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Exploration criteria for Ernest Henry style IOCGs in the Mt Isa Block

Nick Oliver

Director, HCOVGlobal,

Adjunct Professor of Economic Geology, JCU

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- General IOCG characteristics
- General features of EH that relate to exploration
- Magnetite chemistry at EH
- EH Ore genesis model
- Alteration and metal zonation around the EH orebody
- two difference types of IOCGs regionally and diversity of geophysical signals
- Regional to local distribution of specific breccia styles
- Geomechanical modelling (2D) of structural corridors and their significance → 3D modelling at Ernest Henry, John McLellan

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Iron Oxide Copper-Gold Deposits:
Geology, Space-Time Distribution, and Possible Modes of Origin

PATRICK J. WILLIAMS,[†]
Economic Geology Research Unit, School of Earth Sciences, James Cook University, Townsville 4811, Australia

MARK D. BARTON, DAVID A. JOHNSON,
Center for Mineral Resources, Department of Geosciences, University of Arizona, Tucson, Arizona 85721

LLUÍS FONTBOTÉ, ANTOINE DE HALLER,
Département de Minéralogie, Université de Genève, Genève CH-1211, Switzerland

GEORDIE MARK,[°] NICHOLAS H.S. OLIVER,
Economic Geology Research Unit, School of Earth Sciences, James Cook University, Townsville 4811, Australia

AND ROBERT MARSCHIK
Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität, Luisenstrasse 37, Munich D-80333, Germany

Common features of IOCGs

(Williams et al., 2005; Econ. Geol. Anniversary Volume)

1. **Presence of copper with, or without gold as economic metals;**
2. **Distinctly hydrothermal vein, breccia, and/or replacement ore styles, characteristically in specific structural sites;**
3. **Mineral parageneses that indicate ore formation under low activities of reduced sulphur (e.g. high ratios of iron oxides to iron sulfides and/or pyrrhotite more abundant than pyrite);**
4. **The iron oxides have low Ti contents compared to those in most igneous rocks;**
5. **Ubiquitous CO2 and brine fluid inclusions**
6. **Few intimate associations with igneous intrusions such as characterize porphyry and skarn ore deposits.**


NORWAY


WALKABOUT CREEK
HOTEL
FOSTER'S
Menu


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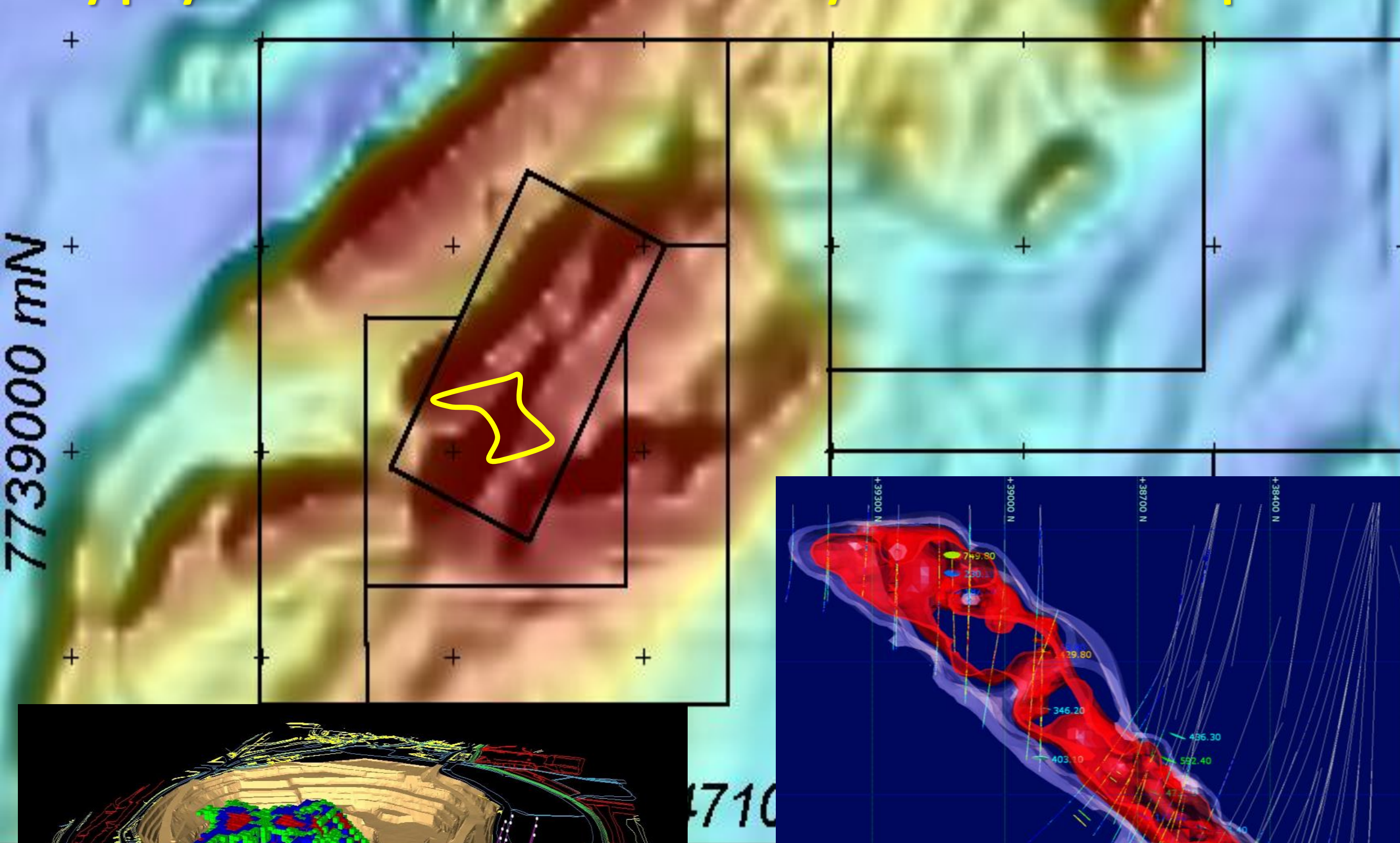
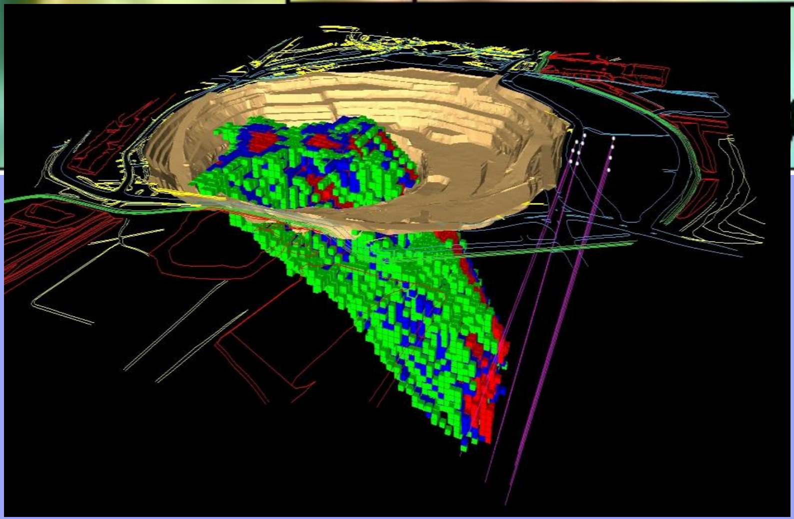
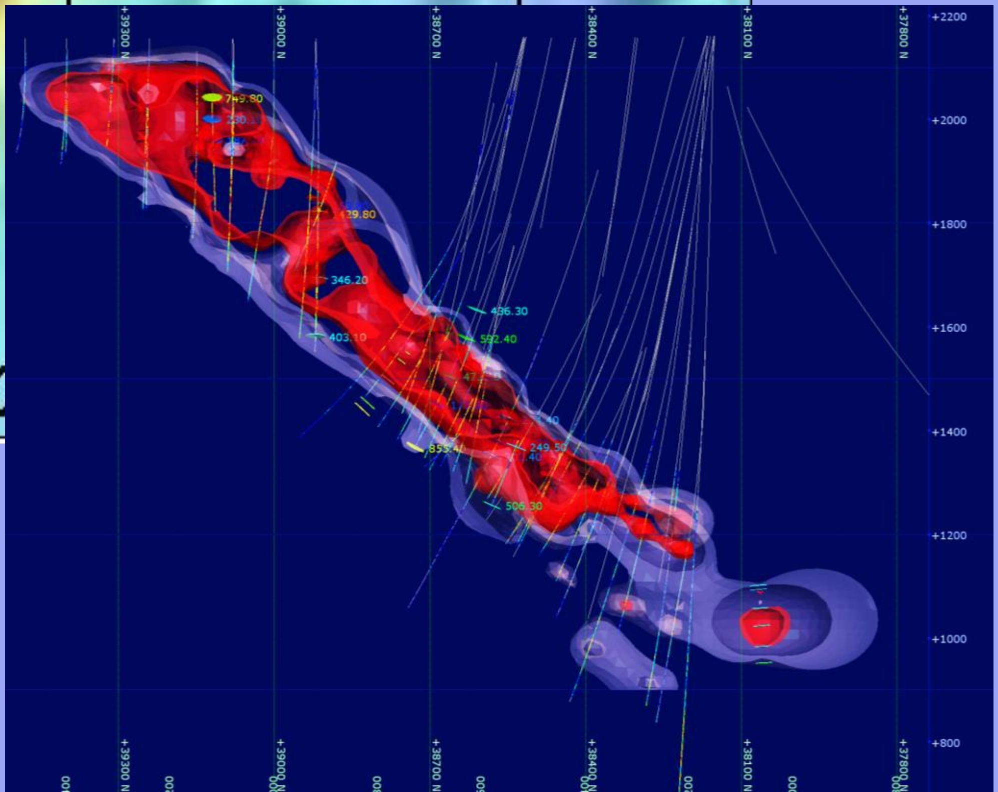
Fundamental orebody characteristics

Key physical features of the orebody that relate to exploration

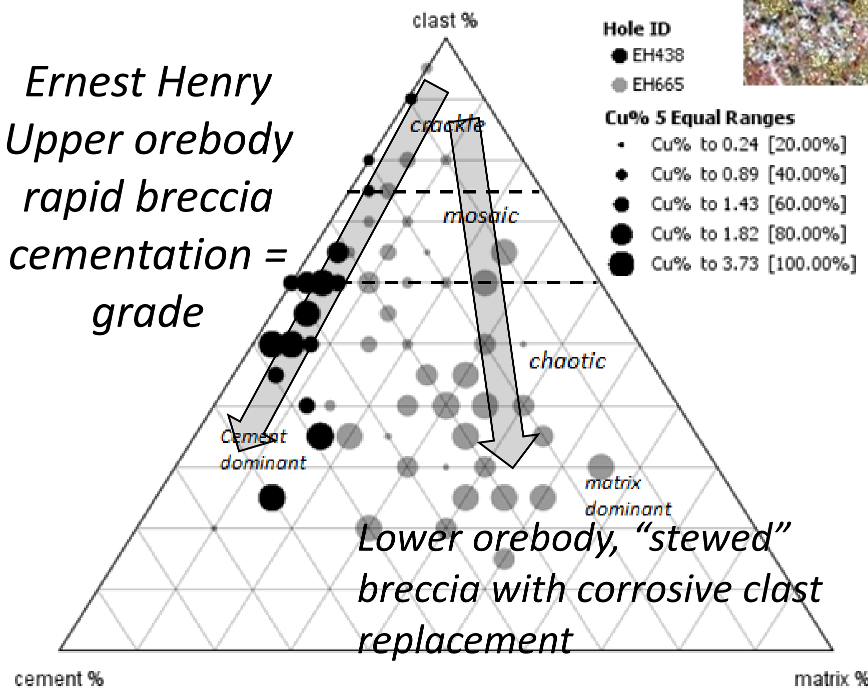


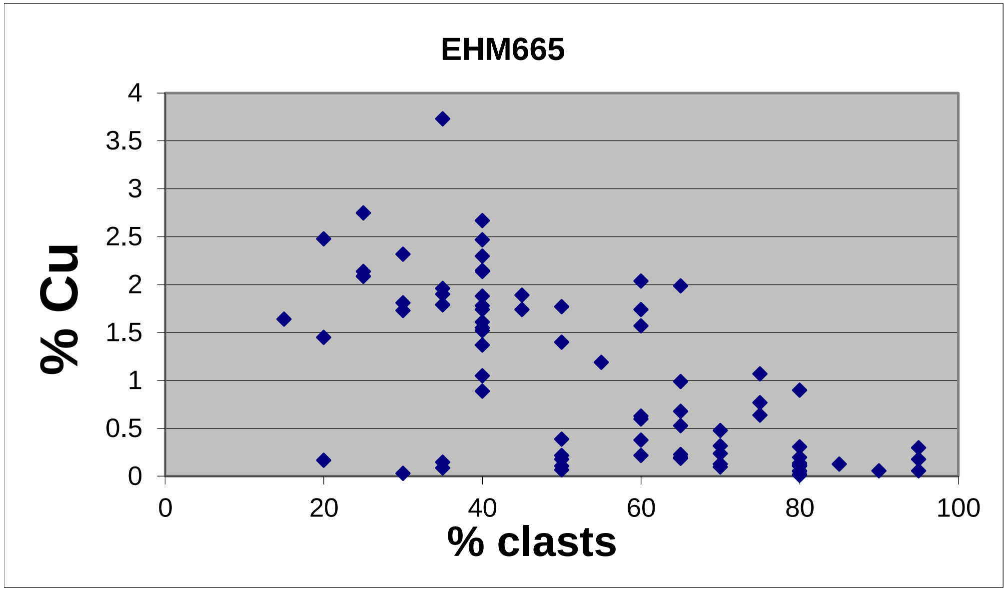




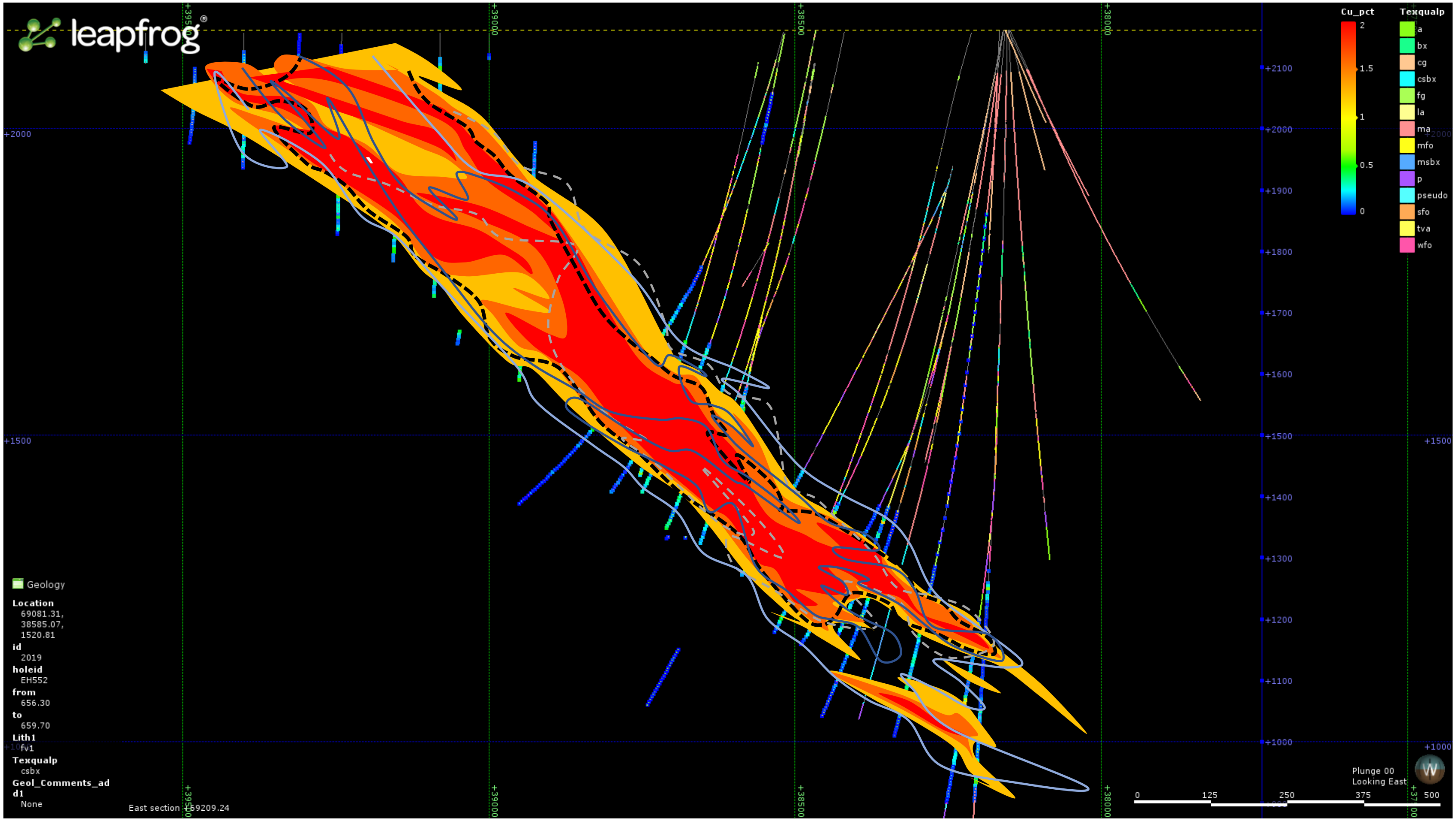

CBX
MBX

- Ernest Henry shows an *almost strict* relationship between detailed breccia character and Cu+Au grades and distributions (clast %, roundness, spacing)
- …. Implying that the specifics of breccia cementation <u>controlled</u> the deposition process





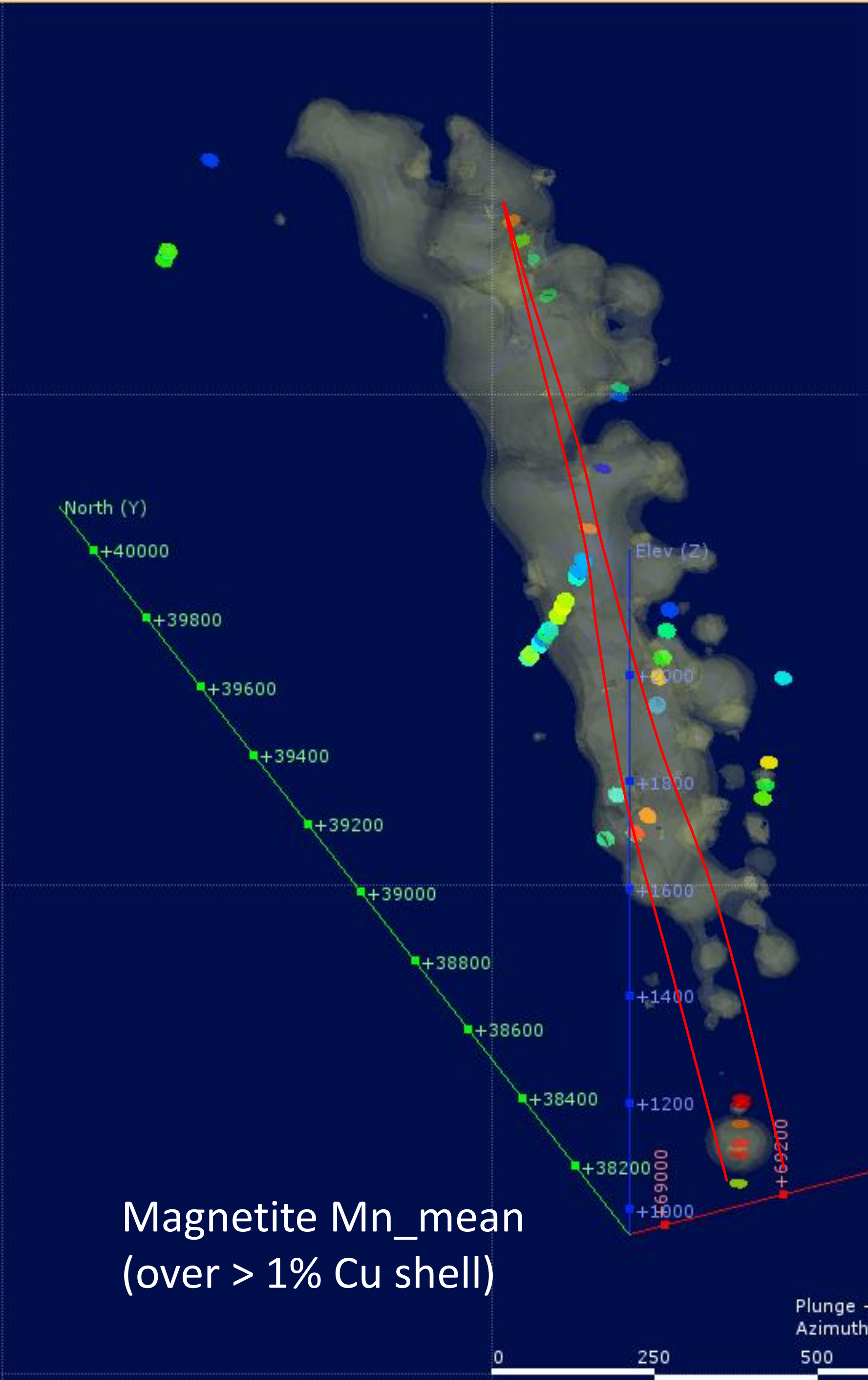
Colour shades: logged breccia style (red MBX, yellow CBX)
Outlines: grade shells (Cu, Au, S)



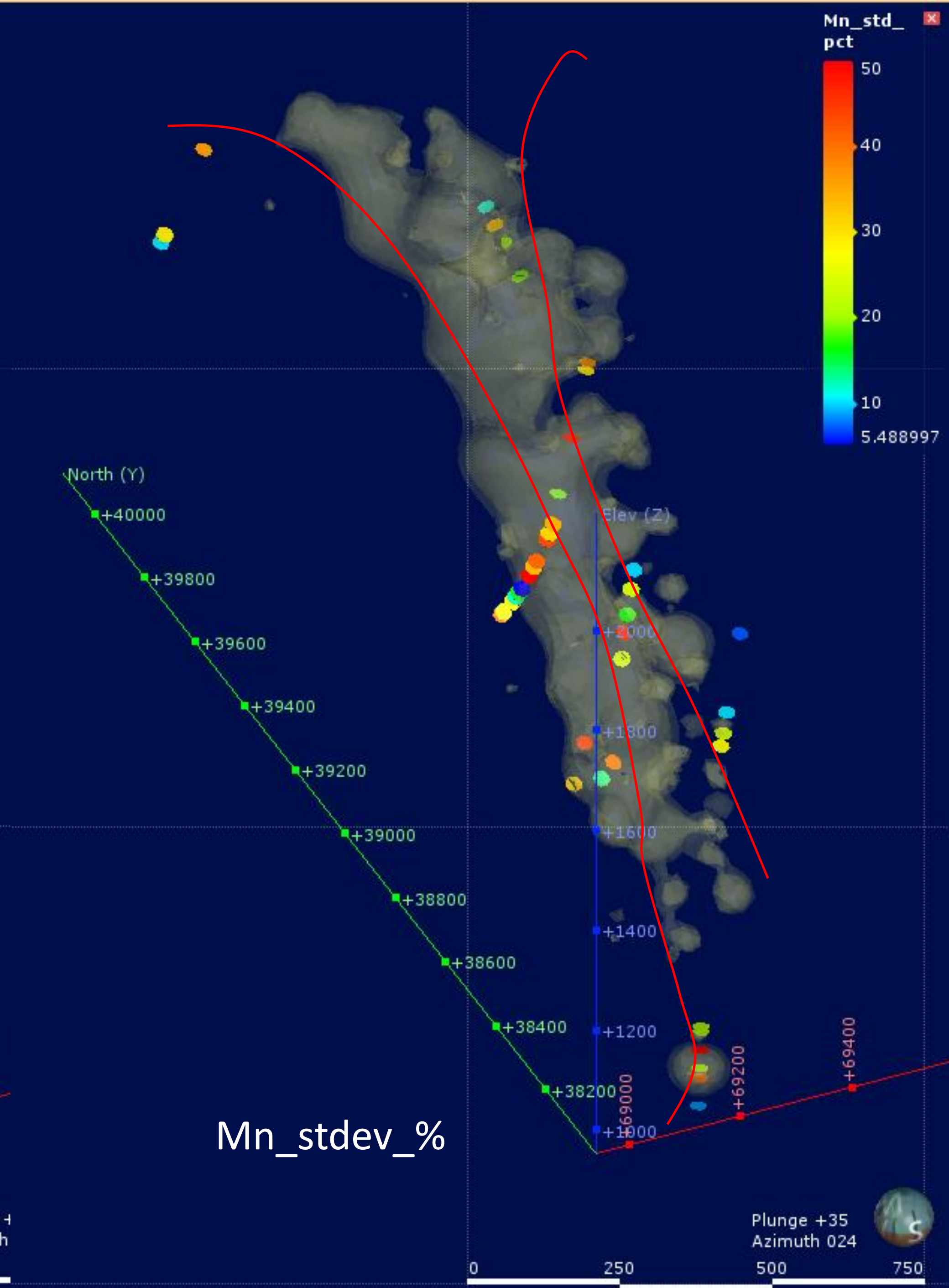
69209.24 E

Au > 0.45 g dashed black, S > 3.7% dashed grey

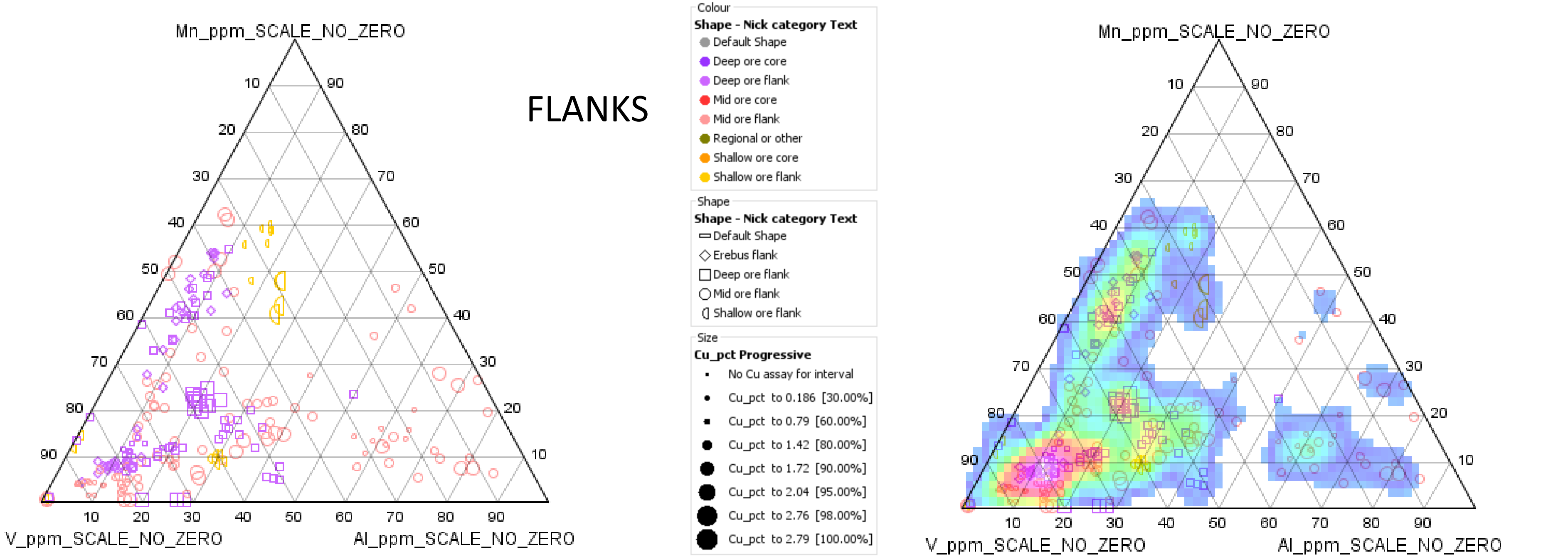
Magnetite chemistry – brownfields or greenfields potential?

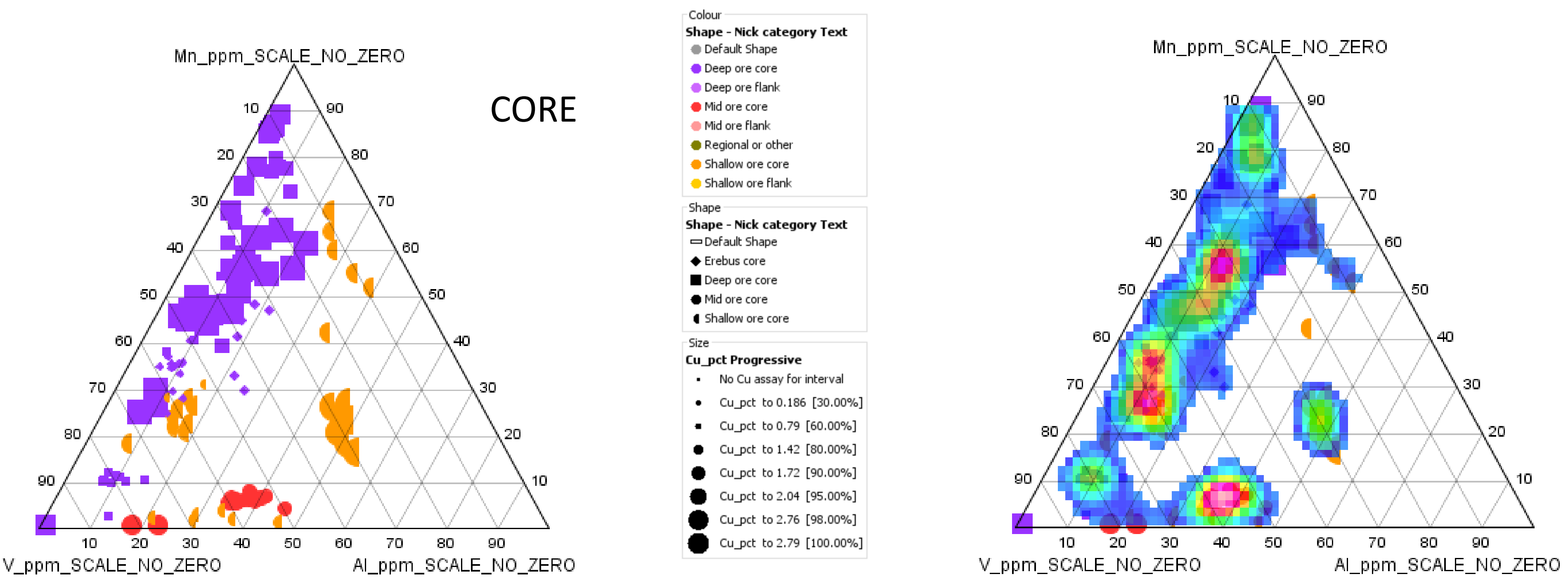


Magnetite Mn_mean (over > 1% Cu shell)



Mn_stdev_%

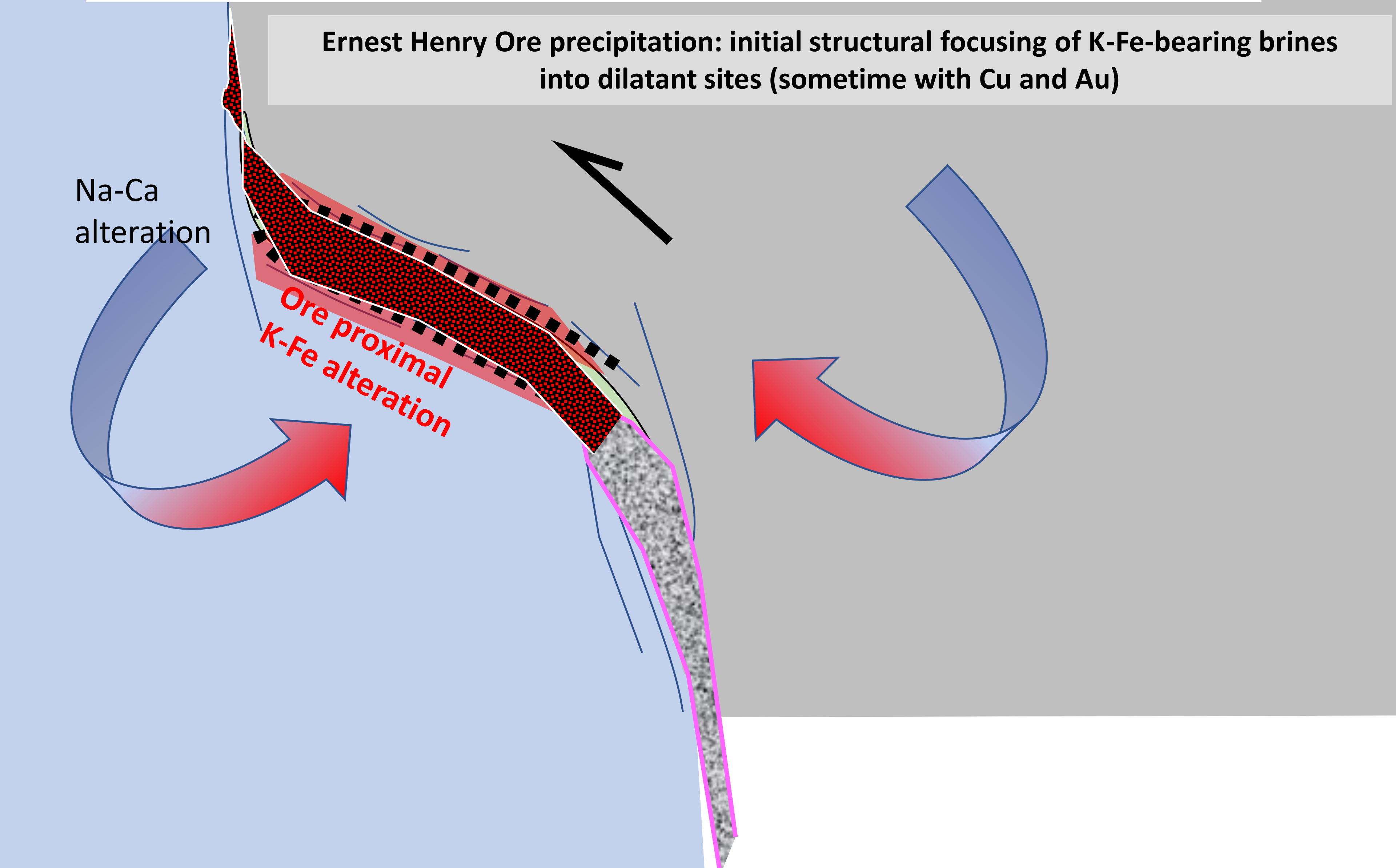

FLANKS
Mn_ppm_SCALE_NO_ZERO
V_ppm_SCALE_NO_ZERO
Al_ppm_SCALE_NO_ZERO
Colour
Shape - Nick category Text
Default Shape
Deep ore core
Deep ore flank
Mid ore core
Mid ore flank
Regional or other
Shallow ore core
Shallow ore flank
Shape
Shape - Nick category Text
Default Shape
Erebus flank
Deep ore flank
Mid ore flank
Shallow ore flank
Size
Cu_pct Progressive
No Cu assay for interval
Cu_pct to 0.186 [30.00%]
Cu_pct to 0.79 [60.00%]
Cu_pct to 1.42 [80.00%]
Cu_pct to 1.72 [90.00%]
Cu_pct to 2.04 [95.00%]
Cu_pct to 2.76 [98.00%]
Cu_pct to 2.79 [100.00%]


CORE
Mn_ppm_SCALE_NO_ZERO
V_ppm_SCALE_NO_ZERO
Al_ppm_SCALE_NO_ZERO
Colour
Shape - Nick category Text
Default Shape
Deep ore core
Deep ore flank
Mid ore core
Mid ore flank
Regional or other
Shallow ore core
Shallow ore flank
Shape
Shape - Nick category Text
Default Shape
Erebus core
Deep ore core
Mid ore core
Shallow ore core
Size
Cu_pct Progressive
No Cu assay for interval
Cu_pct to 0.186 [30.00%]
Cu_pct to 0.79 [60.00%]
Cu_pct to 1.42 [80.00%]
Cu_pct to 1.72 [90.00%]
Cu_pct to 2.04 [95.00%]
Cu_pct to 2.76 [98.00%]
Cu_pct to 2.79 [100.00%]

Ore deposition and alteration

Super-deposits? Volume expansion of entrained magmatic-hydrothermal HCOS-Cu-Au fluidized breccias into brine-dominated structural sites

Ernest Henry Ore precipitation: initial structural focusing of K-Fe-bearing brines into dilatant sites (sometime with Cu and Au)



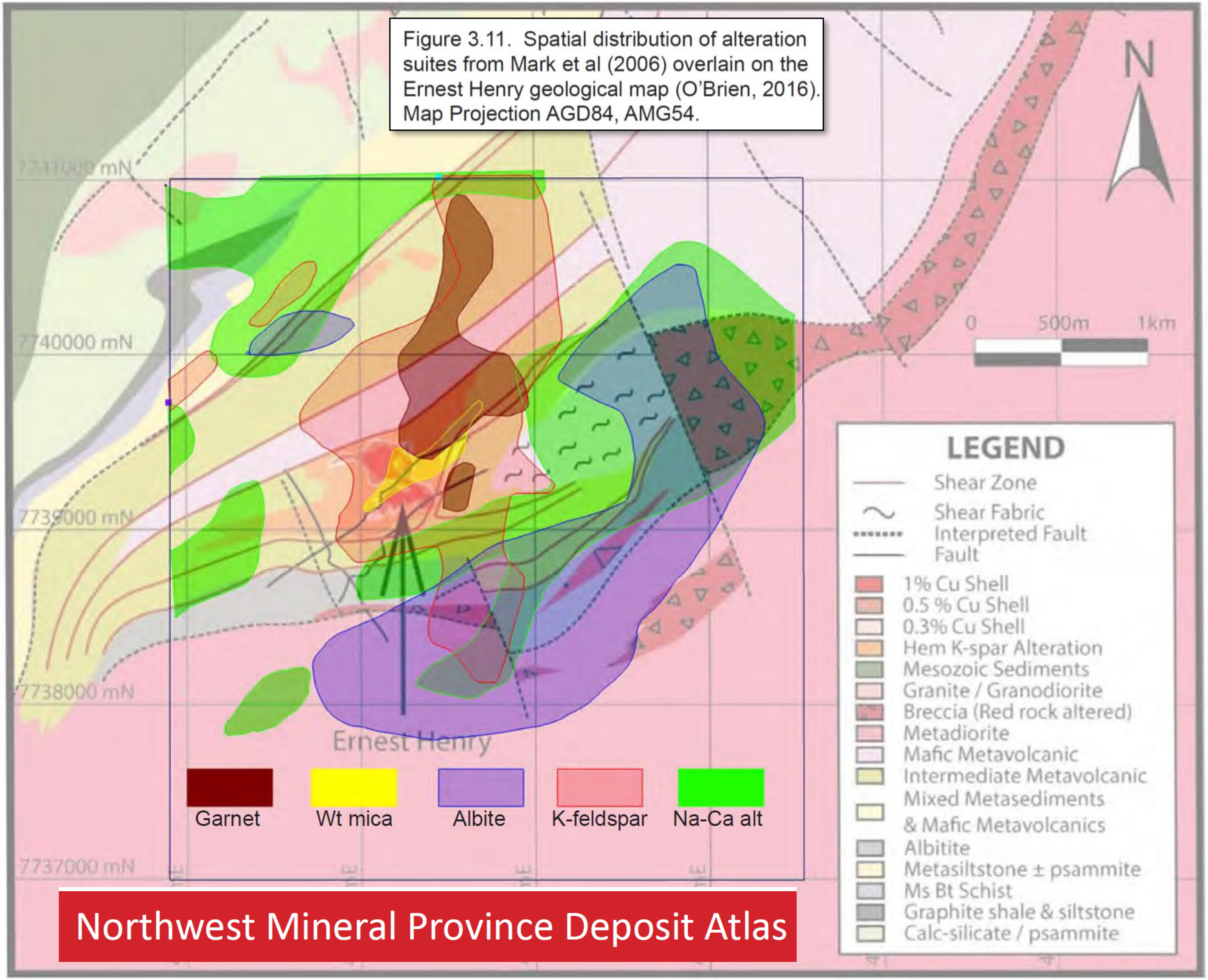
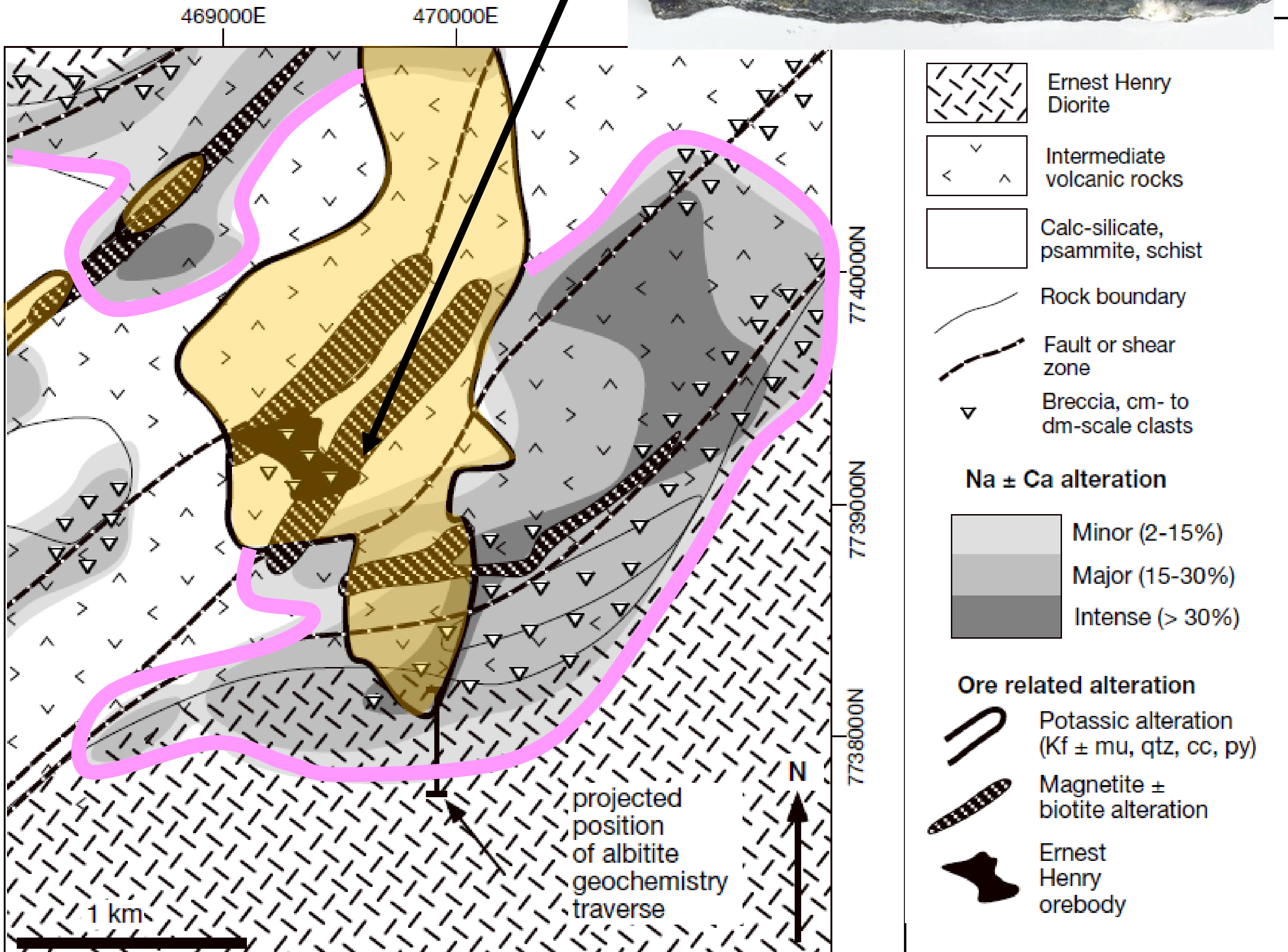


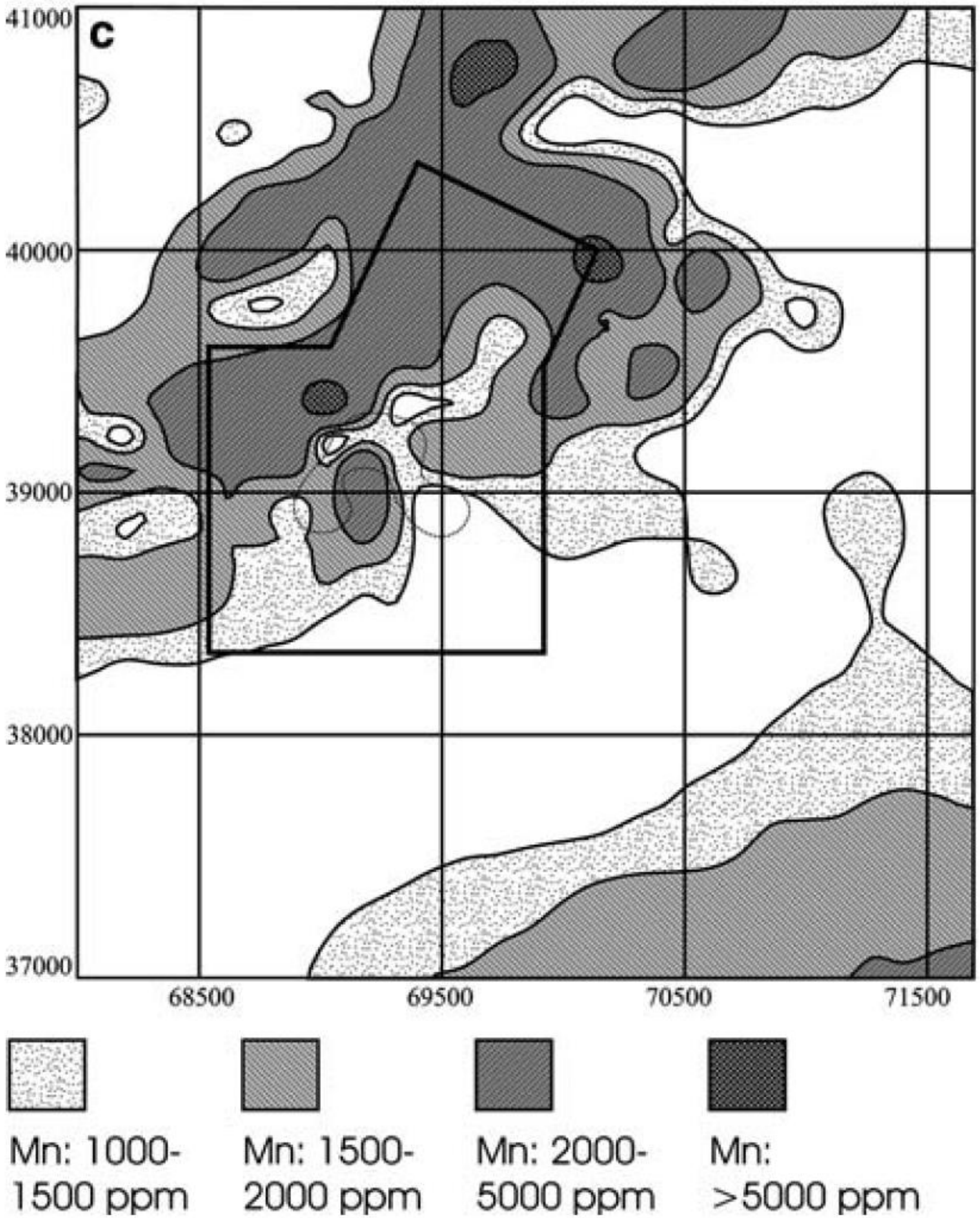
Figure 3.11. Spatial distribution of alteration suites from Mark et al (2006) overlain on the Ernest Henry geological map (O'Brien, 2016). Map Projection AGD84, AMG54.



Future potential research:

Distinguishing different albitite types to identify those which represent ore-related signals (versus regional albitites scouring Fe-K-Ca)

Ore stage alteration, rich in K, Fe, Mn



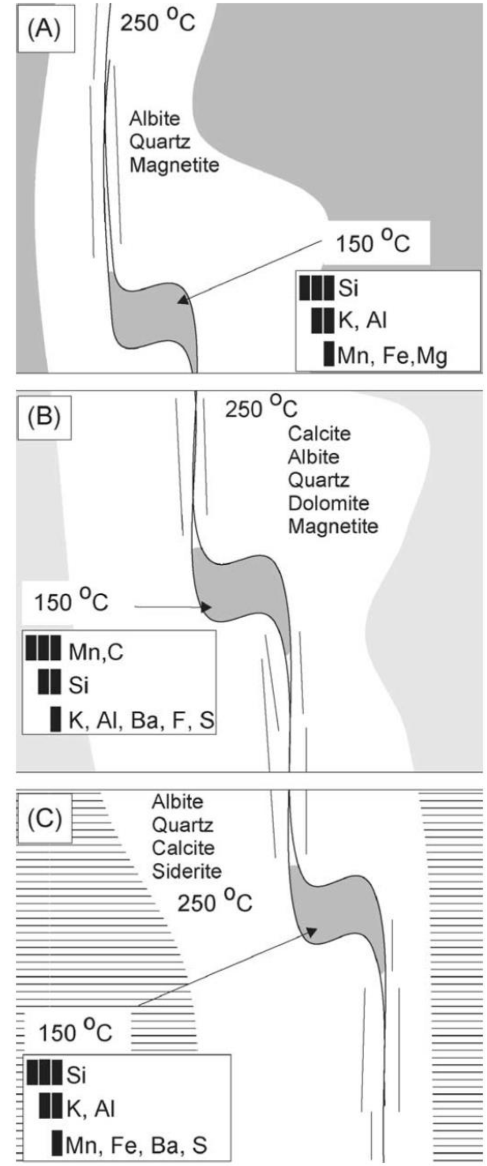
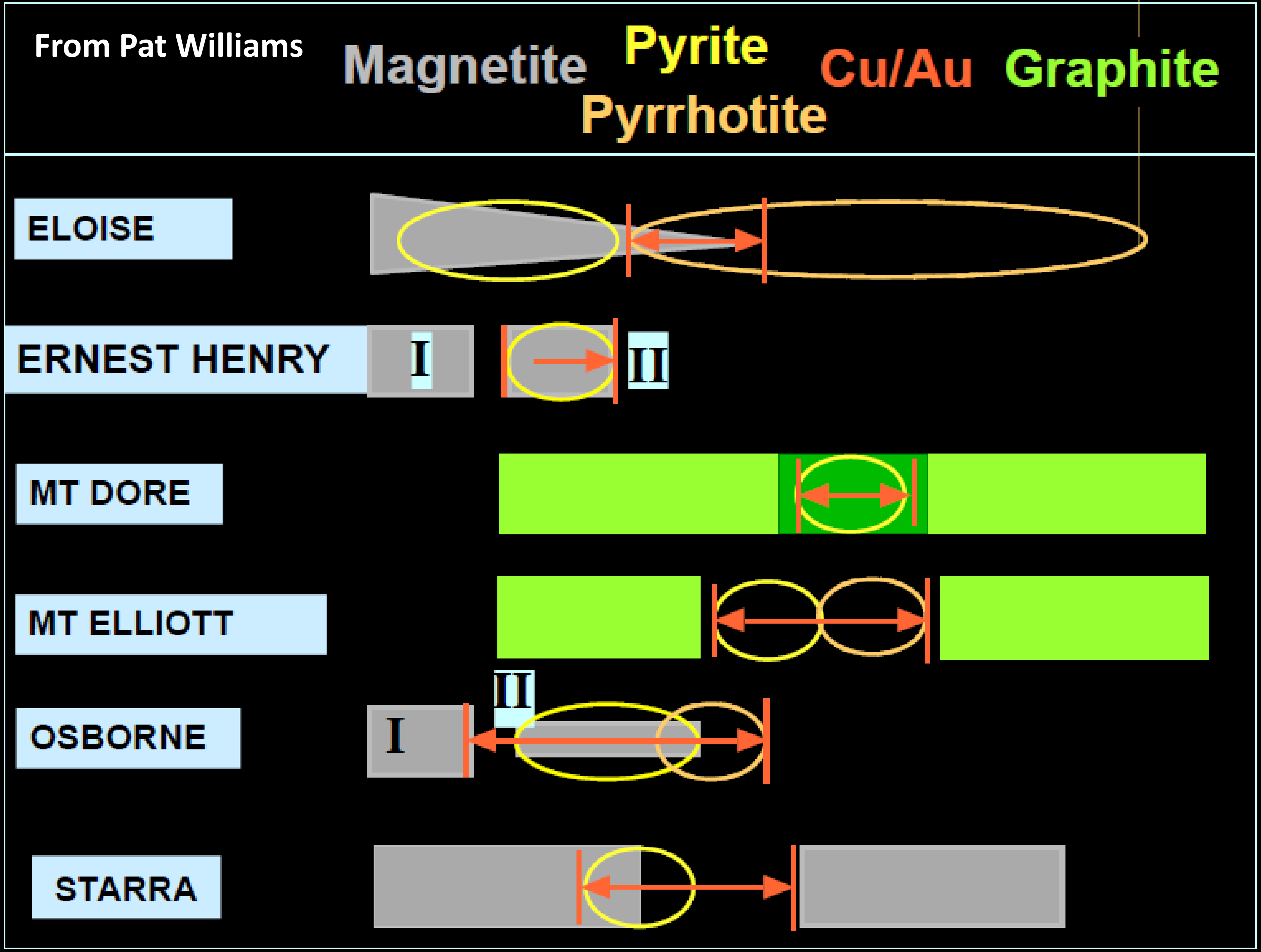
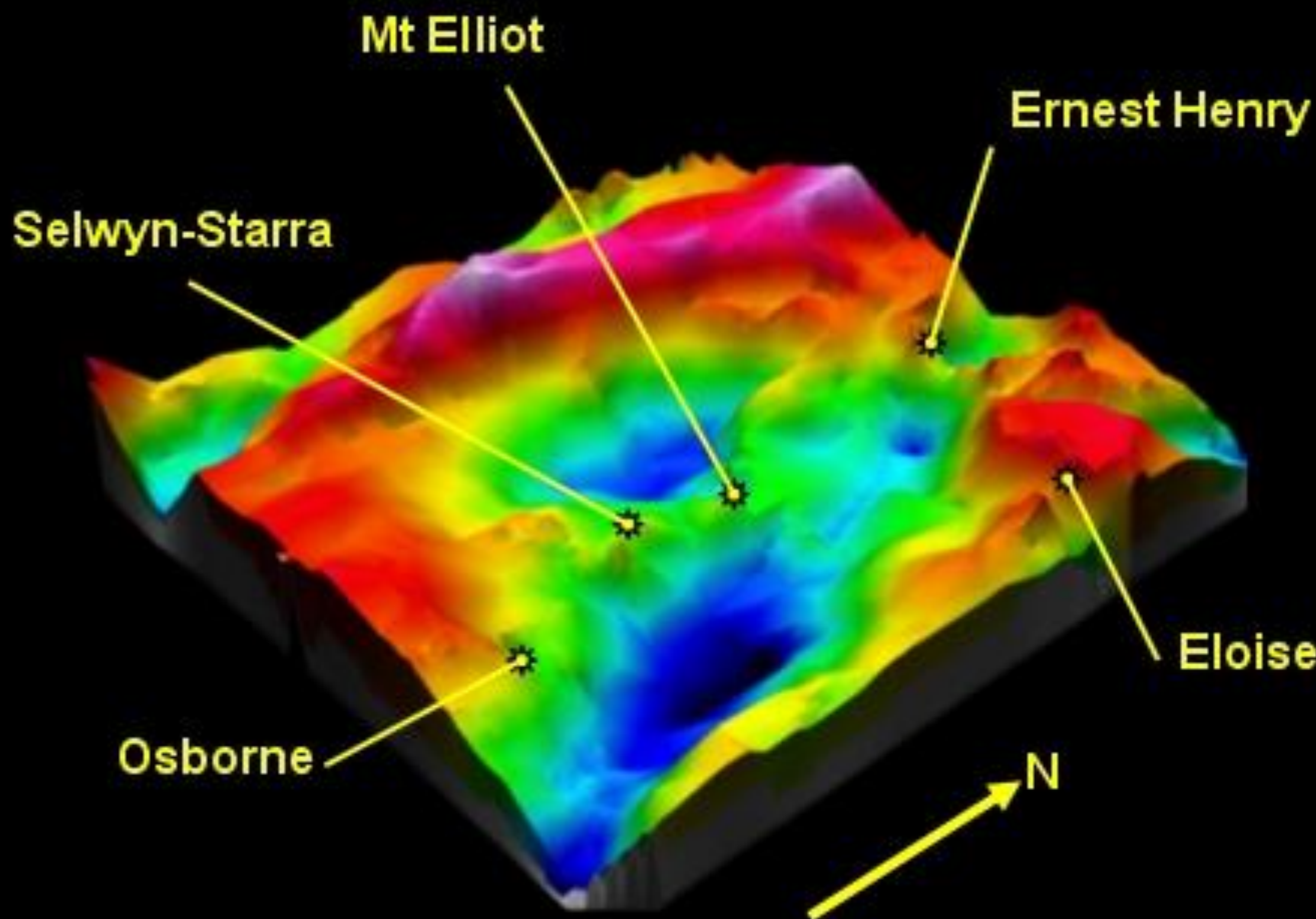


Fig. 8. Schematic cross-section of a hydrothermal conduit through three different rock types: (A) granitic rock; (B) calc–silicate rock; and (C) graphitic schist, showing their respective geochemical and mineralogical changes with cooling (300-100 °C) 'spent fluids'. The changes in chemistry are based on the results of cooling experiments shown in Fig. 6, where the number of bars adjacent to a range of elements represents the relative abundance (i.e., more bars being more significant) of that component at 150 °C in the hydrothermal assemblage.

Geophysical signals and prospectivity


From Pat Williams
Magnetite
Pyrite
Pyrrhotite
Cu/Au
Graphite
ELOISE
ERNEST HENRY
I
II
MT DORE
MT ELLIOTT
II
OSBORNE
I
STARRA

3D GRAVITY

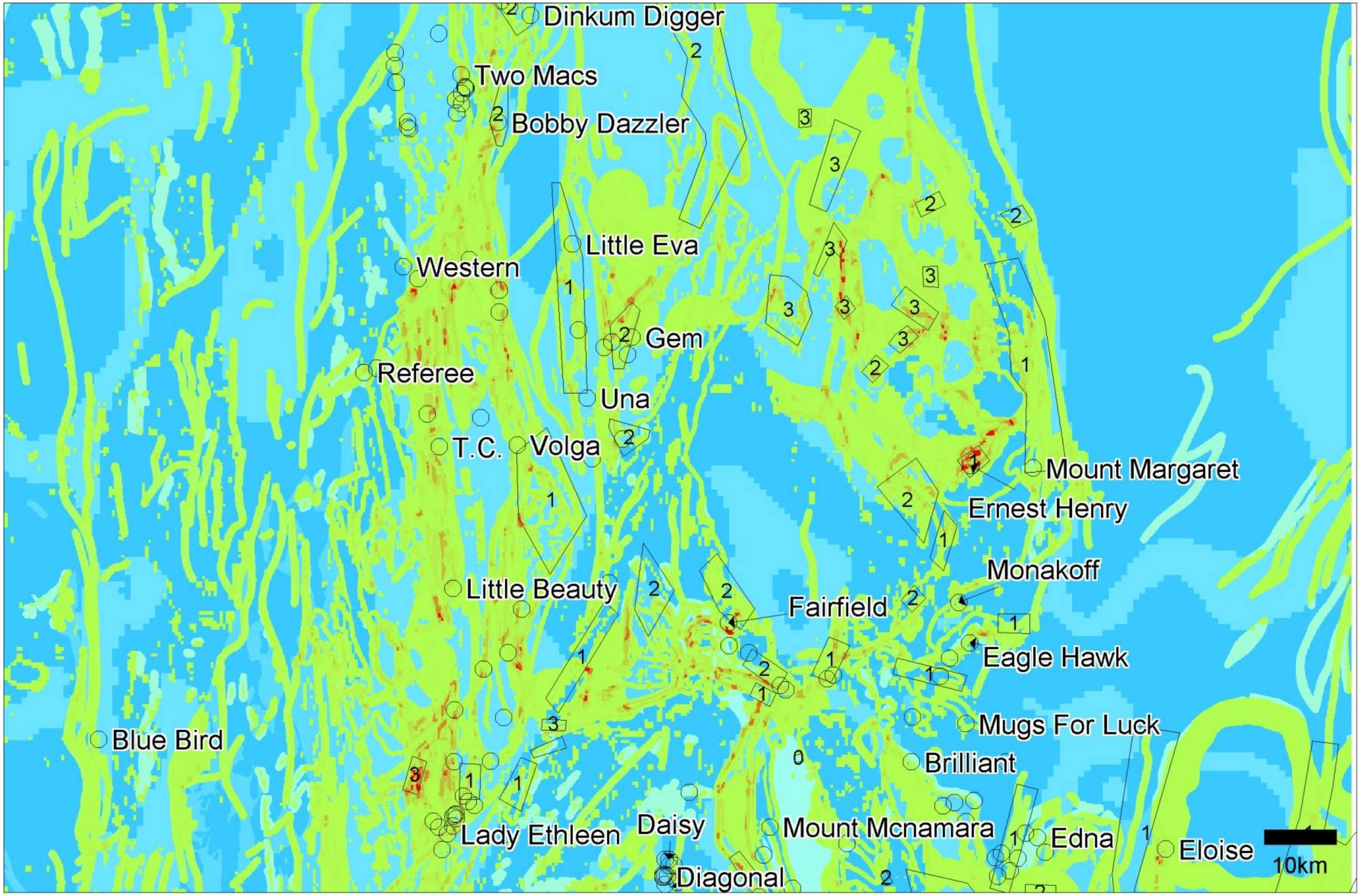


Ranking of Ingredients – prospectivity analysis led by Roger Mustard in the 2001-2008 Predictive Mineral Discovery CRC (pmdCRC)

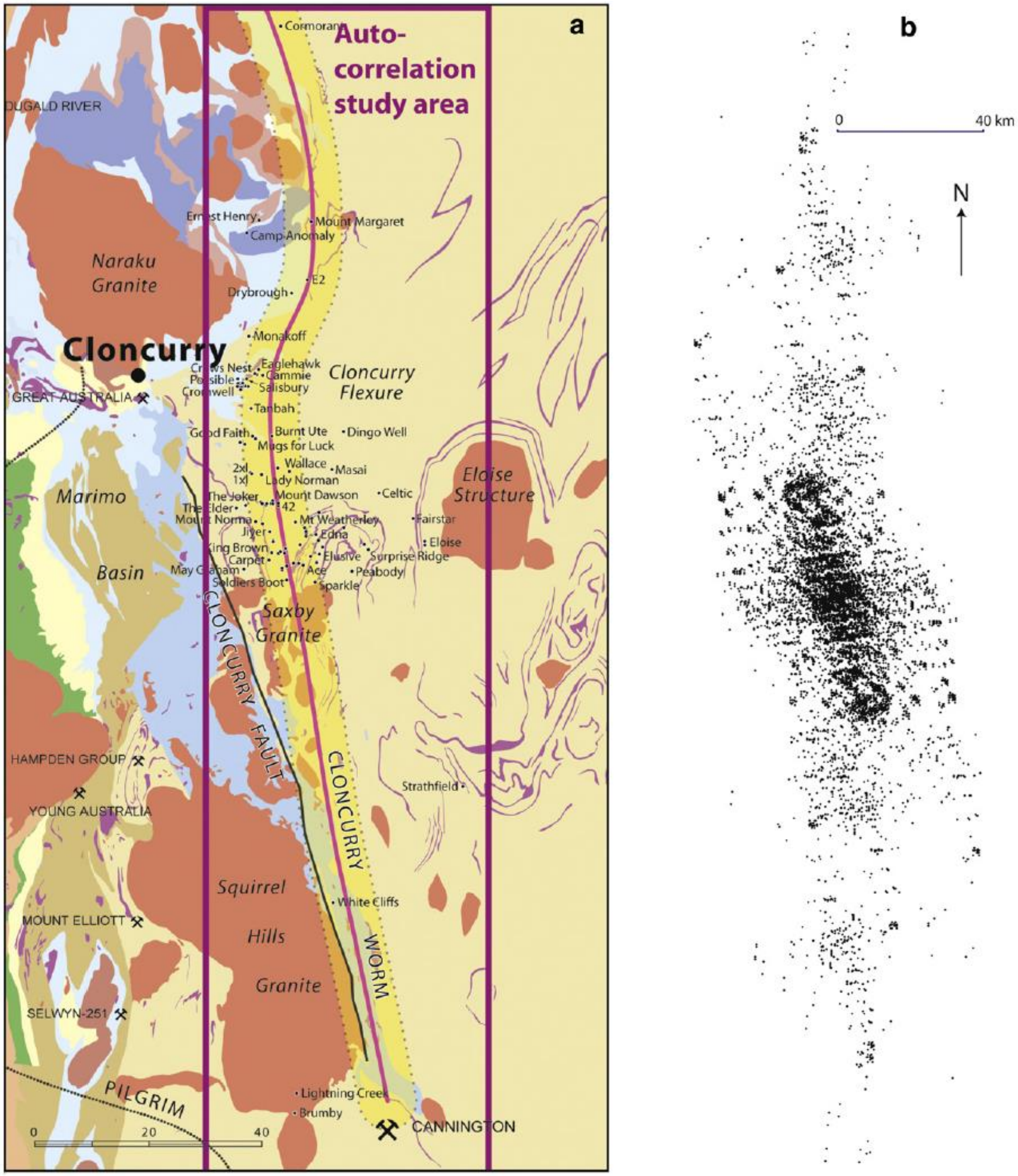
Ranking	Key Ingredient	Contrast	Confidence
1	Copper in rockchips (>249 ppm Cu)	2.50	36.31
2	Gold in rockchips (>0.11ppm Au)	2.38	26.45
3	Corella-Soldiers Cap Contact (750m buffer)	1.87	13.98
4	Aeromagnetics (magnetic highs)	1.82	14.36
5	N-S and NE faults (650m buffer)	1.45	17.20
6	Mafic Intrusives (750m buffer)	1.25	7.47
7	Lithologies (dominantly Cover Sequence 3)	1.21	5.09
8	Gravity (Gradients)	1.03	15.91
9	Bends on N-S and NE faults	1.03	2.33
10	Metamorphic Grade (Amphibolite Facies)	0.98	7.85
11	Radiometrics (U/Th)	0.83	4.46
12	Williams and Naruku batholiths (4km buffer)	0.64	3.36

Expert versus Data Driven

9 Layer Model, Ernest Henry – Cloncurry Region



Structural corridors: what/where and how defined?



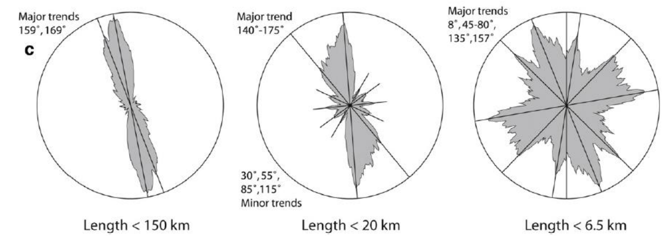
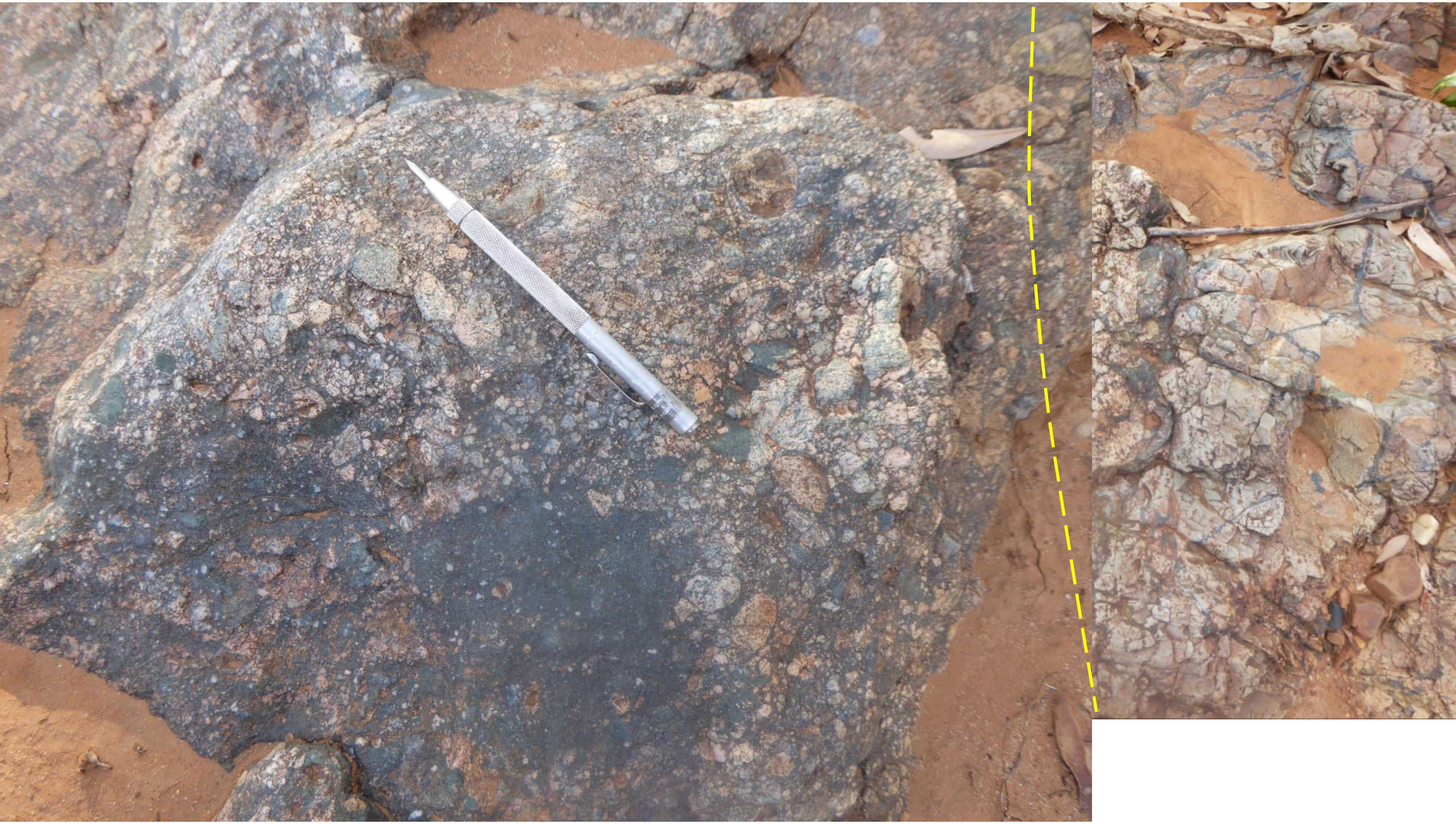
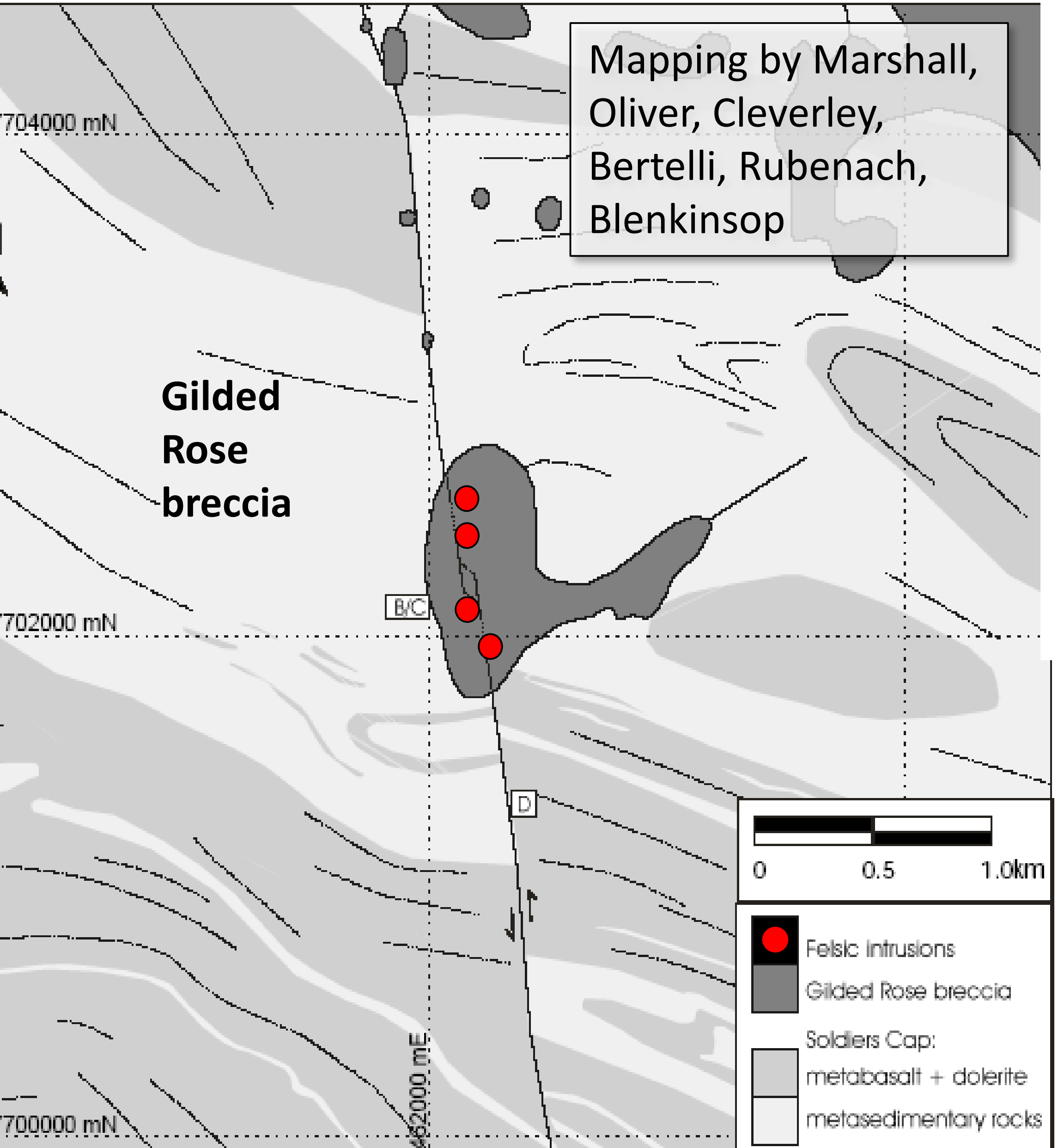
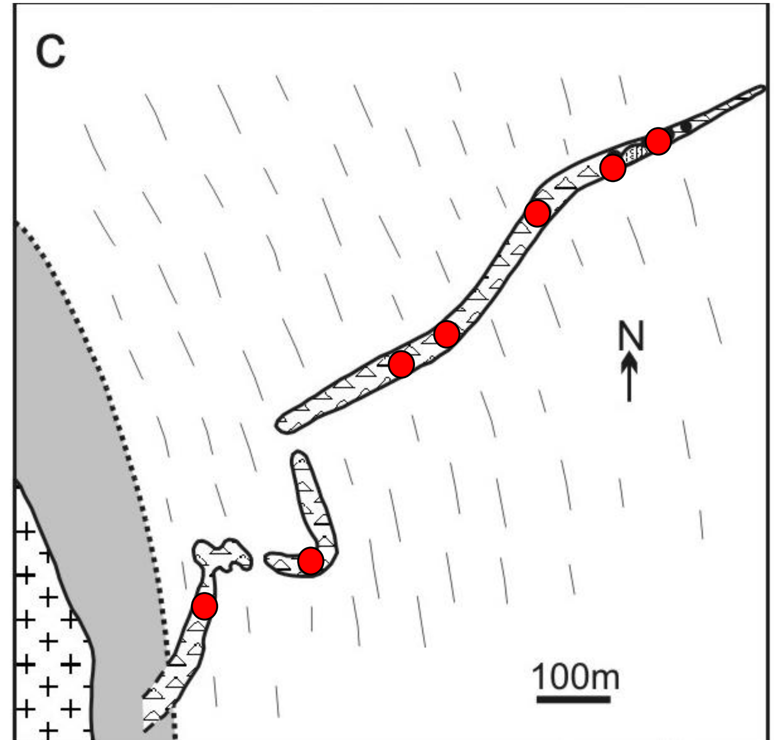


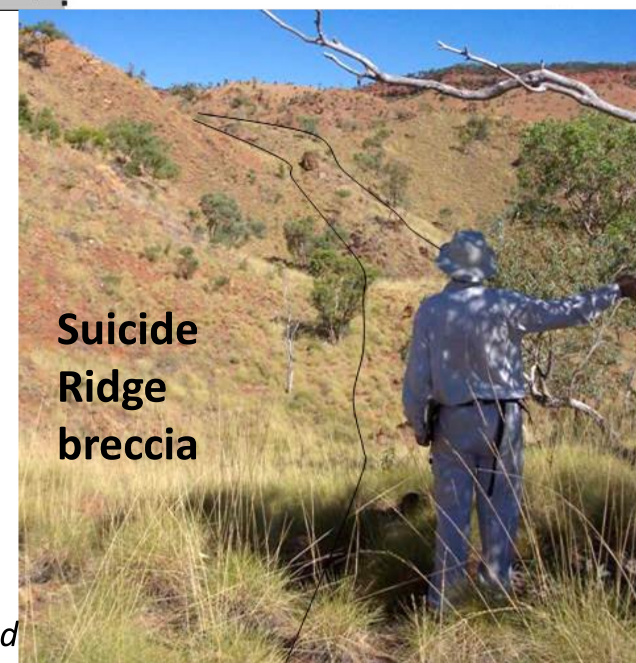
Fig. 6. Autocorrelation results for Cu–Au (including IOCG) mineral occurrences showing: a. Mineral occurrences and geology; b. The autocorrelation plot; c. Rose diagrams for leng
up to 150 km, 20 km and 6.5 km.

Most known Cu-Au deposits (including EH-style IOCG deposits) relate to the Cloncurry Worm at regional scales (the main Cover Sequence 2/3 boundary) but autocorrelation of different sized and differently oriented fault segments with mineralization is unclear at more detailed scales (Austin & Blenkinsop 2009)





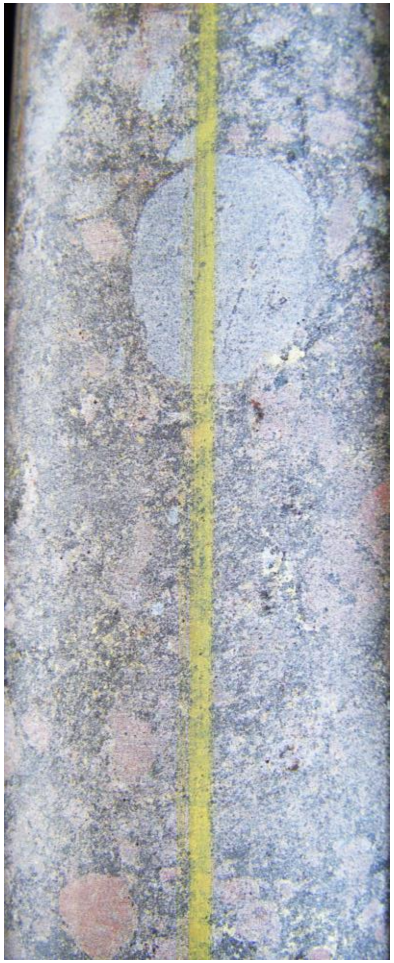




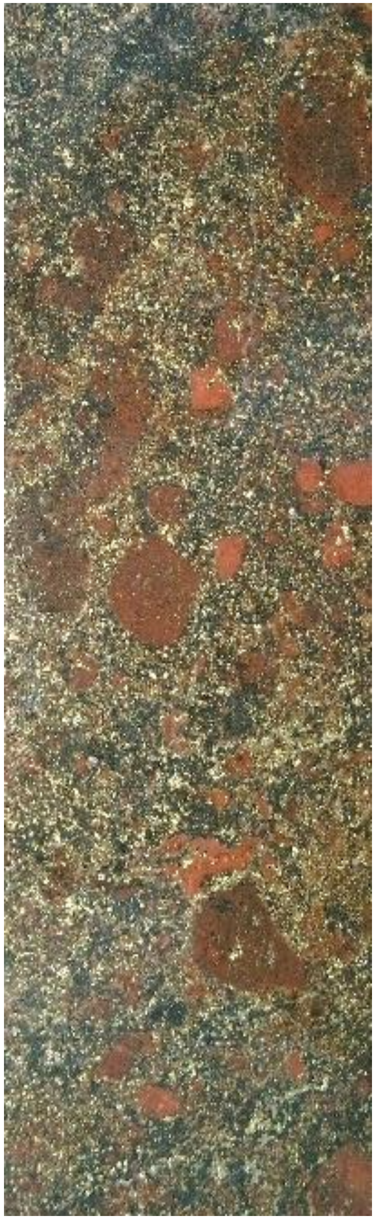
Oliver, N.H.S., Rubenach, M.J., Fu, B., Baker, T., Blenkinsop, T.G., Cleverley, J. S., Marshall, L.R., & Ridd, P.J. 2006. Granite-related overpressure and release in the mid crust: fluidized breccias from the Cloncurry district, Australia. Geofluids, 6, 346–358

Low-mod mt content

high mt content

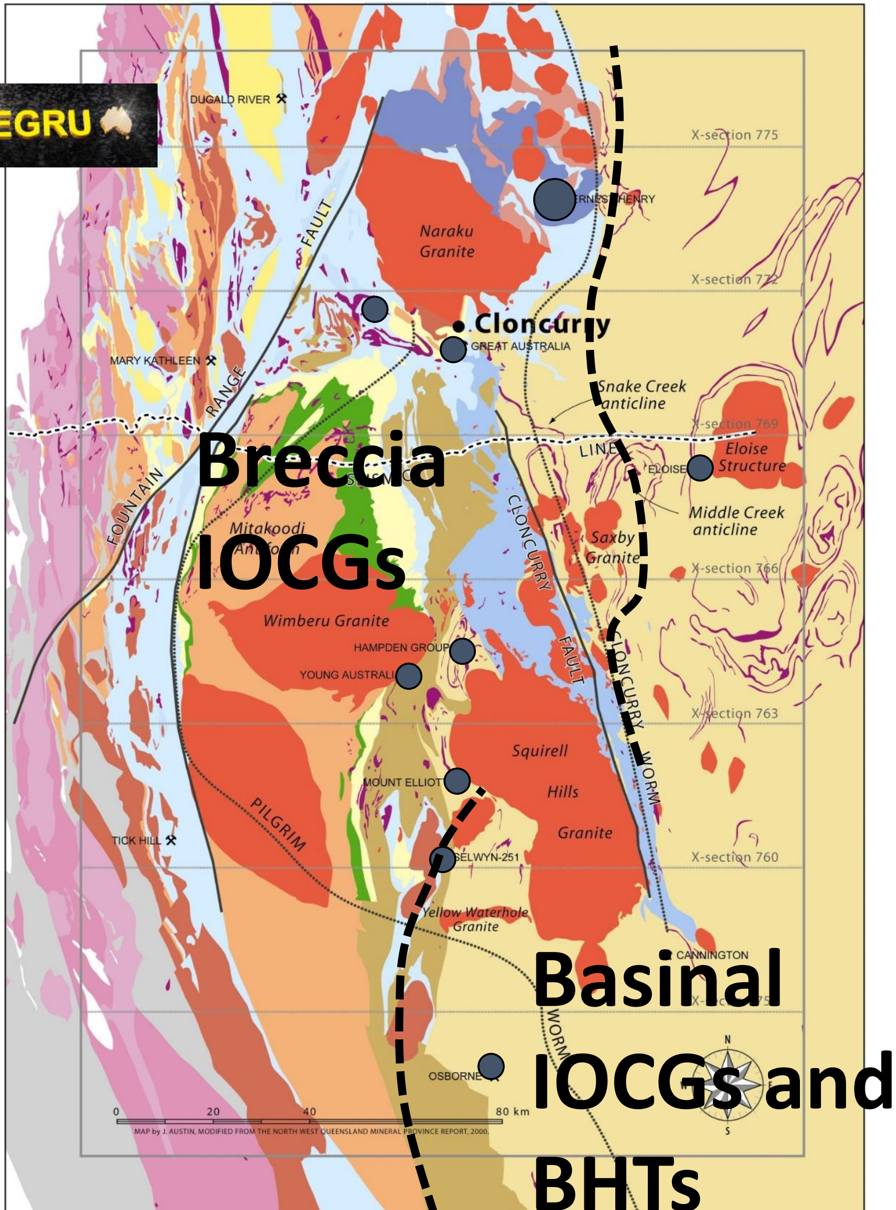


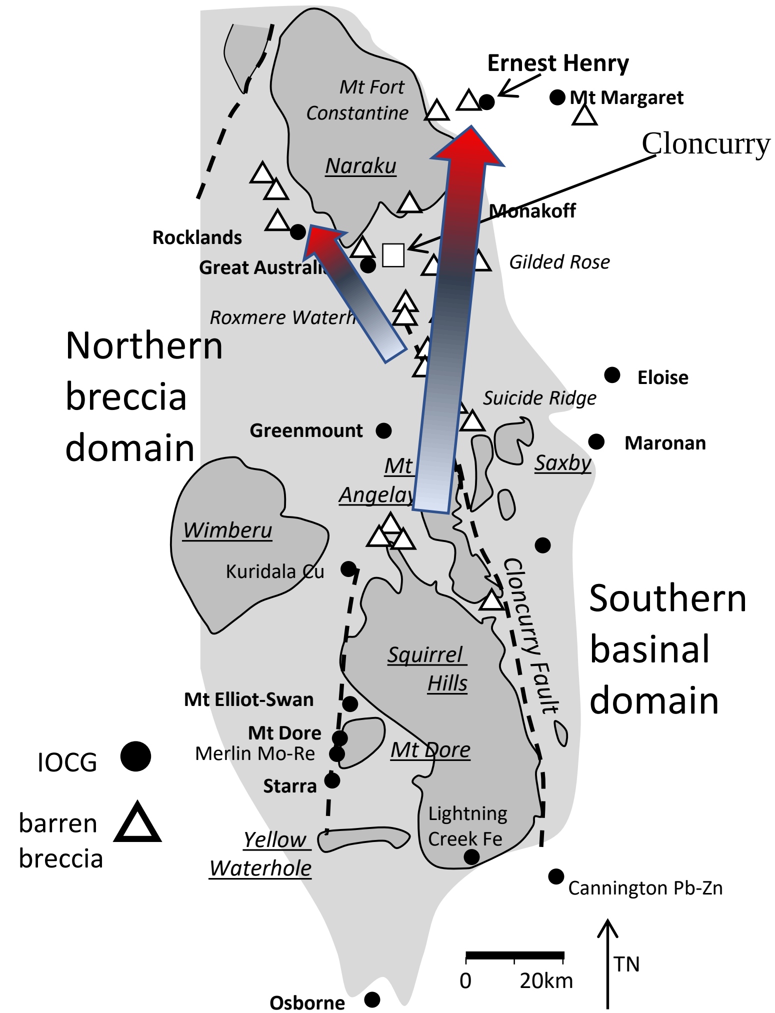
high mt-sulph content



high mt-sulph content

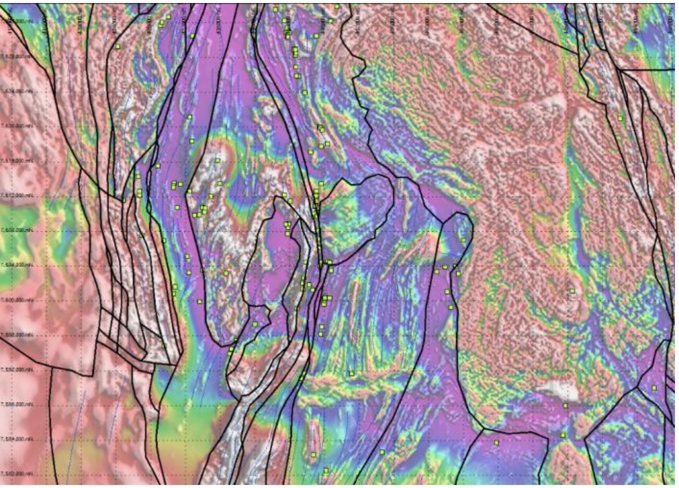
Corridors of diatreme-like breccia pipes and sheets along regional fault/shear zones



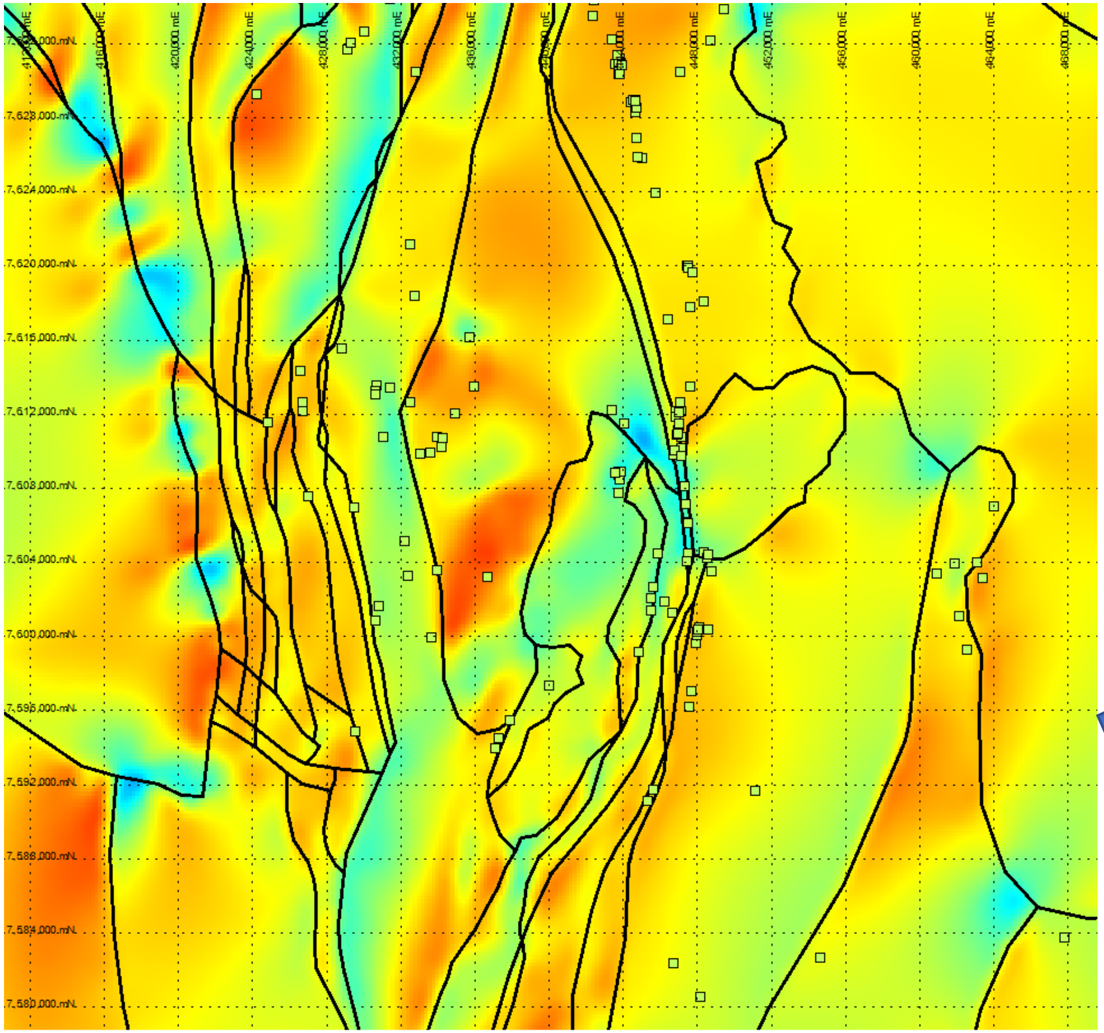


Limited data but suggestion that the discordant breccias are more mt-rich further north

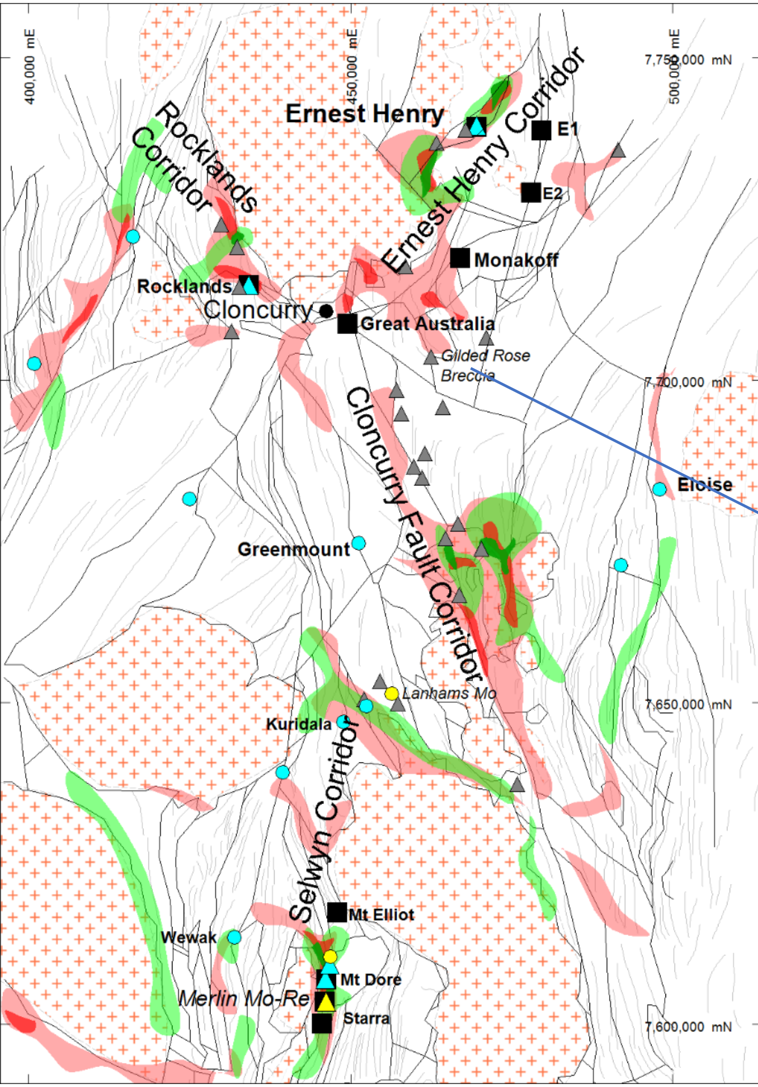
Geomechanical modelling (2D) of late-Isan deformation and fluid flow on fault/shear arrays (John McLellan during pmdCRC, and McLellan, Oliver and Brown GSQ/QEC support 2016-7)



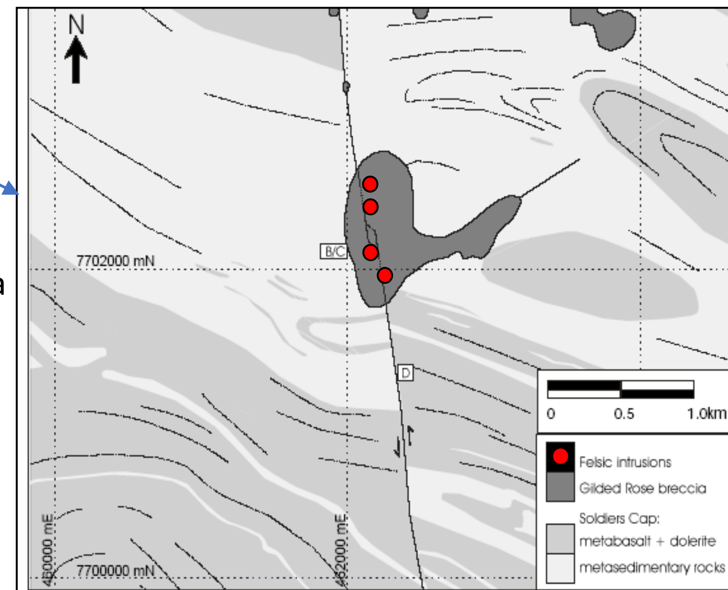
Model outputs: geomechanical parameters relevant to predicted failure on faults and thus mineralization potential



15 sheet ESE shortening PfF



Some regional discordant breccia pipes:
Structural control at one scale, chaos internally



Summary

- Assumed: Williams Batholith, proximity of mafics, proximity to Cover Sequence 2/3 boundary, proximity of magnetic ironstones
- The right structural corridors (existing prospectivity, existing numerical modelling)
- Presence of diatreme-like breccias
- New geomechanical modelling- zooming in (1: 100000, 25000, 5000 scale)
- Albitization outboard of K-Fe alteration? More than one type of albitite
- Mn-K anomalism (rock normalized)
- Magnetite chemistry
- Pyrite chemistry, S isotopes, carbonate C-O and Sr?