Fluid-rock interactions to failed over-pressurisation in intrusion-hosted wallrock porphyry systems

Examples from the Northparkes district, NSW

Jonathon Hoye

Senior Geologist Orebody Knowledge – Northparkes Mines

Disclaimer

These materials have been prepared solely for your personal reference during the presentation and these materials and their contents may not be reproduced, redistributed, passed on or disclosed, directly or indirectly, to any other person (whether within or outside your organisation/firm) or published, in whole or in part, for any purpose. By attending this presentation, you are agreeing to be bound by the foregoing restrictions and to maintain absolute confidentiality regarding the information disclosed in these materials. The information contained in these materials has not been independently verified. No representation or warranty express or implied is made as to, and no reliance should be placed on, the fairness, accuracy, completeness or correctness of the information or opinions contained in these materials. It is not the intention to provide, and you may not rely on these materials as providing, a complete or comprehensive analysis of China Molybdenum Co., Ltd. ("CMOC") financial or trading position or prospects. The information contained in these materials should be considered in the context of the circumstances prevailing at the time and has not been, and will not be, updated to reflect material developments which may occur after the date of the presentation. None of CMOC and its controlling shareholders, affiliates, directors, officers, employees, advisors and representatives shall have any liability whatsoever (in negligence or otherwise) for any loss or damage howsoever arising from any use of these materials or its contents or otherwise arising in connection with these materials.

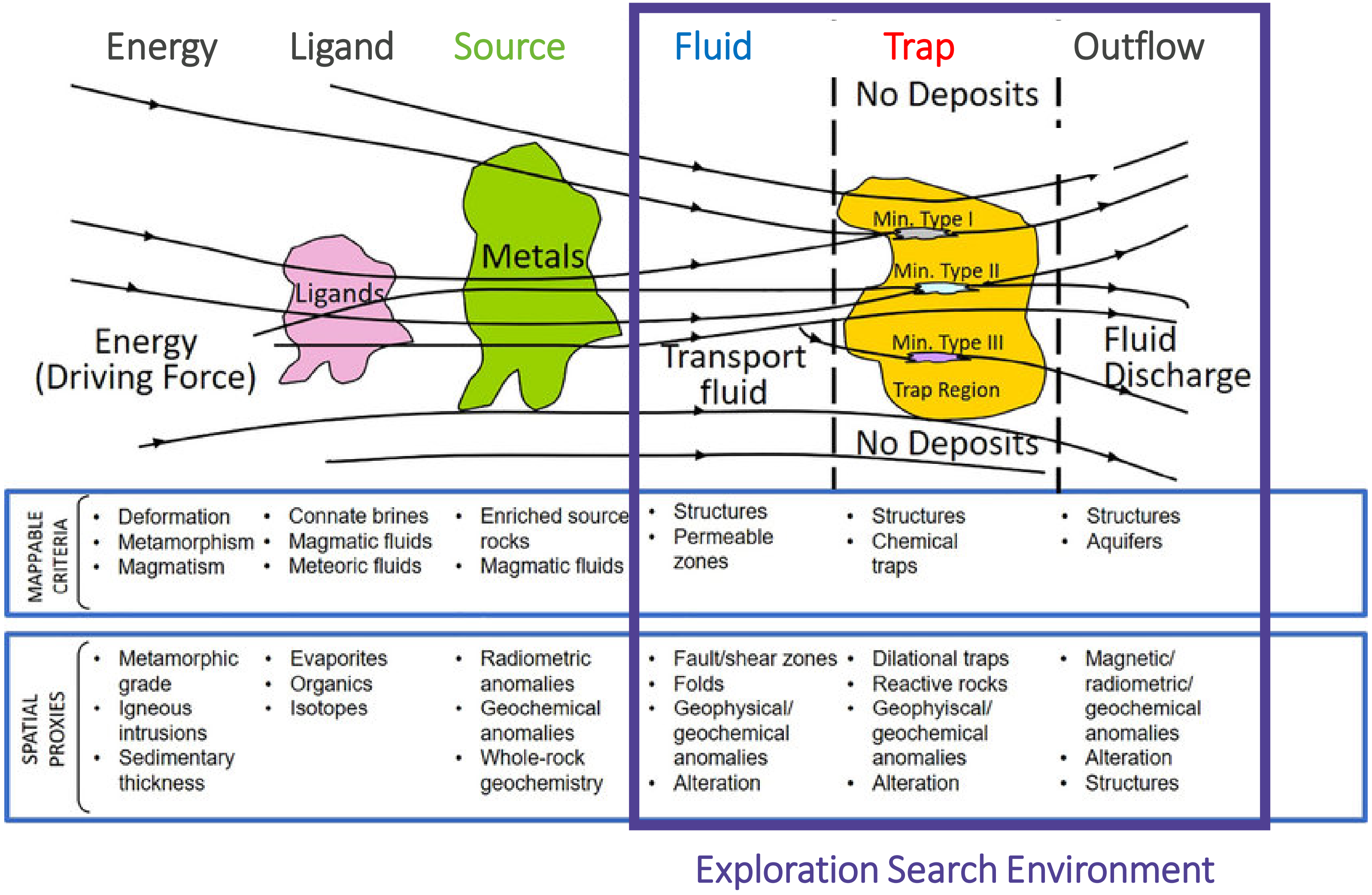
Certain information contained in these materials constitutes forward-looking statements. Forward-looking statements include, but are not limited to, the company's growth potential, costs projections, expected infrastructure development, capital cost expenditures, market outlook and other statements that are not historical facts. When used in these materials, the words such as "could", "plan", "estimate", "expect", "intend", "propose", "may", "will", "potential", "should", and similar expressions are forward-looking statements. Although CMOC believes that the expectations reflected in these forward-looking statements are reasonable, such statements involve known and unknown risks, uncertainties and other factors, certain of which are beyond CMOC's control, that may cause the actual results, performance or achievements to be materially different from those expressed or implied by the forward-looking statements and the forward-looking statements are not guarantees of future performance or achievement. These risks, uncertainties and other factors include, but are not limited to: general business and economic conditions globally or in certain jurisdictions; legislative and/or regulatory changes; the behaviour of other market participants; fluctuations in the price of copper and other commodities; fluctuations in currency exchange rates; CMOC's ability to integrate acquisitions; operating or technical difficulties in connection with development or mining activities; the speculative nature of exploration and development, including the risks of obtaining the necessary permits and licenses; risks and hazards associated with the business of exploration, development and mining; availability and cost of inputs; availability and cost of shipping; risks of maintaining licences and approvals; changes in the tax rates or introduction of new taxes. No assurance can be given that such forward-looking statements will prove to have been correct. Readers are cautioned not to place undue reliance on these forward-looking statements, which speak only as of the date of this presentation. CMOC disclaims any intention or obligation to update or revise any forward-looking statements whether as a result of new information, future events or otherwise, except as required by applicable laws.

These materials should be read in conjunction with CMOC's 2020 Annual Report, 2021 Interim Report and other public disclosures.

This document does not constitute or form part of an offer or invitation to issue or sell or a recommendation to acquire, purchase or subscribe for any securities nor shall it be construed as calculated to invite any such offer and no part of it shall form the basis of or be relied upon in connection with any contract, commitment or investment decision in relation thereto.

Comb quartz crystal unidirectional solidification texture in quartz monzonite porphyry – E22 Deposit (Photo: R. Lesh)

Mineral Systems Context



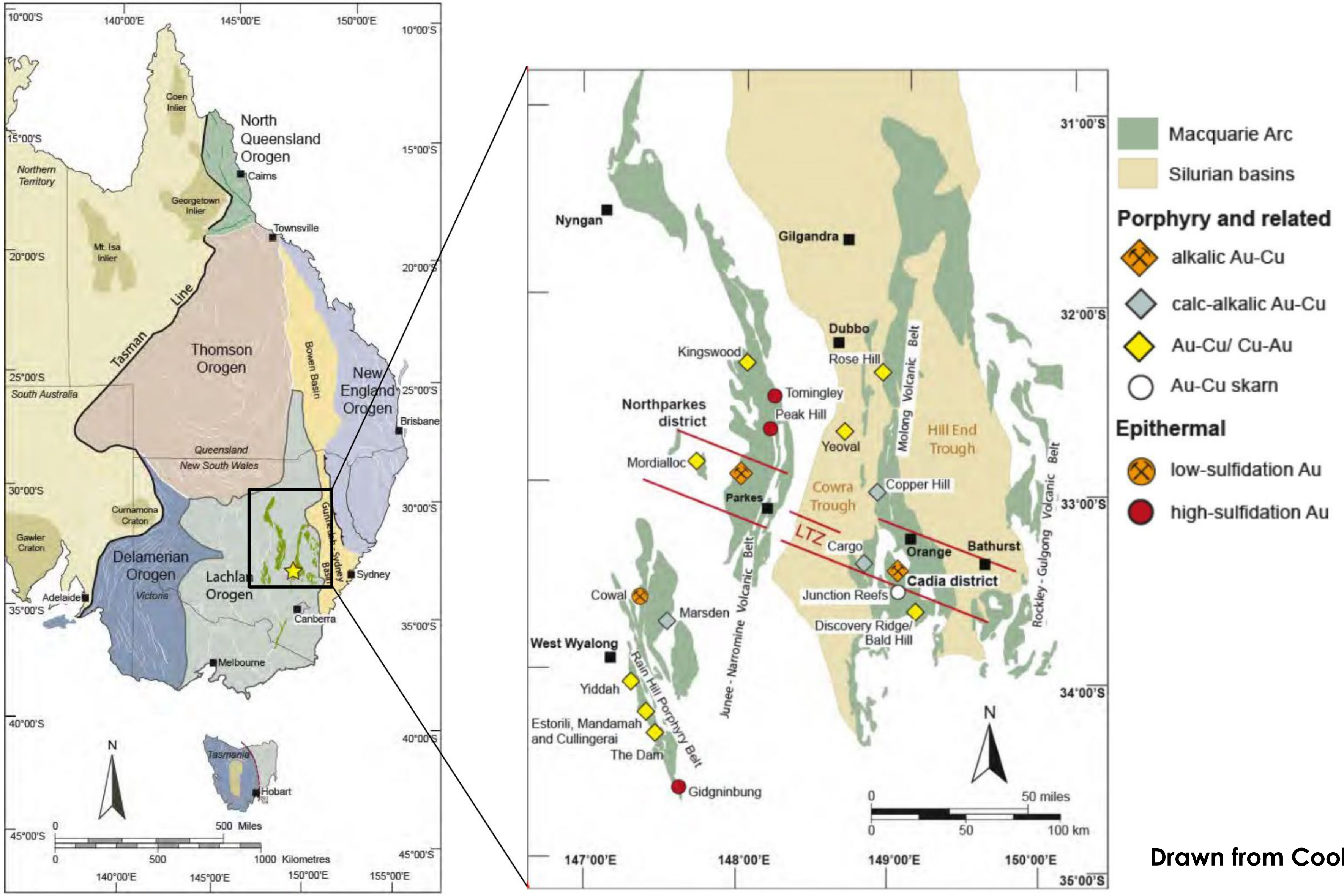
Mineral Systems Model, modified after Knox-Robinson and Wyborn (1997)

Simplified components;

- Source
- Fluid
- Trap
- Outflow

- Recent research focus on ‘Source’ and ‘Fluid’ components (magma fertility)
- ‘Trap’ and ‘Outflow’ are critical for ore formation & exploration targeting

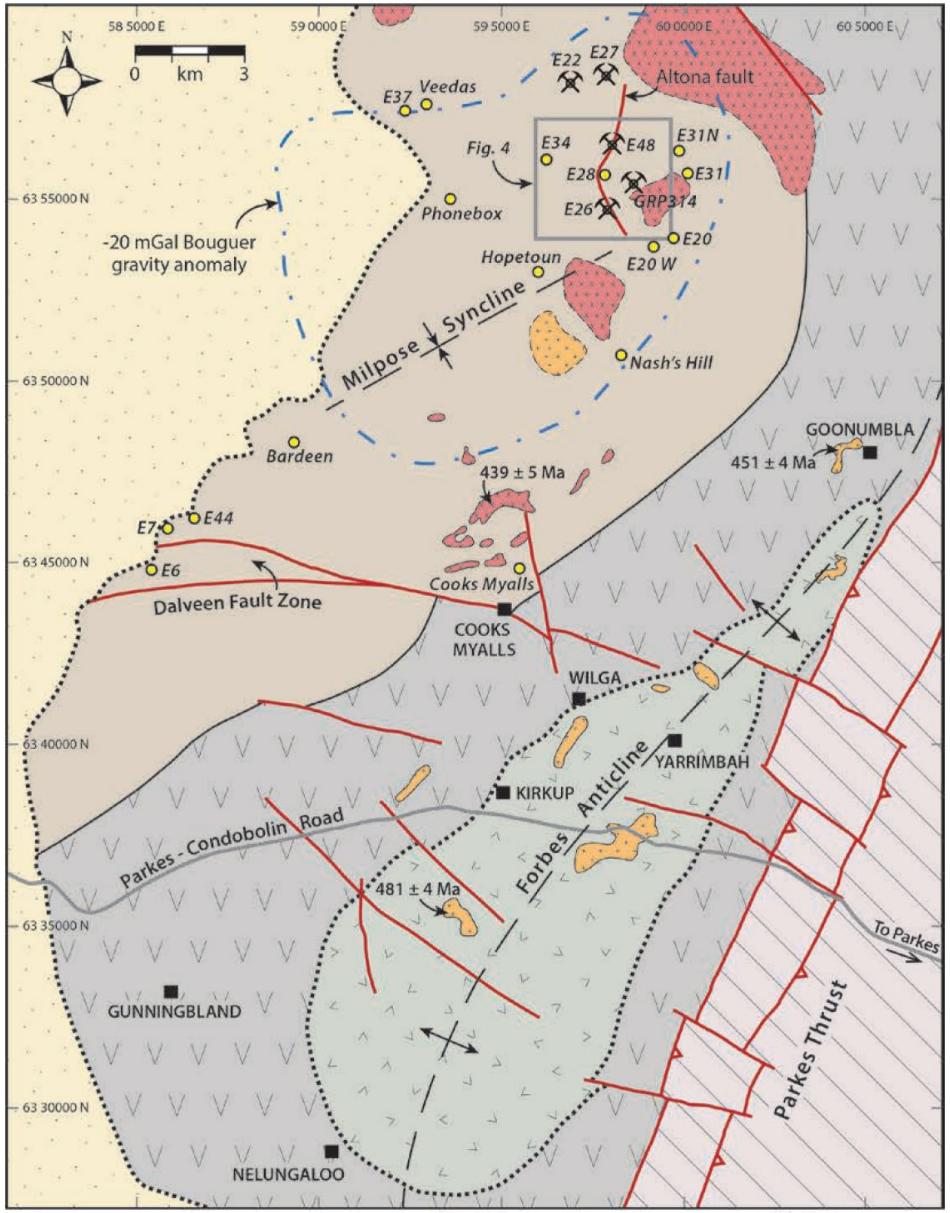
Macquarie Arc Porphyry Systems



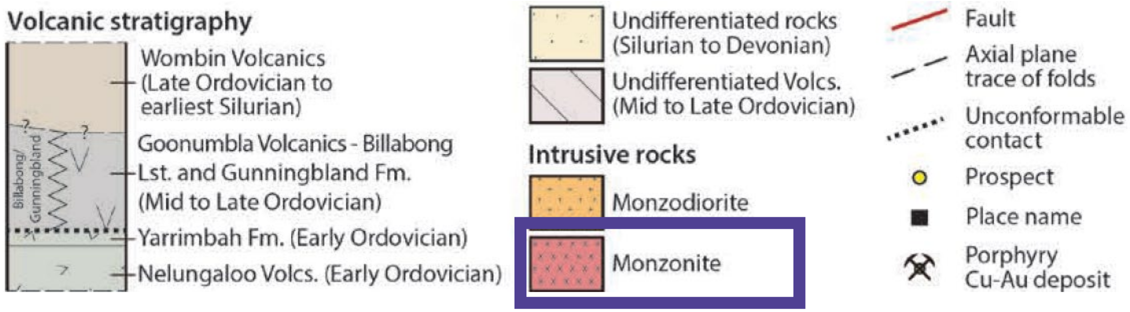
- Segmented Ordovician – Silurian age belt
- Hosts significant alkalic porphyry Au-Cu and Cu-Au deposits
- Intrusion-hosted systems present in most districts

Drawn from Cooke et. al. 2009

Northparkes District Geology



- Silica-saturated alkalic Porphyry Cu-Au and related mineral systems (skarn, epithermal)
- Hosted by variable Shoshonitic to High-K Calc-Alkaline volcanic and volcaniclastic package and comagmatic intrusive suite
- Mineralised porphyry deposits in Northparkes camp L. Ordovician to E. Silurian – 437-439Ma (Lickfold *et. al.* 2007)



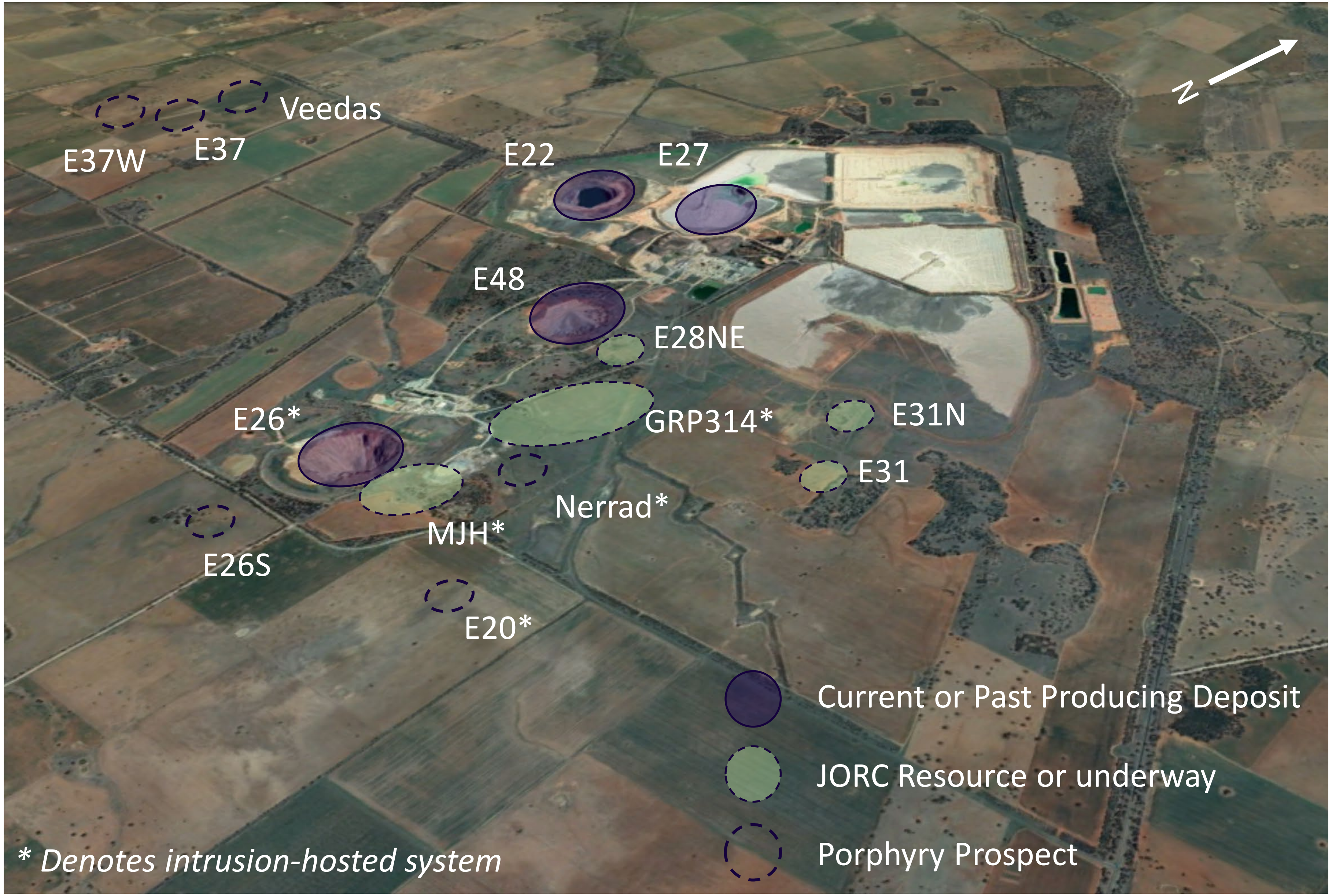
District map modified from Owens et. al. (2017) after Pacey (2016), Simpson et al. (2005), Arundell (1998) and Heithersay et al. (1990)

Northparkes Porphyry Systems

- 22 Porphyry systems defined to date
- Four main ore systems mined, five planned
- Discrete ore system footprints: <500m laterally
- Vertically extensive: > 1200m deep
- Mineralisation associated with potassic, sodic, and phyllic alteration around monzonite intrusions
- Zoned sulphides: bn-cpy+/-cct-tn-cov, distal py
- Generally have upright pipe-like geometries
- Also larger, lower-grade intrusion hosted systems
- Vein hosted, vein related, and disseminated mineralisation

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

Metal Endowment



Past Production

146.3 Mt @ 0.83% Cu, 0.30g/t Au

1.2 Mt Cu, 1.4 Moz Au

Current Reserves & Resources

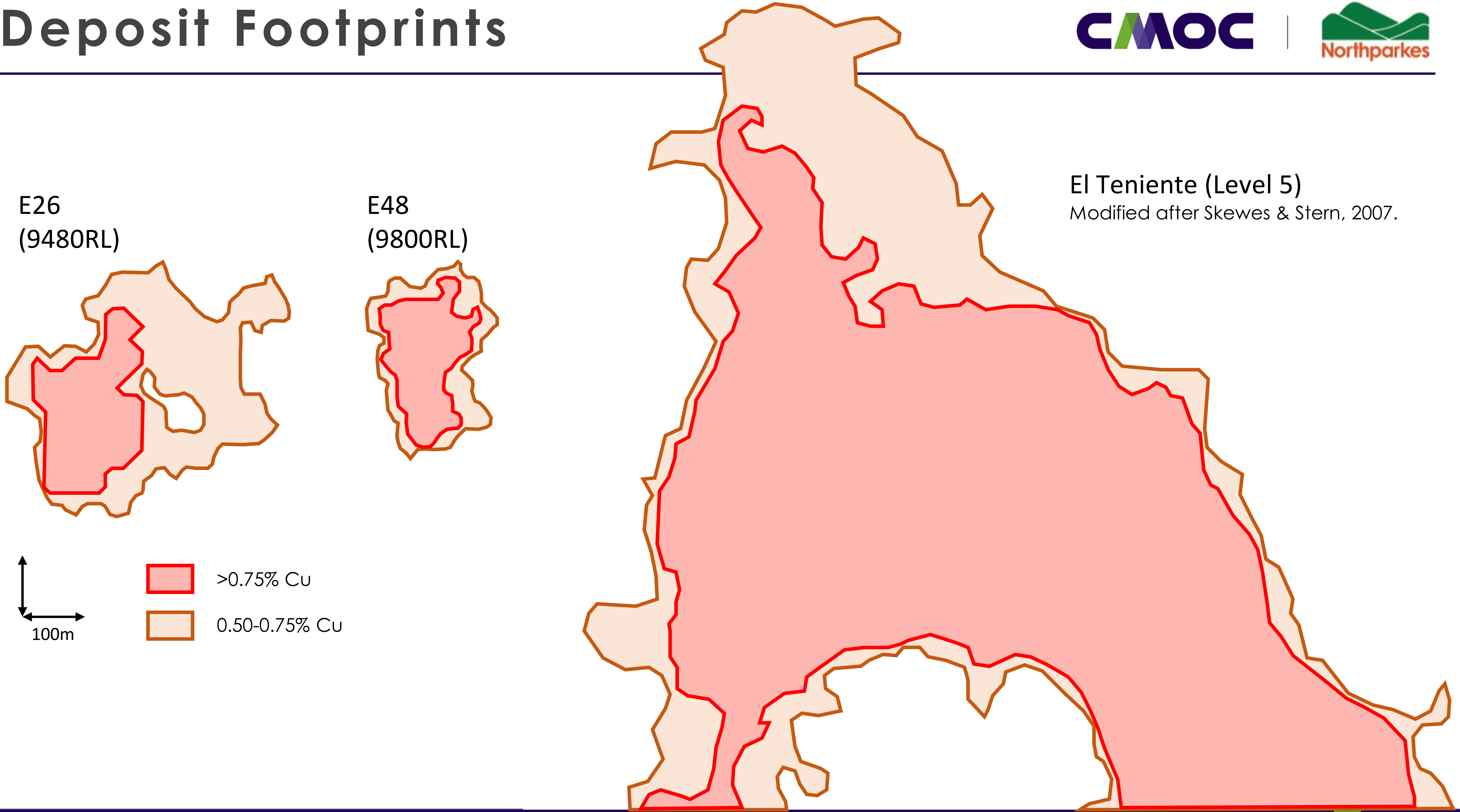
607.4Mt @ 0.55% Cu, 0.21g/t Au

3.4Mt Cu, 4.0Moz Au

Total Mineral Endowment

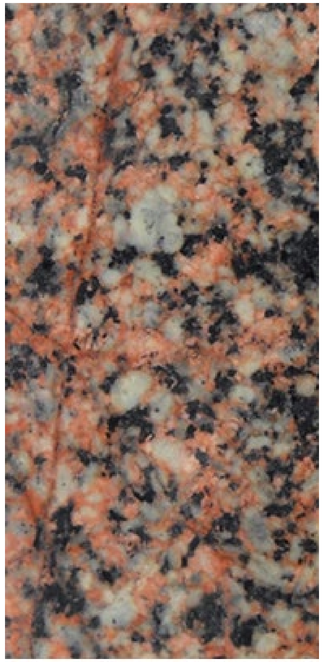
~4.5Mt Cu, 5.4 Moz Au

Deposit Footprints



Intrusive History

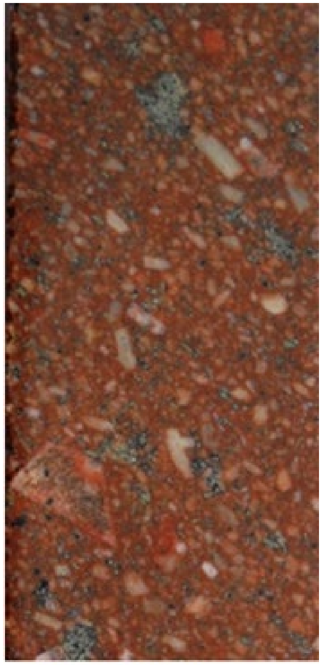
- Protracted intrusive history – 445-436Ma from Re-Os, U-Pb dating (Lickfold et al. 2007, Wells et al. 2020)
- Pre- to early-syn mineral Biotite Quartz Monzonite
- Early syn-mineral Quartz Monzonite (QMZ)



Pre-Mineral Monzonite

Syn-min Qtz Monzonite

Mineralised Porphyries

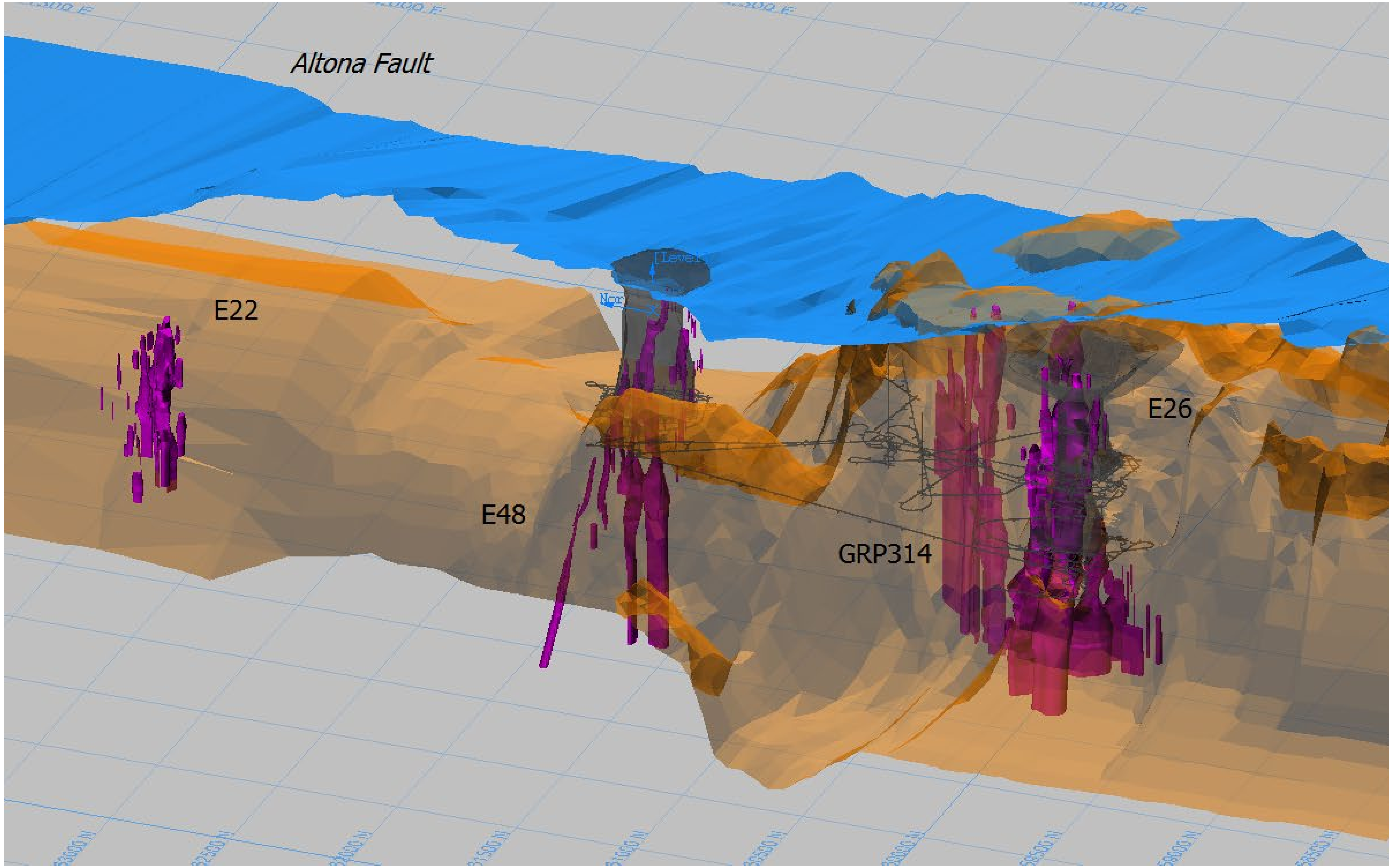


Zero Porphyry

Late Basic Dyke

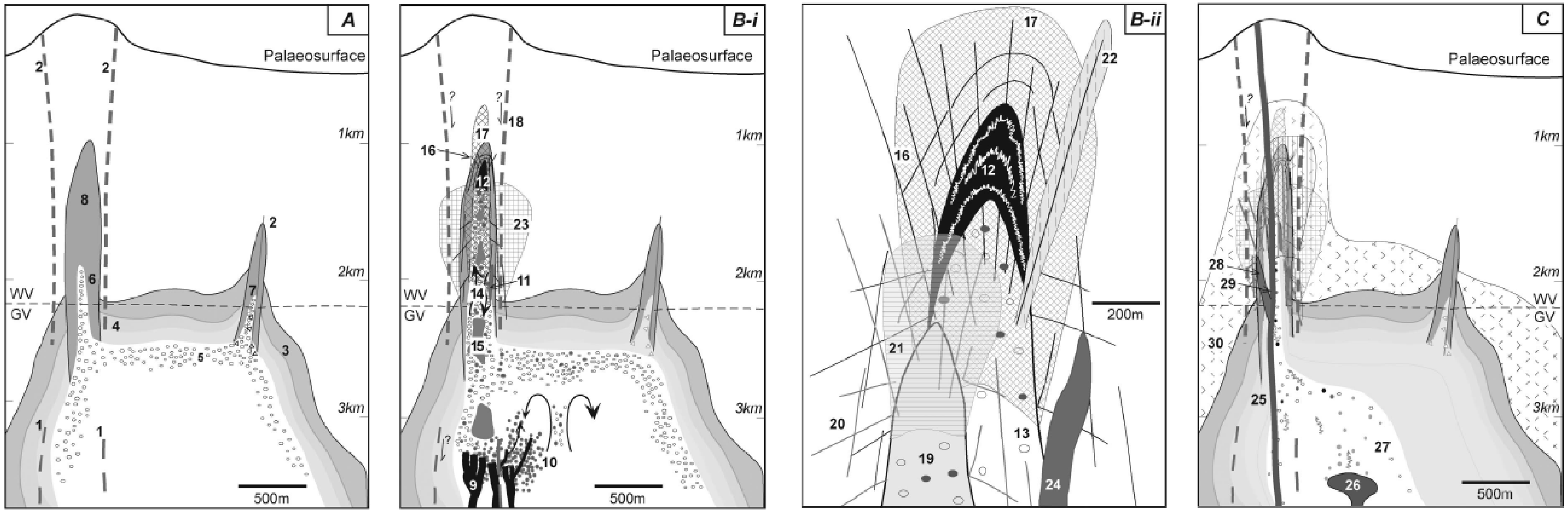
- Syn-Mineral Quartz Monzonite Porphyry (QMP)
- Late Syn-Mineral QMP, Post Mineral Monzonite Porphyry (Zero) & Late Basic Dykes (BAD)

Geological Controls & Morphology



- All known deposits within 500m of BQM contact – fundamental control
- Syn-mineral quartz monzonite bodies intrude through BQM along subvertical structures formed during deflation of BQM (cooling and fluid loss)

Genetic Model for Porphyry Formation



Drawn from Lickfold, 2007

A Formation of BQM magma chamber & generation of planes of weakness by shrinkage during cooling of BQM

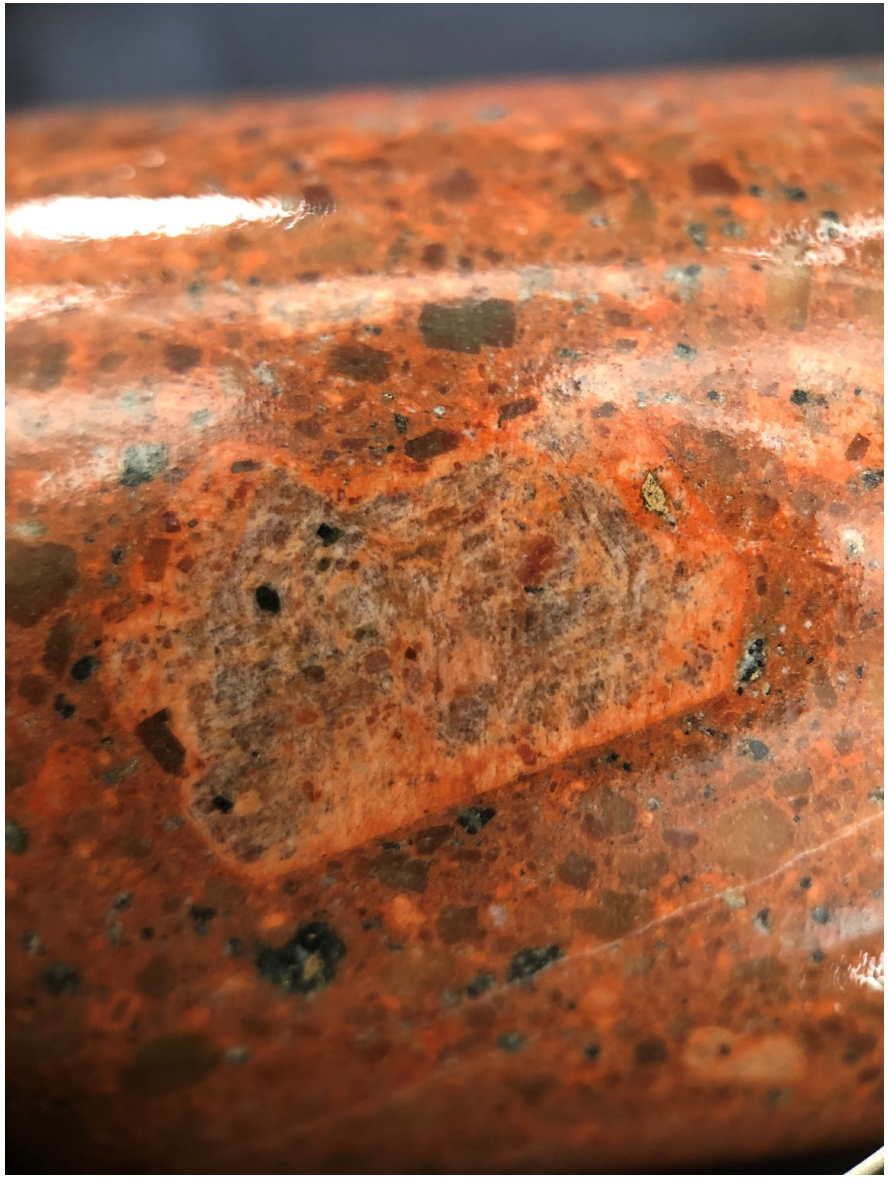
B-i QMP formation at depth, passing through BQM and development of mineralisation

B-ii Successive QMP phases of decreasing volume, overprinting earlier phases and associated alteration and mineralisation, intrusion of post-mineral phases

C Late-stage telescoping of distal alteration assemblages onto system – fault controlled

Variability in Known Systems

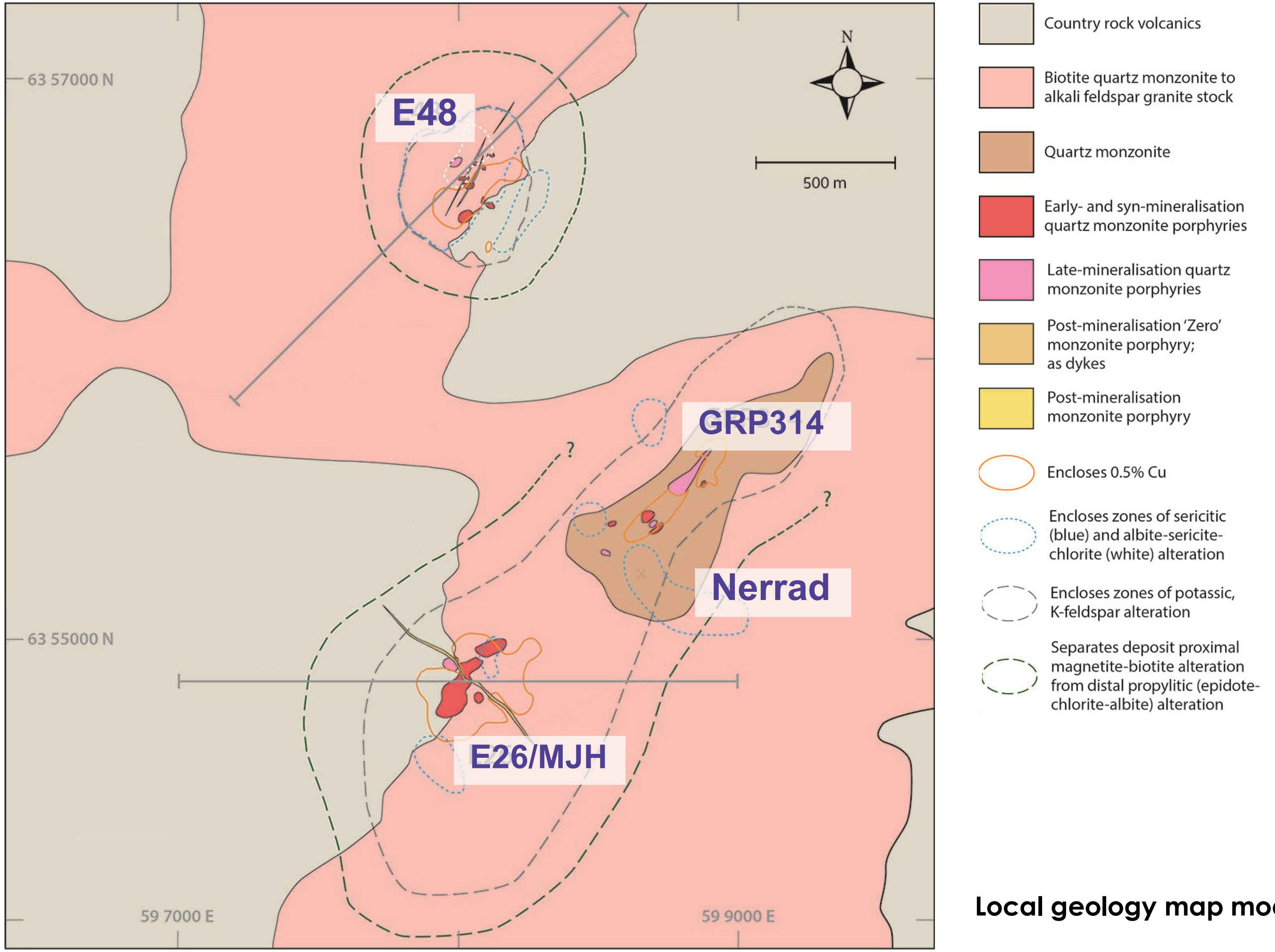
- No appreciable difference in timing of main stage mineralising monzonite intrusions (Wells et. al. 2020)
- Differences in oxidation and volume of fertile melt
- Spatial extent of sulphide mineralisation shells and ore zones in each system observed to be a function of;
    - Primary texture and grainsize of host-rock sequence (porosity and permeability)
    - Lesser (local) influence of secondary permeability caused by fluid overpressure-induced fracturing
- Permeability effects enhanced in intrusion-hosted systems - generally tight, lower grade core, with broad gradation to background copper values



Bornite rimming chalcopyrite within compositionally zoned K-feldspar megacryst in quartz monzonite porphyry – E22 Deposit (Photo: R. Lesh)


THE GOOD
THE BAD
AND THE UGLY
Not As Good
Still OK
Lets talk overpressure and wall rock influence on porphyry formation in intrusion-hosted deposits

Intrusion-hosted Porphyries

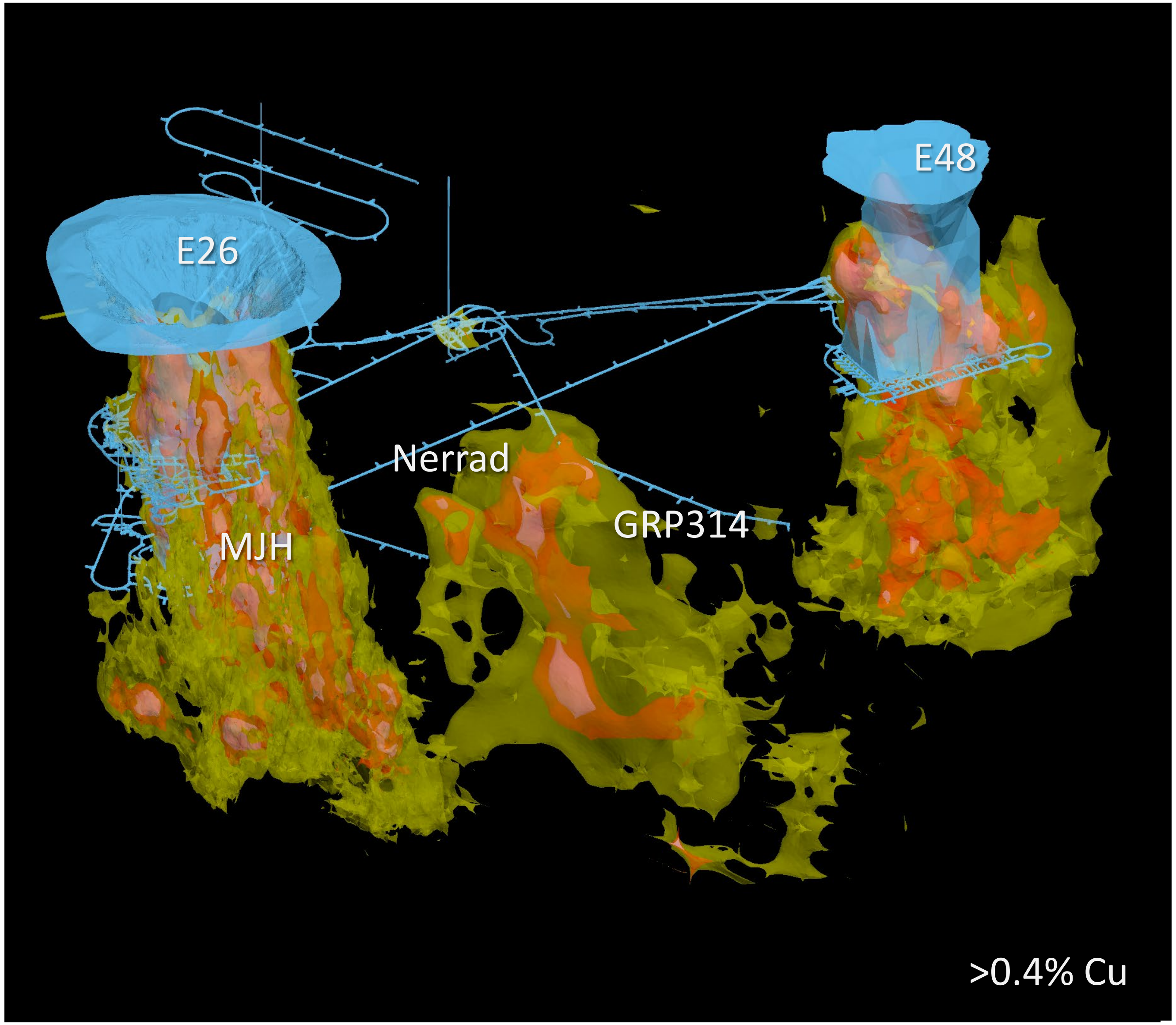


Local geology map modified from Owens et. al. (2017) after Pacey (2016)

- GRP314, MJH, and Nerrad entirely within pre- to early syn-mineral monzonites
- E26 and E48 mineralisation within same monzonites at depth
- GRP314 and Nerrad truncated by E-dipping low angle structure (Altona Fault)

Features of Intrusion-Hosted Deposits

CMOC | Northparkes



- Commonly broader low-grade halo compared to volcanic-hosted systems
- Ubiquitous ‘red-rock’ alteration

  albite > k-feldspar > hematite

- Common upward-flaring structurally controlled zones of phyllic alteration
- Low As (<10ppm), elevated Zn (60-100ppm) compared to volcanic hosted systems
- Better grades (Cu) where overpressure has occurred on mineralising porphyry carapace
- Poorly defined contacts to intrusive phases

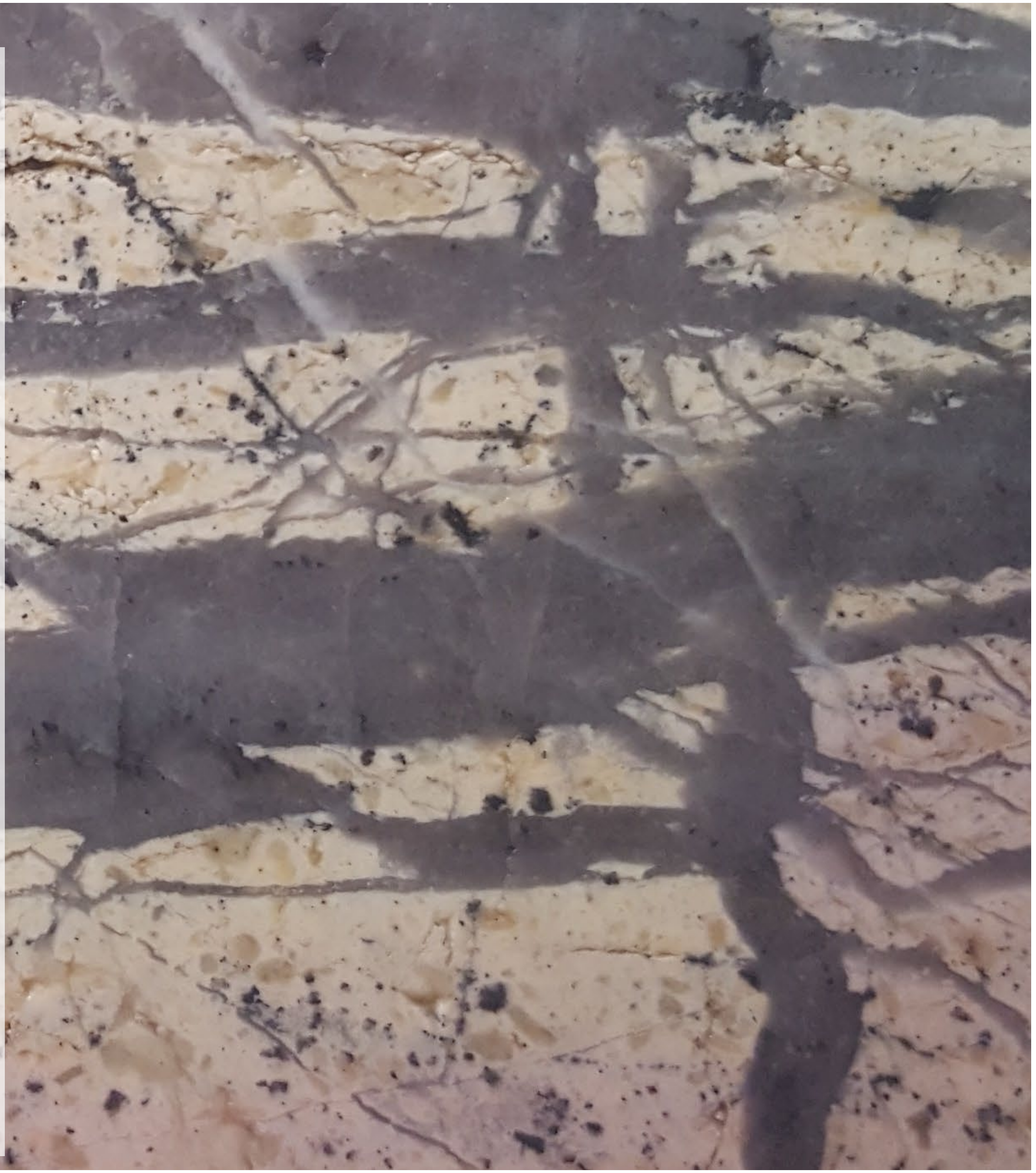
Factors Required for Good Porphyry

Fundamental Controls

- Fertility of the Magma (can it carry metal?)
- Volume of fertile magma you can flux up (how much metal-rich magma?)
- An efficient (but not too efficient!) plumbing system to get the magma into the shallow crust

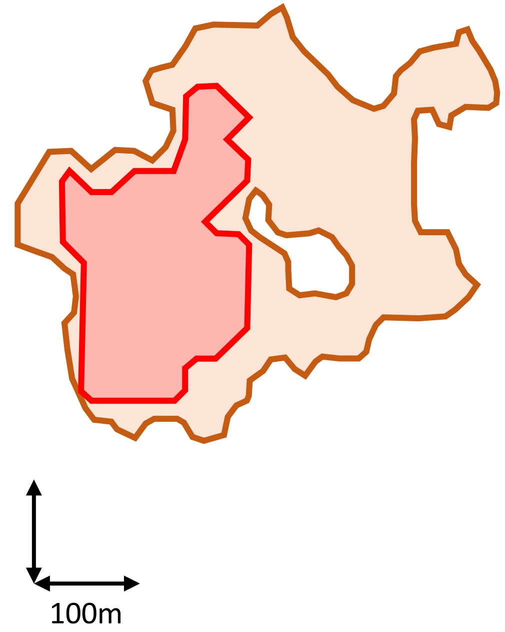
Local Factors

- The environment the magma is fluxed into in the shallow crust (porosity/permeability)
- The rate at which the magma cools and exsolves the metals (and the things that carry them…)

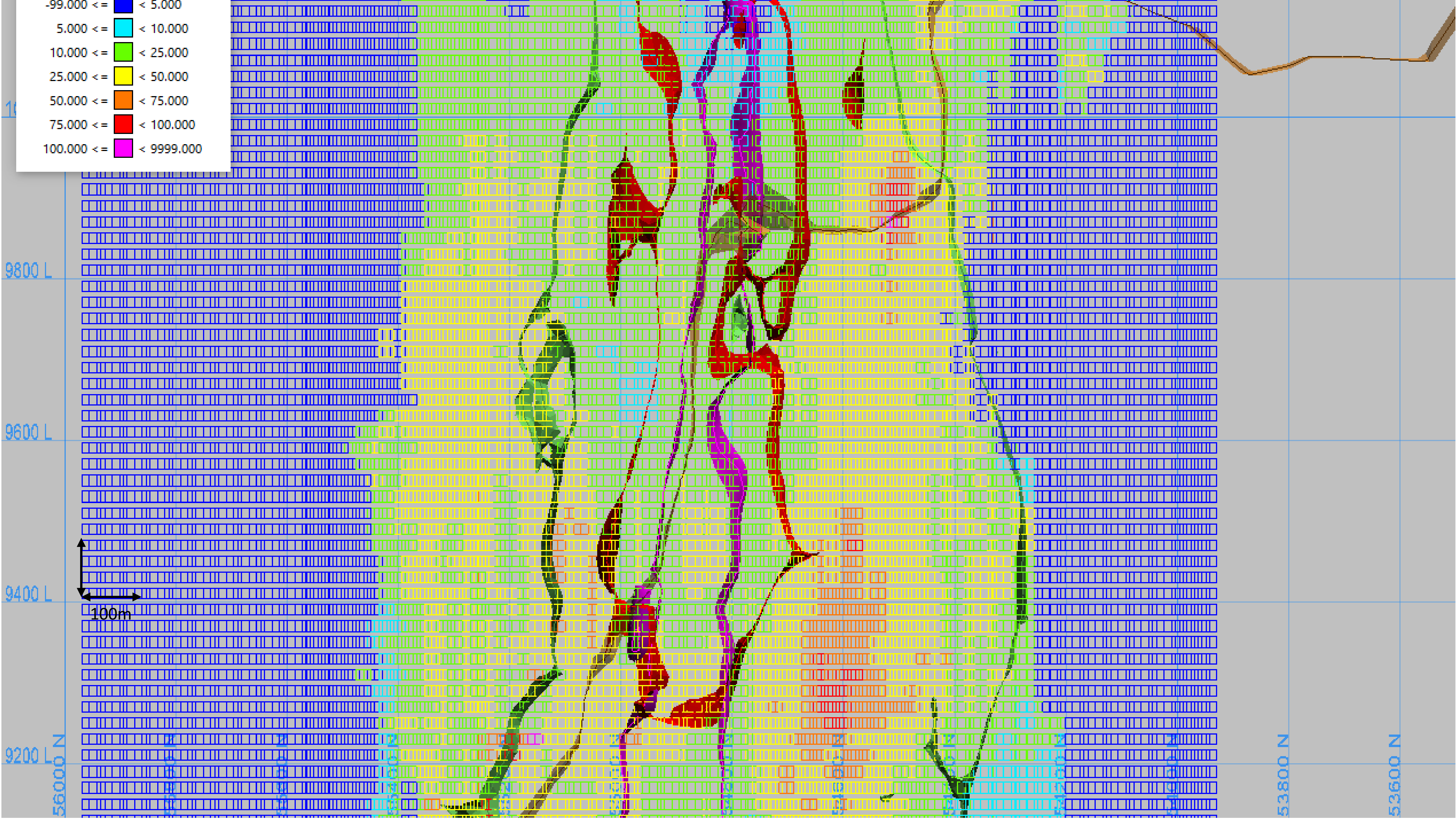


THE GOOD

E26



- Brittle volcanic, and monzonite (BQM) hosts
- Multiple mineralising phases
- >600m of mineralizing QMP emanating through and above BQM stock
- Successive overpressure events on carapaces
- Sulphate-stable system – anhydrite-quartz veins
- Higher vein density associated with higher Cu and Au grades
- Vein-hosted, fracture controlled, and disseminated mineralization
- Au focused in and around QMPs - Mo outboard of best Cu
- Evidence of early fluid leakage – high level phyllic argillic alteration and elevated As, Mo, Sn, W in shallow portions of system
- Average core grades 1.2-1.8% Cu, 0.2-0.6ppm Au

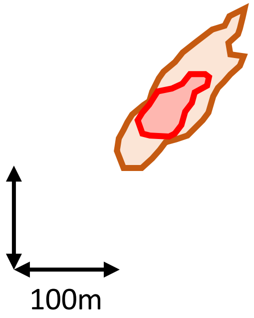


-99.000 <= < 5.000
5.000 <= < 10.000
10.000 <= < 25.000
25.000 <= < 50.000
50.000 <= < 75.000
75.000 <= < 100.000
100.000 <= < 9999.000
9800 L
9600 L
9400 L
9200 L
100m
56000 N
53800 N
53600 N

THE BAD

Not As Good

Nerrad

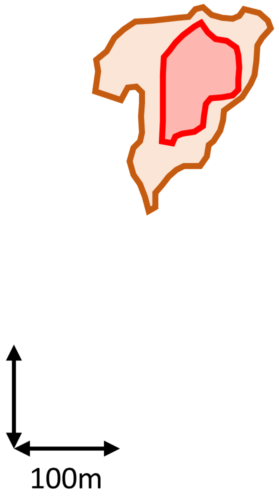


- Massive monzonite (BQM) and early fractionated equivalent (QMZ) hosts
- Single recognized mineralizing phase - entirely enclosed by stock
- Diffuse gradational contacts, common anisotropic textures - Little to no evidence of overpressure
- Sulphate-stable system – Anhydrite & quartz as phenocrysts
- Higher Cu and Au associated with less fractured core zones in mineralizing intrusion
- Disseminated >> fracture controlled>>vein-hosted, mineralisation
- Mo bearing veinlets crosscut strongest mineralization – minor evidence of fluid leakage – generally late quartz-sericite-pyrite faults
- Average core grades 0.6-0.8% Cu, 0.4-2.0ppm Au

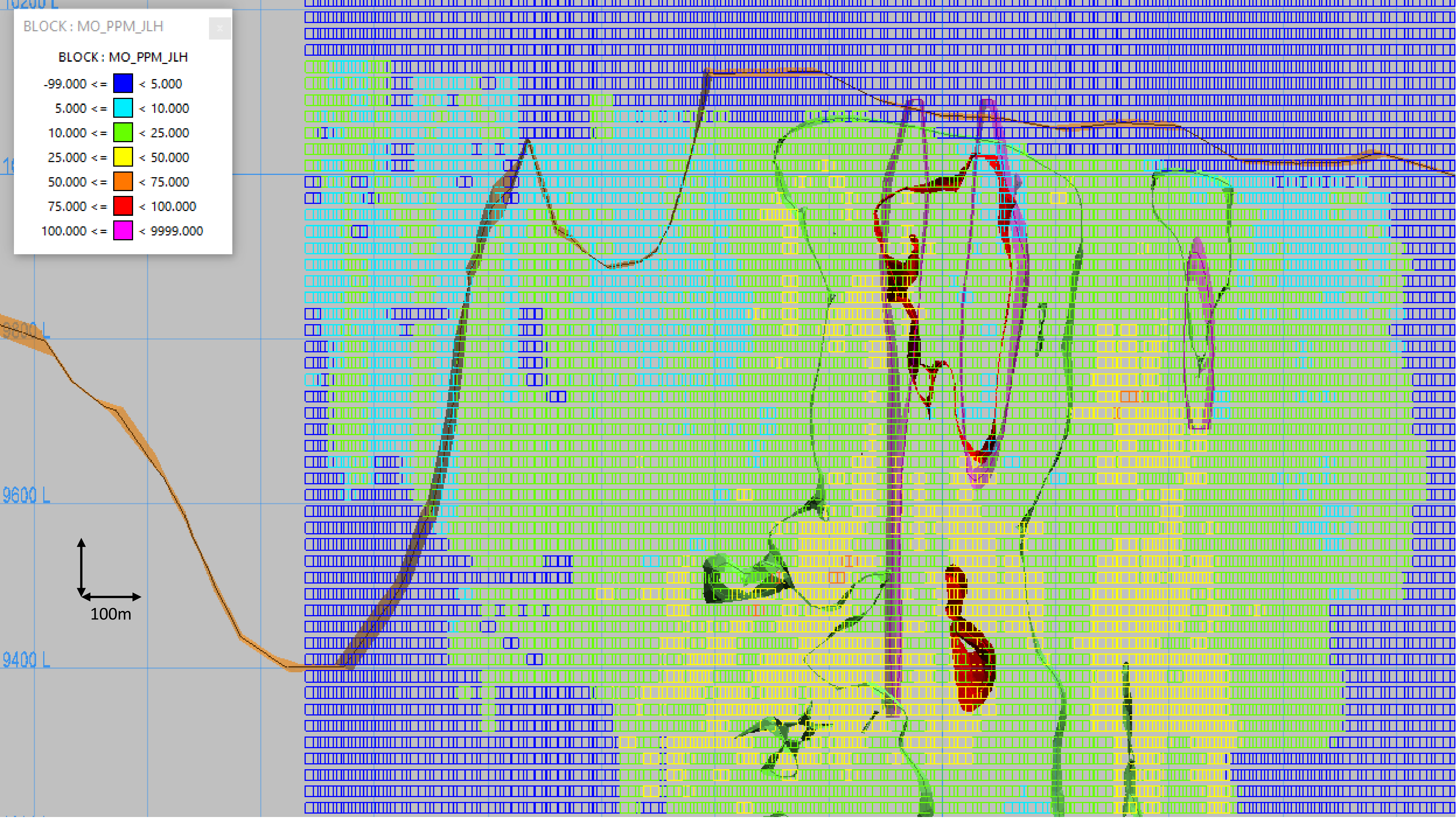
AND THE UGLY

Still OK

GRP314



- Hybrid system
- Massive monzonite (BQM) and early fractionated equivalent (QMZ) hosts
- Multiple mineralizing phases - within stock
- Some sharp, some diffuse gradational contacts, local anisotropic textures – some evidence of overpressure
- Sulphate-stable system – anhydrite & quartz as phenocrysts and veins
- Higher Cu and Au associated with stronger veining, lower tenor high-grade zones in less fractured late syn-mineral intrusions
- Fracture controlled>>vein-hosted= disseminated mineralisation
- Mo bearing veinlets over the top of the system, less at depth – common evidence of fluid leakage as late quartz-sericite-pyrite faults
- Average core grades 0.5-0.8% Cu, 0.1-0.3ppm Au


BLOCK : MO_PPM_JLH
BLOCK : MO_PPM_JLH
-99.000 <= < 5.000
5.000 <= < 10.000
10.000 <= < 25.000
25.000 <= < 50.000
50.000 <= < 75.000
75.000 <= < 100.000
100.000 <= < 9999.000
9800 L
9600 L
9400 L
100m

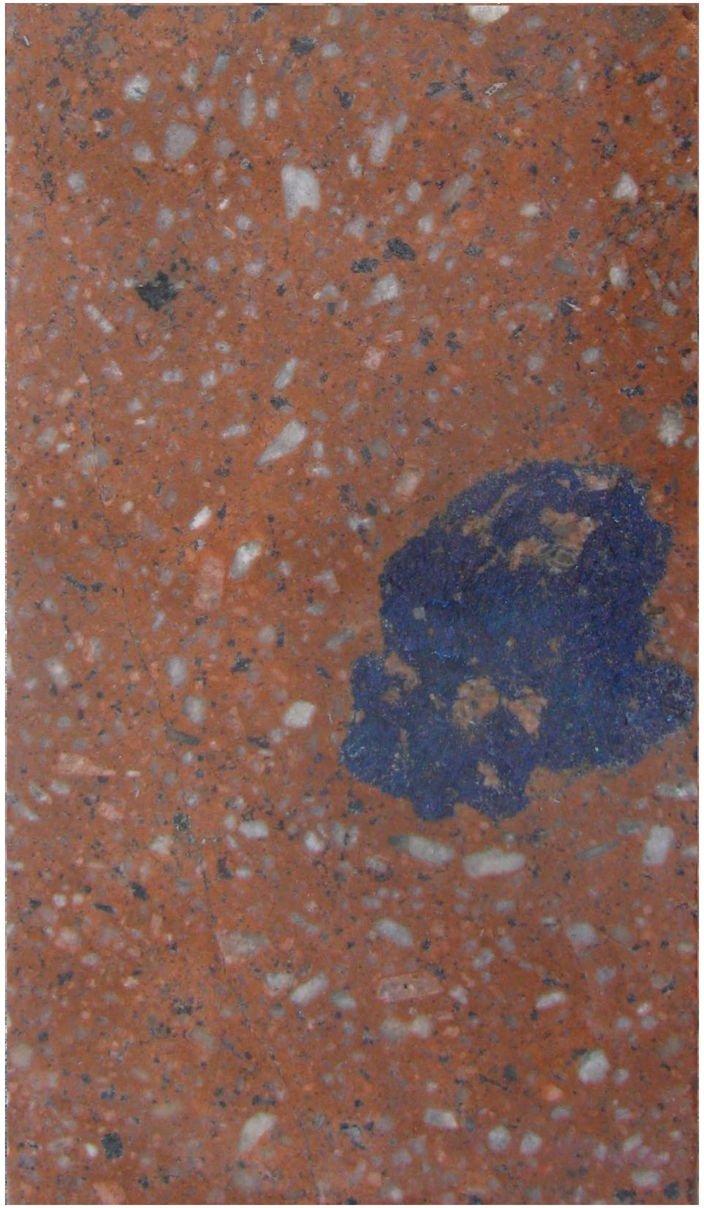
Why the Differences Between the Good, the Bad, and the Ugly?

- Fundamental Controls
- Fertility of the Magma
- Volume of fertile magma you can flux up
- An efficient plumbing system to get the magma into the shallow crust

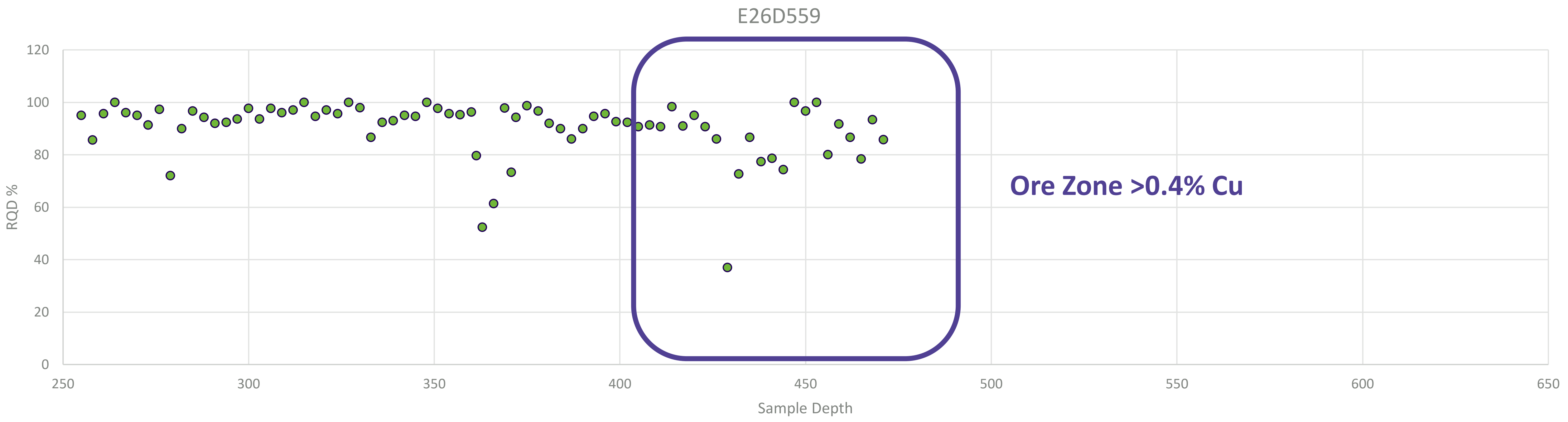
- Local Factors
- The environment the magma is fluxed into in the shallow crust
- The rate at which the magma cools and exsolves the metals

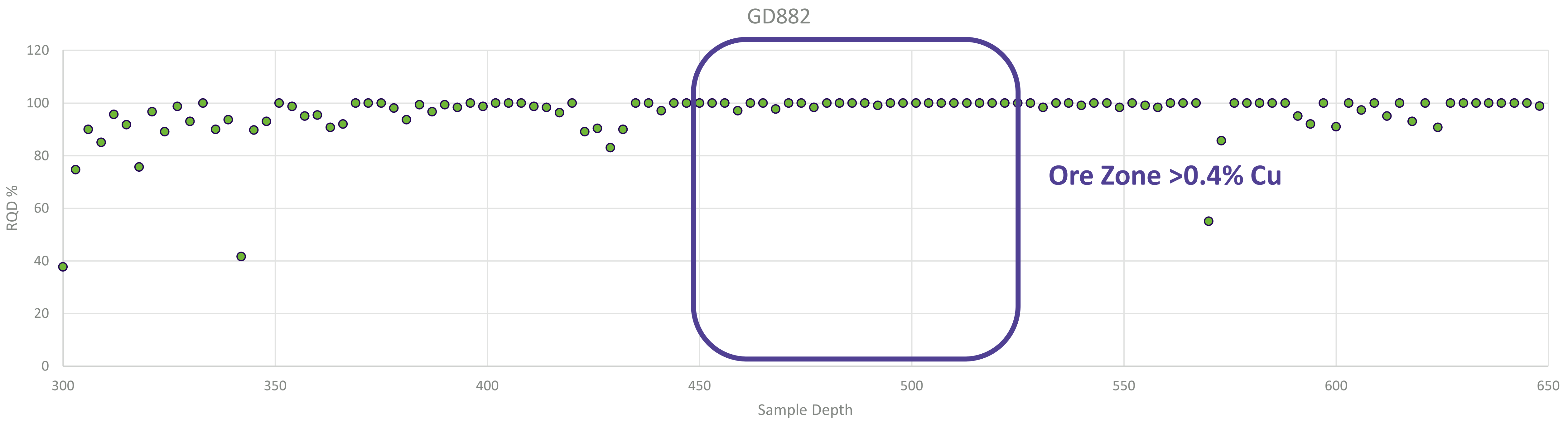
Elements of <u>Failed Overpressure</u> in the system

Evidence of Failed Overpressure



- Confining pressure too great for volume of magma fluxed = stalled system
- *Recognised through texture, contacts, and vein density*
- Absence of clear discordant contacts –small thermal gradient between host / porphyry
- 'Mushy' contact breccias, with grain-boundary controlled margins on wallrock clasts
- Abraded feldspar phenocrysts in a f.g. to m.g. equigranular groundmass
- Abundance of quartz or sulphate 'phenocrysts'
- Lower vein density – low # natural rockmass defects (RQD)
- Dominance of disseminated sulphide –at grain boundaries in groundmass
- Anisotropic textures – mairolitic cavities, sulphide clots
- Strongly telescoped alteration assemblages


E26D559
RQD %
Sample Depth
Ore Zone >0.4% Cu


GD882
RQD %
Sample Depth
Ore Zone >0.4% Cu

Failed Overpressure Due to Depth?

- If Failed Overpressure was solely a function of increased confining pressure at depth…
- Expect to see similar effects at depth in the known economic systems (E26, E48)
- Drilling >1400m vertical in E26, and >1100m vertical in E48- within BQM stock
- Some features present – e.g. ‘mushy’ contacts
- Still strong evidence of overpressure
- Implies differences between the systems due to volume of fertile magma fluxed, and time difference between host / mineralizing porphyry

Implications of Failed Overpressure

- Importance of recognizing local controls to mineralisation
- Variability within Districts/Camps
- Early recognition may give clues to scale of mineralized system and grade
- Also changes the exploration process – alteration and grade may indicate an 'edge of core' position, when actually in centre already
- Prospectivity modelling based on relative position to vs. within regional stock
- Different exploration methods – not necessarily looking for 'damaged rock'

Conclusions

- Significant economic porphyry systems can occur within larger comagmatic intrusions, where a permissive setting is present (e.g. E26 deposit)
- 'Hot' hosts like the BQM and QMZ at Northparkes can lead to gradual broad fluid loss at time of formation, leading to small or lower grade systems, depending on volume of magma batched up into shallow crust
- Hard boundaries on larger stocks, where intruded by mineralising porphyries can inhibit magma ascent – homogenising magma with cooling host rock
- These conditions prevent overpressure from occurring in low-volume mineralising magma batches
- Slow-cooling also inhibits development of typical porphyry features such as true porphyritic texture and stockwork vein arrays formed during overpressure
- Care is required to assess potential at each exploration stage

Acknowledgements

- Past discoverers/workers on the stock hosted deposits: Dedy Hendrawan, Adam Schwarz who set the ball rolling…
- The discovery team for Nerrad and MJH: Fuyuki Kaneto, Corey Jago, Darren Priest, Tristan Wells, Luke Perry & Krista Sutton
- The entire Exploration and Life of Mine team at Northparkes, past and present
- Researchers at UTAS – CODES for being a sounding board for random ideas: Dave Cooke, Lejun Zhang and past PhD students
- Thanks to the organising committee for the opportunity, and CMOC – Northparkes Mines for permission to present