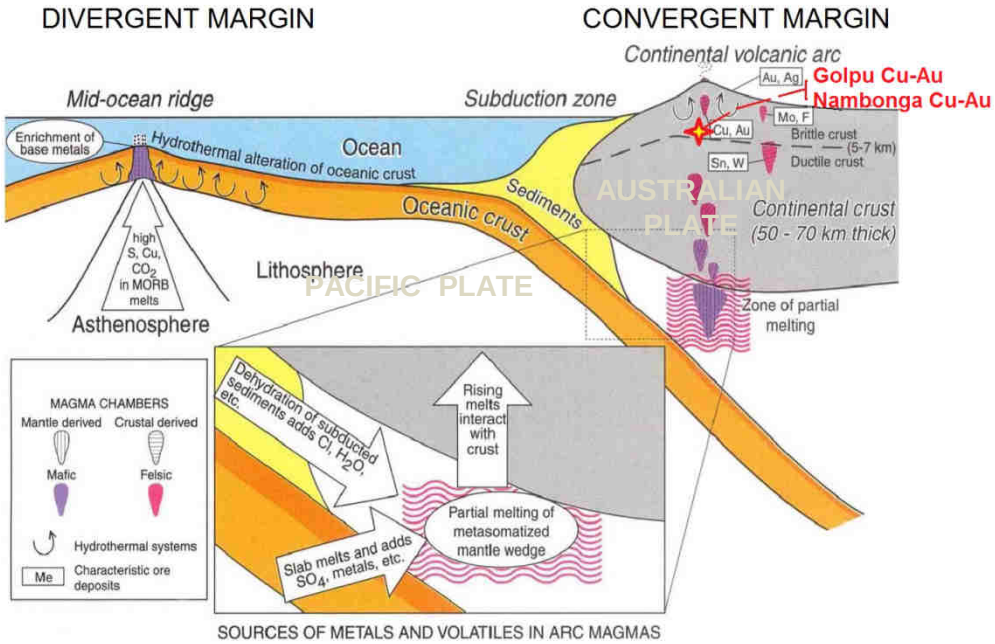
❖ Built by successive collisions of fragments of lithosphere. Some are continental fragments and some were volcanic island arcs.

❖ The collisions happened as the Australian plate moved northwards into the Pacific plate like a great bulldozer.

❖ hosts Golpu and Nambonga North porphyry Cu-Au, high and low sulfidation epithermal Au and carbonate base-metal Au deposits.



Schematic section showing the principal components of magma genesis, fluid flow and metallogenesis in divergent and convergent margin settings.



(Hedenquist and Lowenstern, 1994)

❖ **Golpu and Nambonga North porphyries formed in a continental volcanic arc setting.**

- The Golpu porphyry deposit is centered on multi-phase, calc-alkaline diorite porphyries (Main Golpu, Golpu West and Golpu North)
- Nambonga North porphyry deposit is 2.5 km NW of the Golpu deposit.

- Morobe Mining Joint Venture, a 50% partnership between Harmony Gold Limited and Newcrest Mining Limited
- 1 Bt of ore containing 13 Moz of Au and 4.4 Mt of Cu *(www.newcrest.com)*

Golpu Mineral Resource

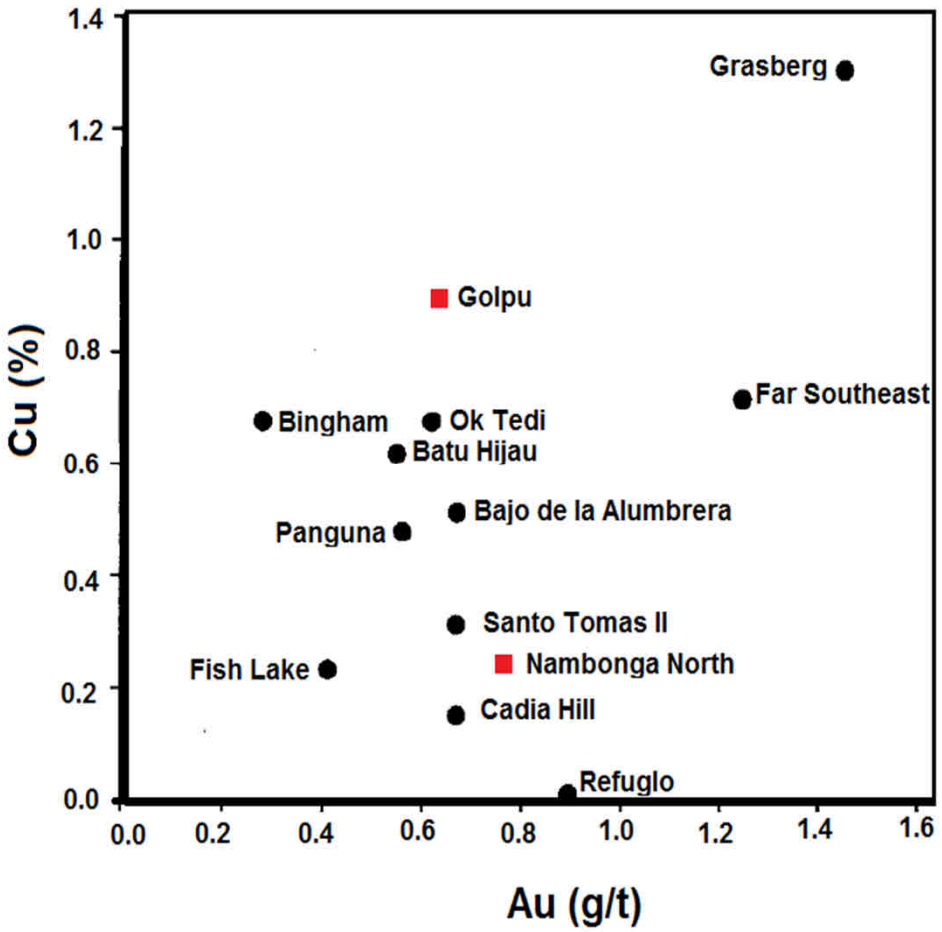
	Ore	Gold		Copper		Silver	
	Mt	g/t	Moz	%	Mt	g/t	Moz
Total	410	0.7	9.3	1	4.3	1.3	17

Nambonga Mineral Resource

	Ore	Gold		Copper	
	Mt	g/t	Moz	%	Mt
Total	20	0.79	0.51	0.22	0.04

Annual Mineral Reources and Ore Reserves Statement-31 December 2015 (www.newcrest.com)

Contents of Au and Cu for the largest Au-rich porphyry Cu deposits in the Circum-Pacific region (Slightly modified after Sillitoe, 1997). All deposits contain >200 t of Au.



Objectives of the study

The aims of the thesis were to characterize the Golpu and Nambonga North porphyry systems via:

i. Detail hand specimen description of core samples and petrographic study of polished sections under transmitted and reflected light microscopy;

ii. Investigation of hydrothermal biotite, pyrite and chalcopyrite using Laser Ablation-Inductively Couple Plasma Mass Spectrometry (LA-ICPMS) and electron microprobe analyses;

iii. dating of alteration and mineralization using $^{40}Ar/^{39}Ar$ and Re-Os methods; and

iv. development of a composite deposit model that incorporates both porphyry deposits, including the high sulfidation epithermal alteration-mineralization.

This paper:

❖ ***Aims to discusses the study undertaken for the sulphides, i.e. the pyrites and chalcopyites***

Importance of this study:

❖ **Apart from iron, sulfur and other contemporaneously deposited mineral phases, the trace element composition of pyrite and chalcopyrite may unravel critical data about the chemical composition of the mineralizing fluids, elemental substitution and replacement, residence and concentration of metals such as Au, Te, Bi, Ag and As, including possible complexing agents (e.g., Deer et al., 1966).**

❖ **Understanding the residence and concentration of these metals and closely associated mineral phases will provide important information about fluid chemistry and mill and metallurgical processes that are required for optimal metal recovery.**

Analytical Method

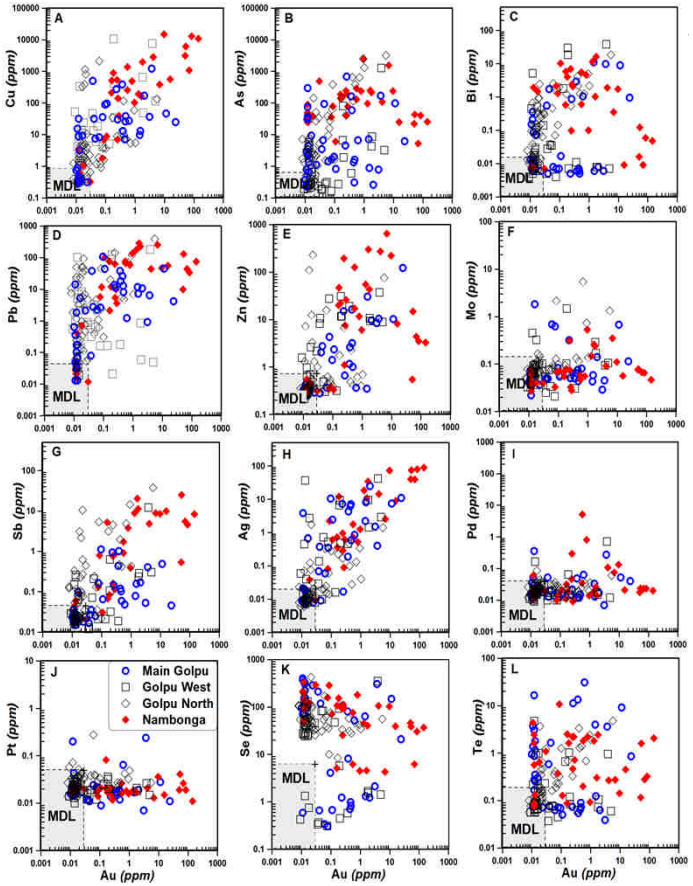
❖ Trace element geochemistry of the sulphides (pyrites and chalcopyrites) from Nambonga North and Golpu porphyries were analyzed by LA-ICPMS at the Friedrich Alexander University, Erlangen, Germany (between 2010 and 2012)

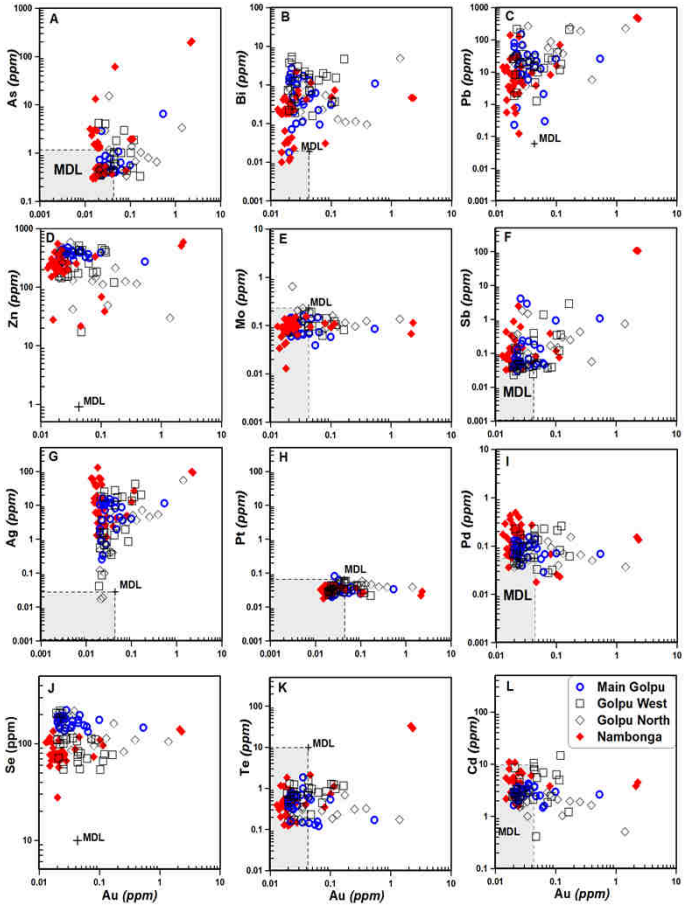
❖ Analysis was conducted on pyrite (n=165) and chalcopyrite (n=114) from 14 drill-core samples (polished sections) representing altered-mineralized samples from Nambonga North, Main Golpu, Golpu West and Golpu North porphyries.

❖ The trace elements measured are Pd, Pt, Au, Cu, Zn, As, Se, Mo, Ag, Sb, Te, Pb and Bi.

Results

Logarithemic plots comparison trace element concentrations in:





- pyrite from the Nambonga and Golpu porphyries.
- Nambonga North the highest Au content in pyrite 143,000 ppb.

chalcopyrite from the Nambonga and Golpu porphyries.

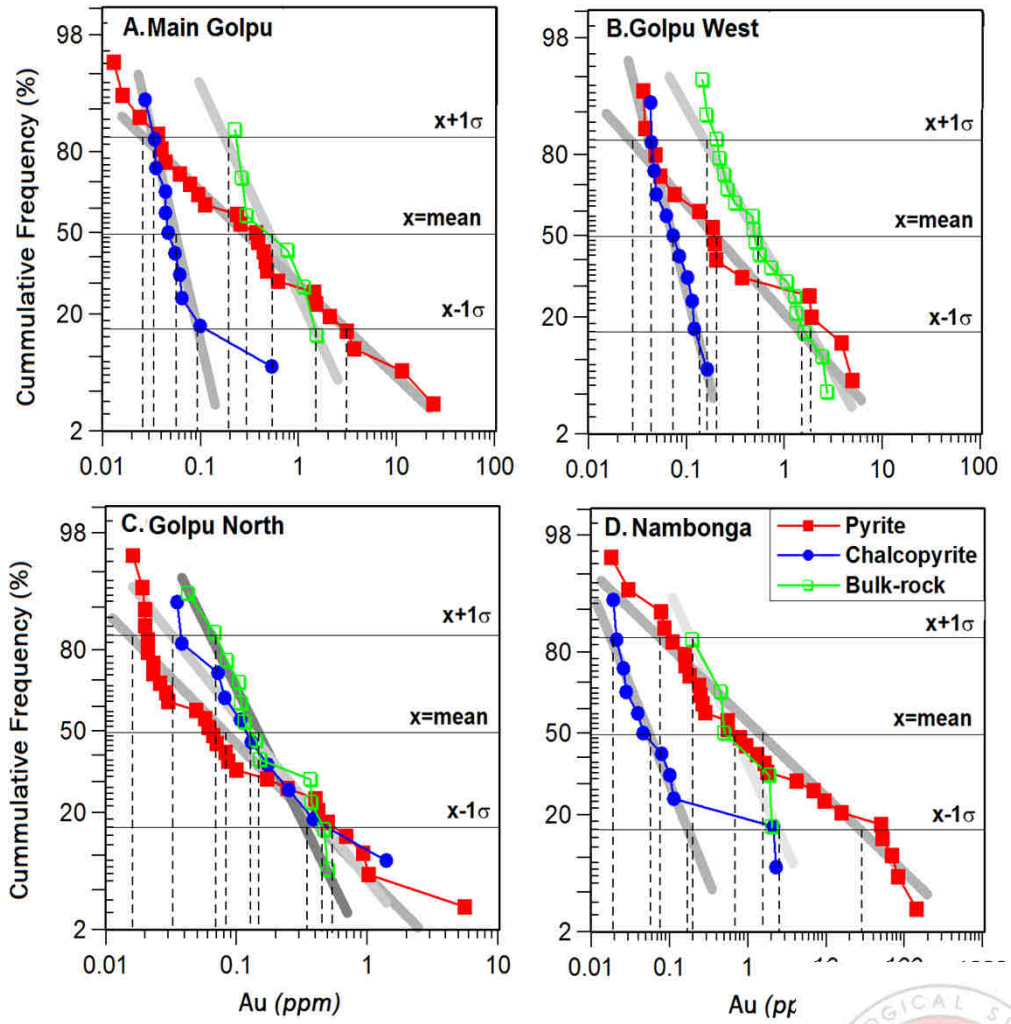
Nambonga North the highest Au content in pyrite 2,300 ppb

Cumulative Frequency Plots:

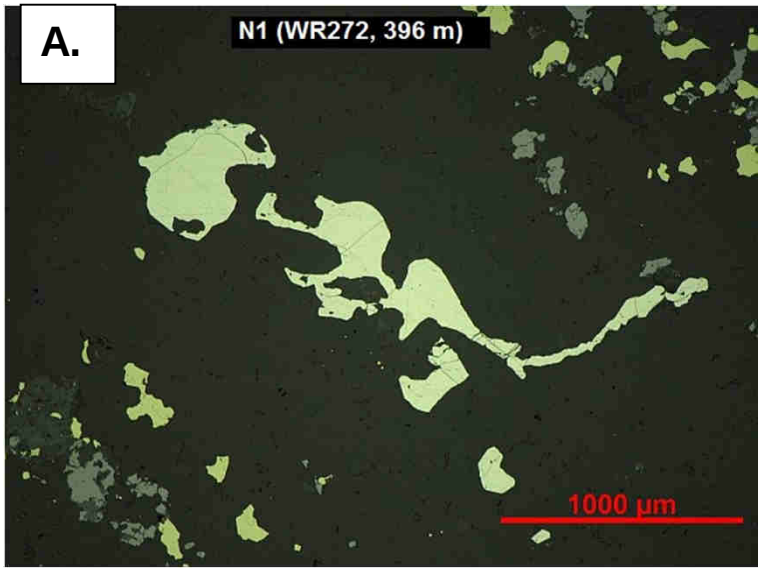
❖ By this method, a geometric mean is derived taking into account those data below the analytical detection limit.

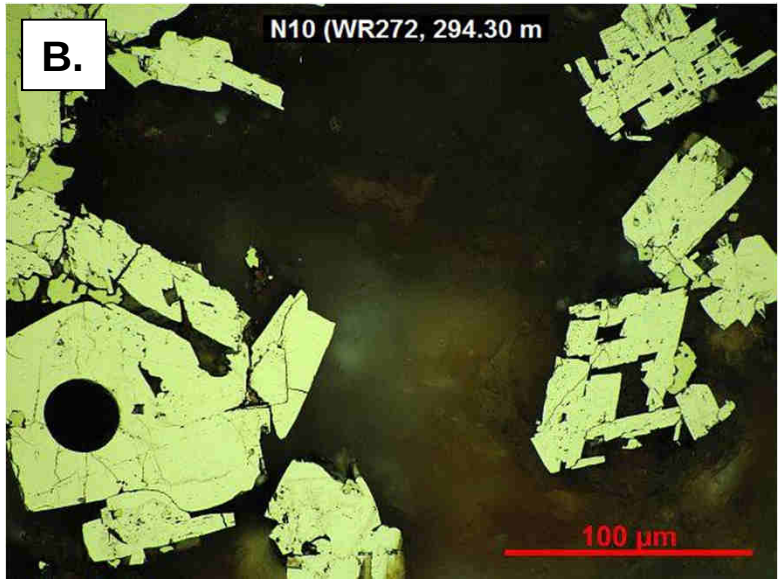
❖The data define an approximate log-normal distribution of the Au concentration in the porphyries

❖Au is higher in the pyrite from Nambonga North than in those from Golpu.



❖ two distinct generations in Nambonga North porphyry with similar vein mineralogy *(infill in a 2 cm-wide quartz±magnetite±pyrite±chalcopyrite vein)* but discrete morphological textures which correspond to their differences in Au contents.





A. Pyrite crystals from N1 have granoblastic textures, as do most pyrite crystals in the porphyries studied,

B. Pyrite crystals from N10 have platy, prismatic and lamellar textures, suggestive of pseudomorphic replacement of a hexagonal mineral, likely hematite.

❖The coexistence of both N1 and N10 pyrites suggests several stages of deposition, and the pseudomorphic pyrite (N10) seems to be most favourable for Au fixation.

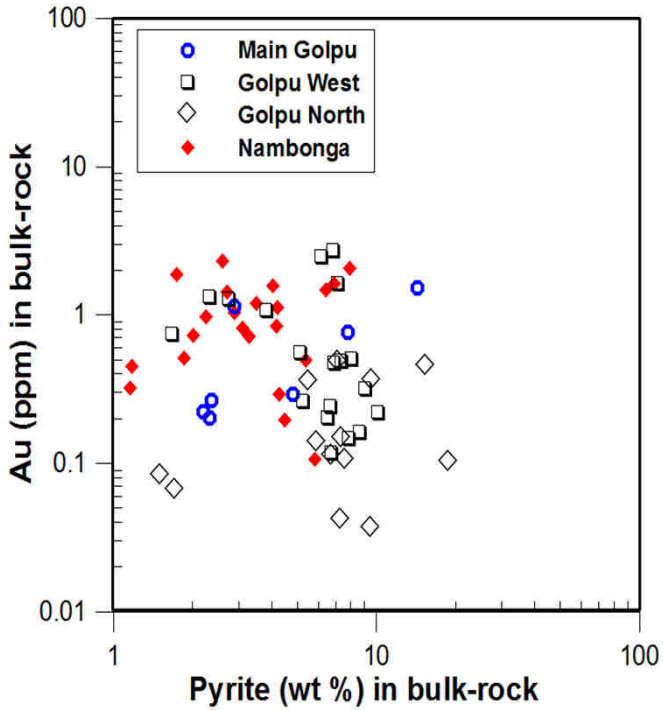
❖ Quantitative evaluation of the Au contribution in pyrite to the bulk-rock Au content in each porphyry system, the maximum possible amount of pyrite was calculated using the sulfur (S) concentration in the bulk-rock analyses times the stoichiometric molar ratio in pyrite , FeS_2/S_2

❖This calculation gives only an upper limit, as there are other but less abundant S-bearing minerals in the system (anhydrite, chalcopyrite, marcasite, sphalerite, molybdenite and galena).

❖No correlation between the calculated Au concentration in the pyrite and the Au content in the bulk-rock

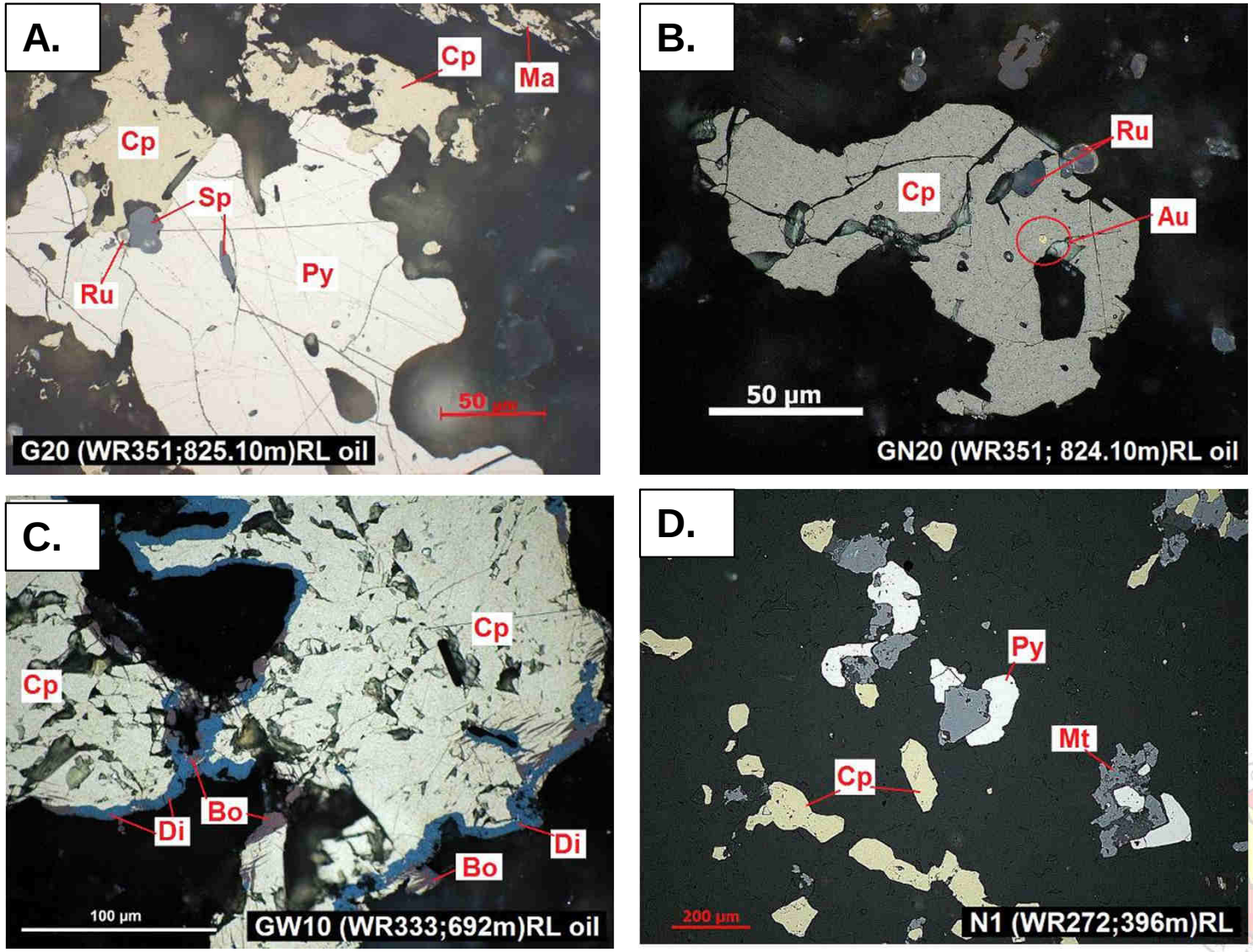
❖ Mass balance shows >90% of the Au comes from elsewhere apart from pyrite

❖ Considering this and taking into account the low Au concentration in the chalcopyrite, there must be a third Au-carrier in the porphyries.



❖The third Au-carrier is most likely sub-microscopic native Au observed as Au aggregates and inclusions.

❖ ***mineralogy studies identified presence of other Au and Cu bearing minerals***



Conclusions

❖ Pyrite and chalcopyrite are the main Au- and Cu-bearing minerals respectively in both porphyry deposits.

❖ Enrichment of Cu and Au in the Golpu deposit is also due to the presence of other bearing minerals such as bornite, digenite, covellite and chalcocite

❖The high Au in the Nambonga North deposit is associated with As-deficient pyrite deposited during formation of phyllic alteration.

❖Chloride complexes transported Au and Cu deposited during and/or immediately after potassic alteration. Bisulfide ligands complexed Au and Cu precipitated during phyllic and/or chlorite-sericite alteration, including the Au deposited by the high sulfidation fluids.

❖The Nambonga North porphyry does not have a high sulphidation mineralization overprint like that of the Golpu porphyries and represents a moderate tonnage, low grade Cu-Au porphyry system