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Distinguishing Intrusive Phases in Strongly Altered Hydrothermal Settings:

A CASE HISTORY OF THE APPLICATION OF 4-ACID MULTI-ELEMENT DATA IN A PORPHYRY ENVIRONMENT

CMOC | Northparkes

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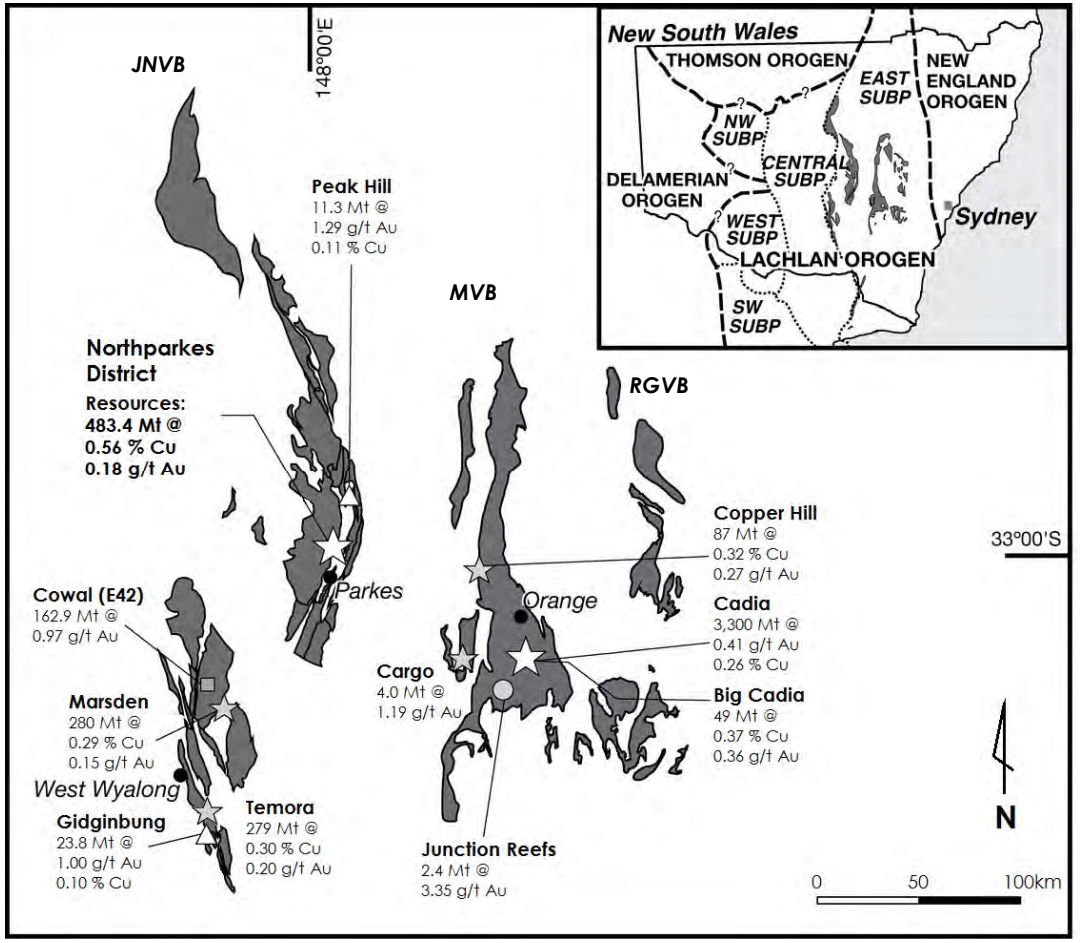
Overview of Northparkes Mines

- Joint venture – CMOC Mining Ltd(80%) and Sumitomo Group (20%)
- 300+ employees
- Copper and gold producer
- Commenced mining in 1994
- First underground block cave mine in Australia
- 1,630 ha of mine lease within 5,670 ha of agricultural land (+ 2,102 ha nearby)
- **Current Life of Mine is 2034**

Chalcopyrite-cemented hydrothermal breccia – regional prospect

Macquarie Arc- Porphyry Cu-Au deposits



Legend

- Ordovician volcanic and intrusive rocks
- Silica-saturated Alkalic Porphyry Cu-Au ~440 Ma
- Calc-Alkalic Porphyry Cu-Au ~450-440 Ma
- Carbonate-Base Metal Epithermal Au ~440Ma
- High Sulfidation Epithermal Au ~440 Ma
- Au Skarn

Modified from Henry *et al.* 2014, and Cooke *et al.*, 2007

Northparkes Porphyry Systems

- Late Ordovician to Early Silurian age – 437-439Ma (Lickfold *et. al.* 2007)
- Silica-saturated Alkalic Porphyry Cu-Au Systems
- Higher grade orebodies have pipe-like geometries
- Hosted by Shoshonitic to High-K Calc-Alkaline volcanic and volcaniclastic package
- Sulphides dominated by Cu-bearing species; bn-cpy+/-cct-tn-cov
- Vein hosted, vein related, and disseminated mineralisation

Bornite mineralised quartz-veined monzonite – E48 Deposit (S.Smith)

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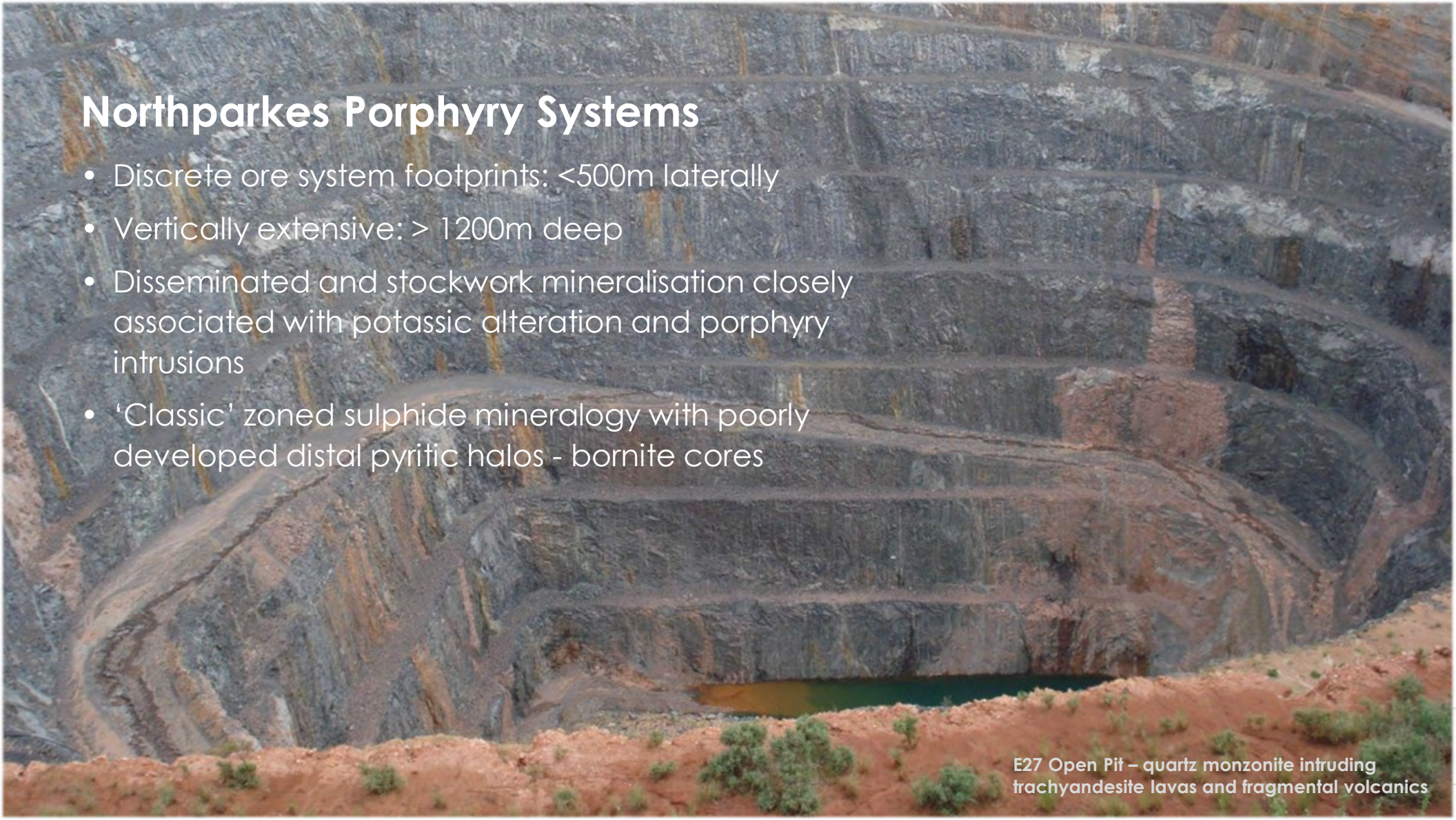
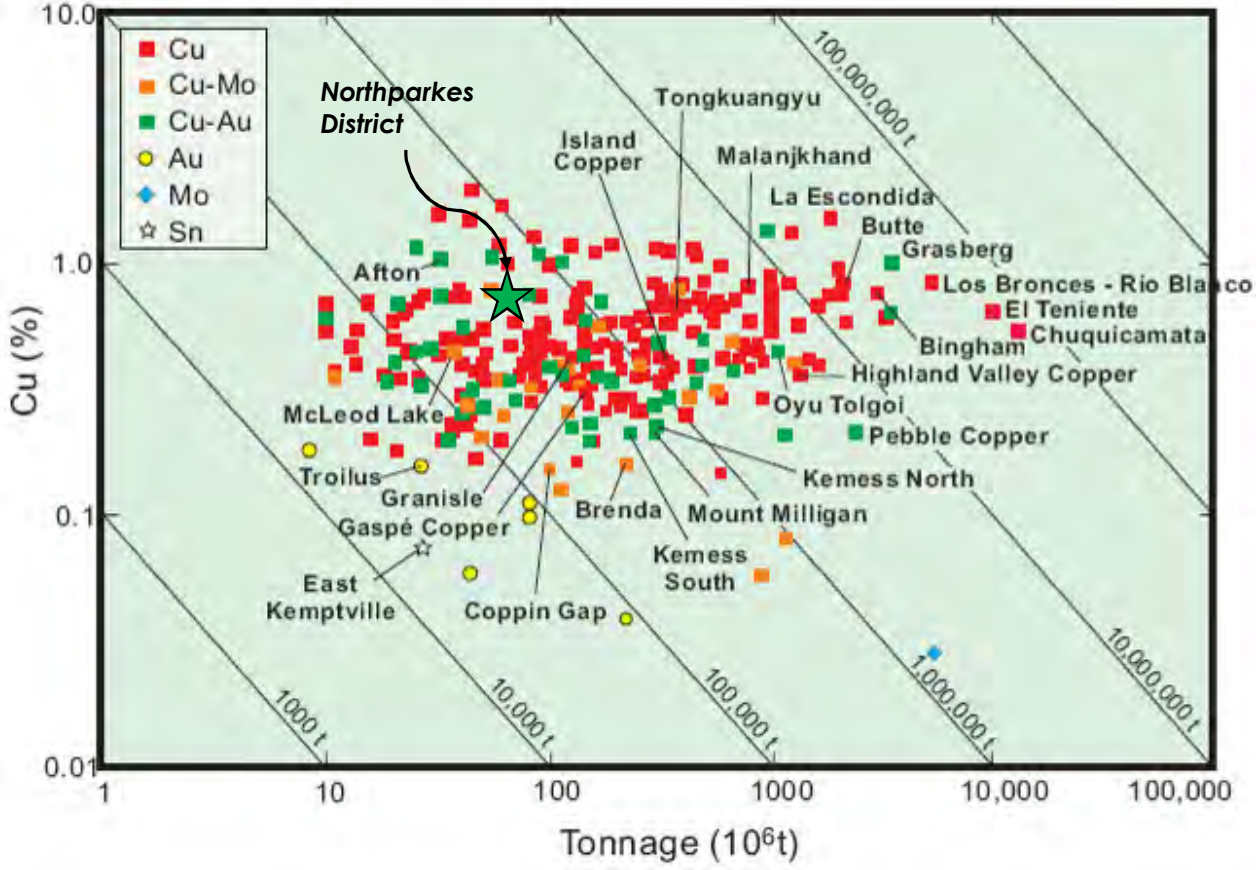
Northparkes Porphyry Systems

- Discrete ore system footprints: <500m laterally
- Vertically extensive: > 1200m deep
- Disseminated and stockwork mineralisation closely associated with potassic alteration and porphyry intrusions
- 'Classic' zoned sulphide mineralogy with poorly developed distal pyritic halos - bornite cores



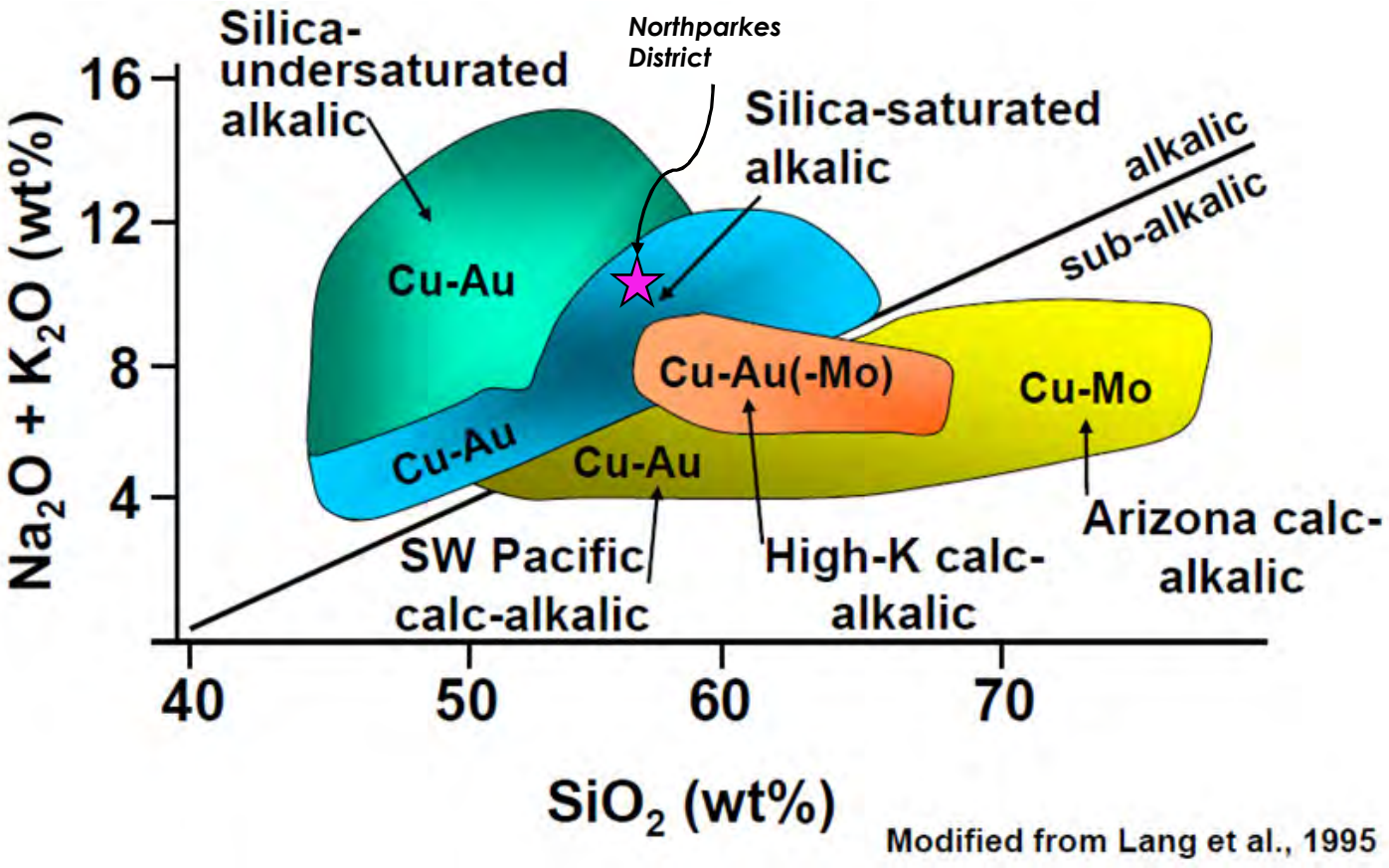
E27 Open Pit – quartz monzonite intruding trachyandesite lavas and fragmental volcanics

Northparkes Porphyries: High Grade Cu/Au



Modified after Sinclair, 2007

Northparkes Porphyries: High Grade Cu/Au



Modified from Lang et al., 1995

Main Deposits

- **E22** and **E27** surface pits – production ceased in 2010
- **E26** Underground – two lifts extracted – potential third
- **E48** Underground – currently extracting from one level
- **GRP314** – Potential Underground

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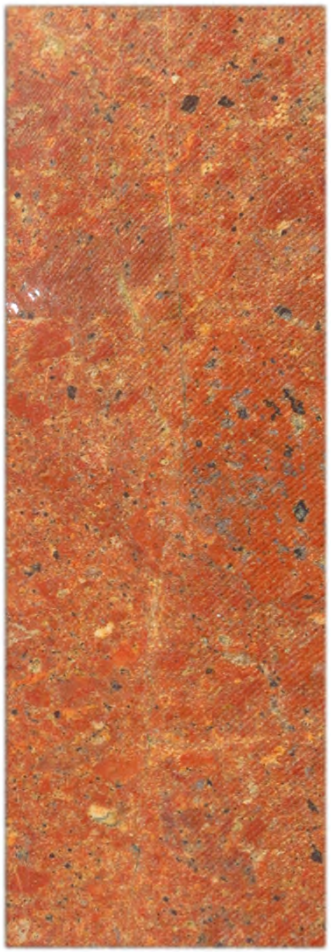

Advances in Exploration Thinking

- Driven by advances in understanding of Alkalic Porphyry systems worldwide – Industry/CODES/MDRU research
- Recognition of 'wallrock porphyry' mineralisation:
  - Texturally destructive k-feldspar-albite-sericite alteration assemblages
  - Subtle differences between host rocks and mineralizing intrusions

- Recognition of intact/preserved porphyry systems under cover:

  - ***with little to no surface geochemical signature***
  - associated with cryptic silica-muscovite-albite alteration plumes: 'grey sericite'
  - Importance of 'red rock' alteration as indicator of prospectivity/system fertility

Move away from looking for a direct hit:
Applying trace level multi-element geochemistry

Trachyandesitic volcanic breccia – Hopetoun Prospect

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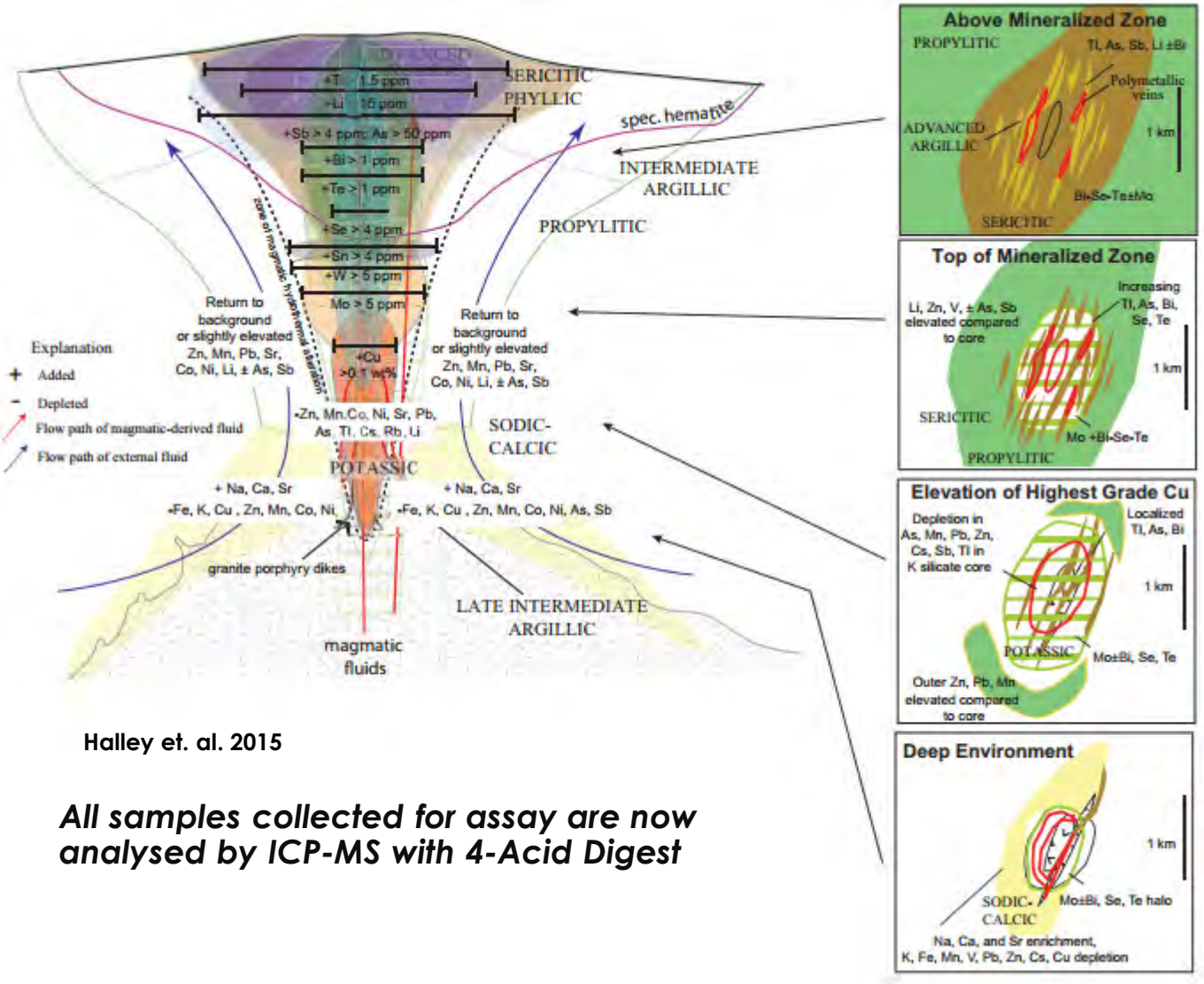
Acquisition of 4-Acid Multi-element Geochemical Data

- 4-Acid digest uses a combination of HCl (hydrochloric acid), HNO3 (nitric acid), HF (hydrofluoric acid) and HClO4 (perchloric acid)
- Because hydrofluoric acid dissolves silicate minerals, these digestions are often referred to as 'near-total digestions'
- Solute analysed by ICP-AES/ICP-MS combination (ALS method ME-MS61)

ANALYTES & RANGES (ppm)								CODE
Ag	0.002-100	Cu	0.02-10,000	Na	0.001%-10%	Sr	0.02-10,000	ME-MS61L
Al	0.01%-25%	Fe	0.002%-50%	Nb	0.005-500	Ta	0.01-500	
As	0.05-10,000	Ga	0.05-10,000	Ni	0.08-10,000	Te	0.04-500	
Ba	1-10,000	Ge	0.05-500	P	0.001%-1%	Th	0.004-10,000	
Be	0.02-1,000	Hf	0.004-500	Pb	0.01-10,000	Ti	0.001%-10%	
Bi	0.005-10,000	In	0.005-500	Rb	0.02-10,000	Tl	0.004-10,000	
Ca	0.01%-25%	K	0.01%-10%	Re	0.002-50	U	0.01-2,500	
Cd	0.005-1,000	La	0.005-10,000	S	0.01%-10%	V	0.1-10,000	
Ce	0.01-500	Li	0.2-10,000	Sb	0.02-10,000	W	0.008-10,000	
Co	0.005-10,000	Mg	0.01%-25%	Sc	0.01-10,000	Y	0.01-500	
Cr	0.3-10,000	Mn	0.2-50,000	Se	0.2-1000	Zn	0.2-10,000	
Cs	0.01-500	Mo	0.02-10,000	Sn	0.02-500	Zr	0.1-500	

Acquisition of 4-Acid Multi-Element Geochemical Data

- Extends assay data beyond the obvious…
- Moving into the world of 'Applied Lithogeochemistry'
- Building comprehensive multi-element database



Halley et. al. 2015

All samples collected for assay are now analysed by ICP-MS with 4-Acid Digest

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Now You've Got it… What Next?

- How to use the data to derive ***value***
- Common in industry to acquire data, but still get dragged to the old favourites; Cu, Au, Pb, Zn, As
- Most data sits 'unloved' because of a lack of a clear path for how to use it
- 3 main areas for using this data for ***Applied Lithogeochemistry***:
  - Identify Rock Types
    - Sc, Ti, V, Zr, Hf, Nb, Th, La, Ce
  - Quantify Alteration
    - Al, K, Na, Ca, Fe, Mg, Rb, Cs, Sr
  - Pathfinder Patterns
    - As, Sb, W, Mo, Bi, Te, Tl, Ag, Au – value lies in the detection limits!

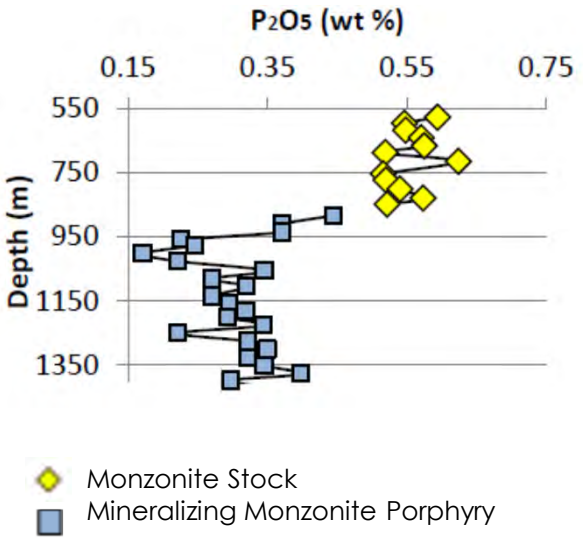
The Problem:

- Strong alteration at Northparkes commonly obscures or obliterates original rock texture making logging and modelling problematic
- Texturally destructive alteration both paragenetically early and late, with both phyllic (sericite-quartz) and potassic (k-feldspar-biotite+/-albite-hematite) assemblages
- Each early to late-syn mineral intrusive phase alters the surrounding rock – compounding the problem!
- Contacts between phases in wallrock hosted systems are gradational and easily missed

Pre-mineral monzonite clasts in syn-mineral quartz monzonite (R. Lesh)

The Solution: The Phosphorus Story

- Northparkes maintains a strong commitment to research
- Honours thesis examining REE fractionation trends within GRP314 orebody (Johnson, 2011)
- Study showed fractionation of magma chamber at depth (Johnson, 2011) evident in P_2O_5 whole rock data



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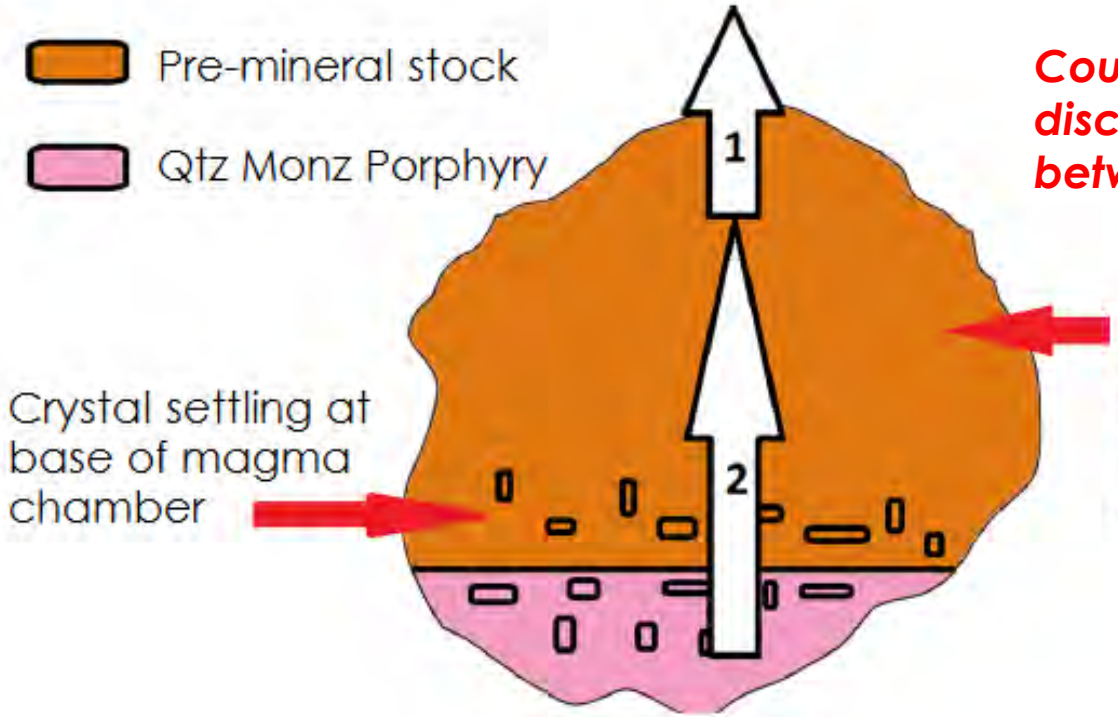
The Solution: The Phosphorus Story

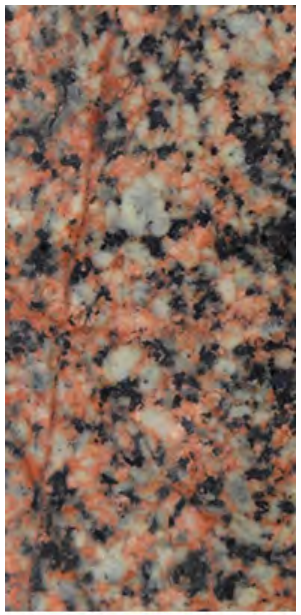


Could this be used to discriminate between phases?

From Johnson, 2011

The Phosphorus Story

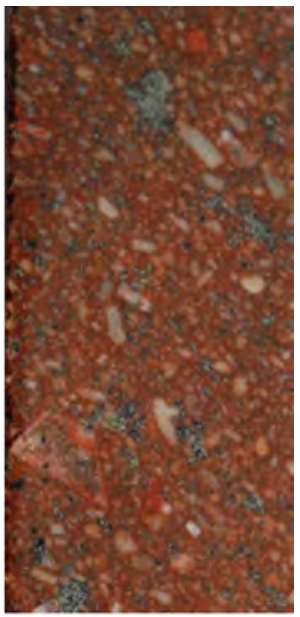
- ***Yes!***
- Intrusive units each have distinct P assay signatures, ***even when partially weathered or intensely altered***



Pre-Mineral Monzonite
900-1500ppm P

Syn-min Qtz Monzonite
700-900ppm P

Mineralised Porphyries
500-800ppm P



Zero Porphyry
200 - 600ppm P

Late Basic Dyke
1000-2000ppm P

The Value in Phosphorus Assays

Exploration

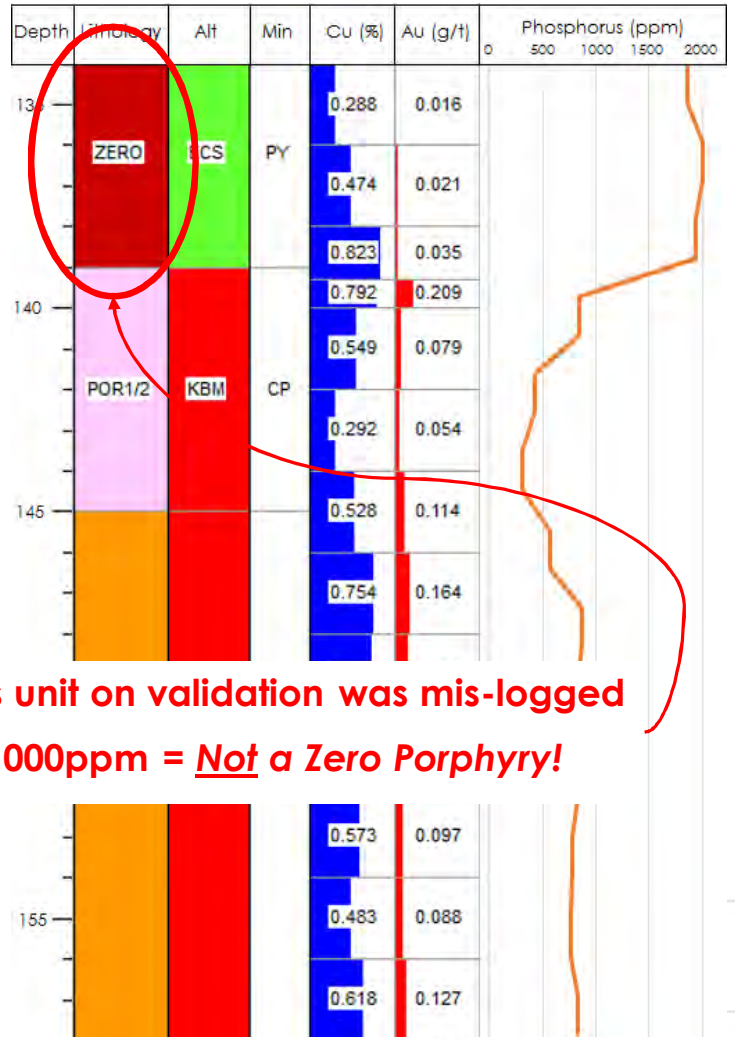
- Potential use in discriminating between fertile systems and 'red herrings'

Evaluation

- Highly useful in modelling of orebodies for resource/reserve and domaining
- Each intrusive type having different geomechanical properties/gangue mineralogy

Data Validation

- Mis-logged lithologies – validation checks



This unit on validation was mis-logged

P>1000ppm = *Not a Zero Porphyry!*

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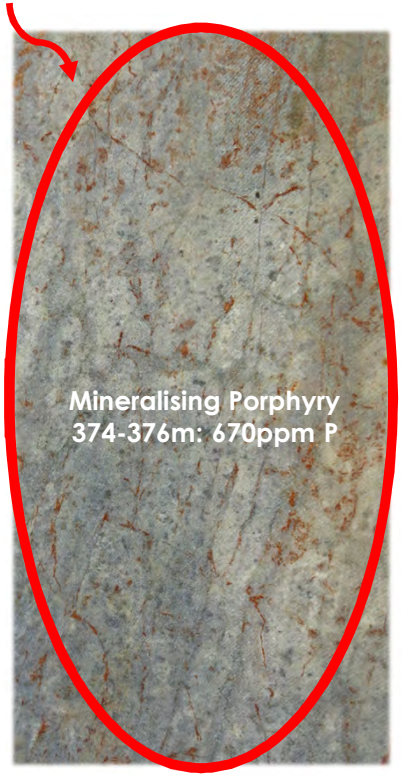
Example:

Which is the mineraliser?

Trick Question – There are two!



Hole GD827 – GRP314 Deposit

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Conclusions

- Most assay data has value – you just have to find out where the value lies!
- 4-Acid near total digest assay data can open up new value opportunities – *differentiating intrusive phases is just one*
  - Looking beyond the game of 'Grade or No Grade'
- Multi-element near-total digest geochemistry pays off at Northparkes
  - ***Both in exploring for new systems, and understanding what you already have***

Stockwork-veined quartz monzonite porphyry – E48 Deposit (R. Lesh)

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