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Geophysical, Structural and Mineralogical Signatures of the Cloncurry Mineral System

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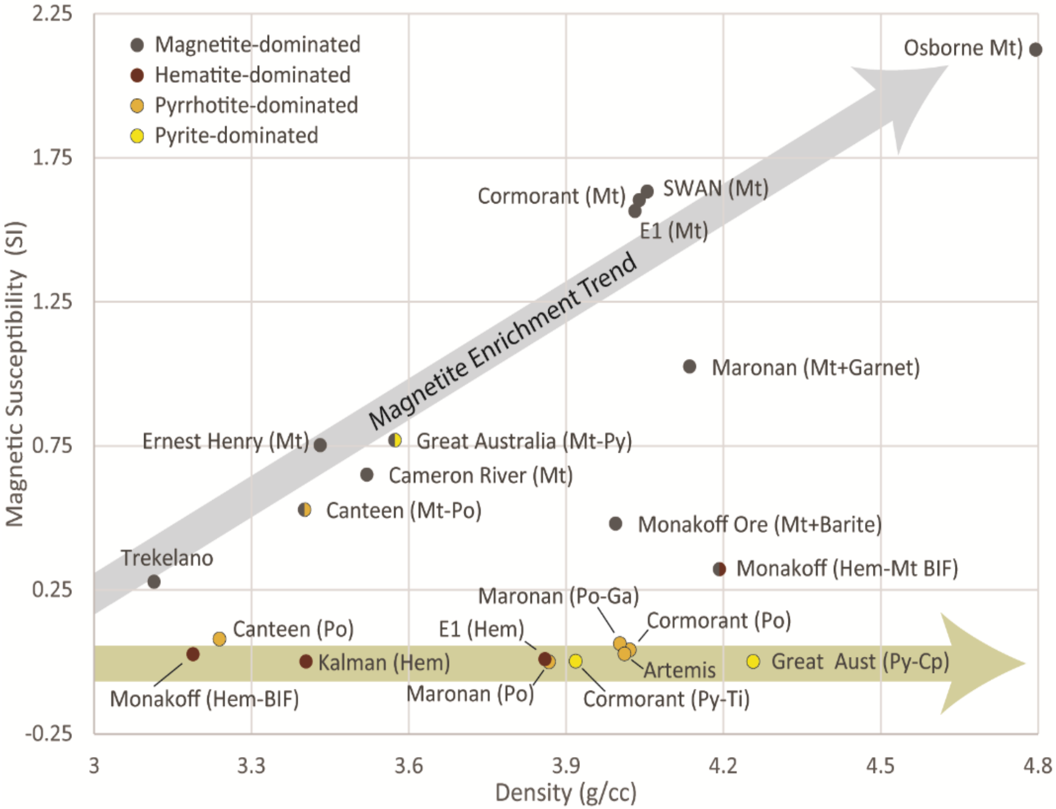
Queensland Government
Department of Natural Resources and Mines

Petrophysics Overview

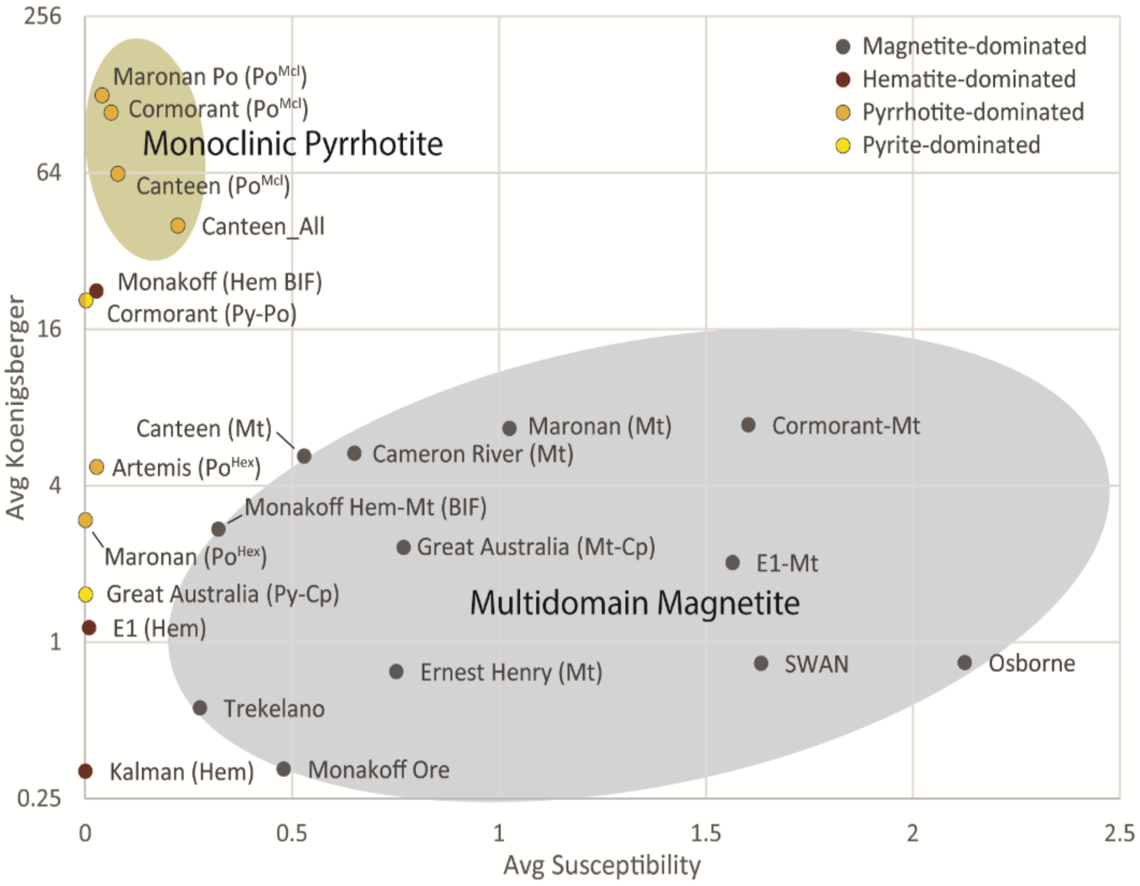
We start with 1 inch cores

- High density, high MagSus, are dominated by coarse MD magnetite, e.g., Osborne, SWAN.
- High density, medium MagSus (e.g., Cormorant, Maronan) may contain magnetite and pyrrhotite.
- High density negligible MagSus contain hex. pyrrhotite, sphalerite, galena, pyrite and hematite,

MagSus vs Density



Petrophysics Overview

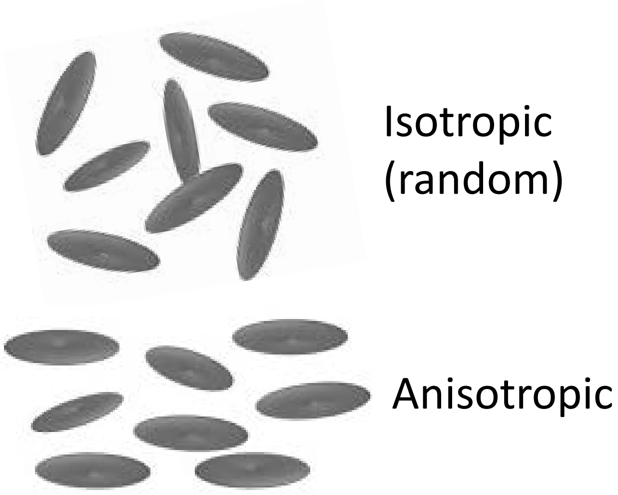


MagSus vs Remanence

- High MagSus, and low Q ratios are dominated by coarse MD magnetite, e.g., Osborne.
- Low MagSus, and high Q are rich in monoclinic pyrrhotite, e.g., Cormorant, Canteen.
- Deposits with low MagSus, and low Q may contain hexagonal pyrrhotite, pyrite or hematite.

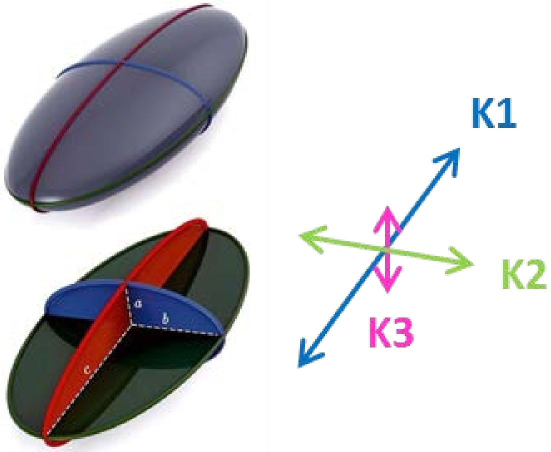
AMS (Anisotropy of Magnetic Susceptibility)

- Measureable petrophysical property of rock
- Preferred orientation of crystallographic axes of anisotropic magnetic minerals,
  - i.e., the magnetic fabric.

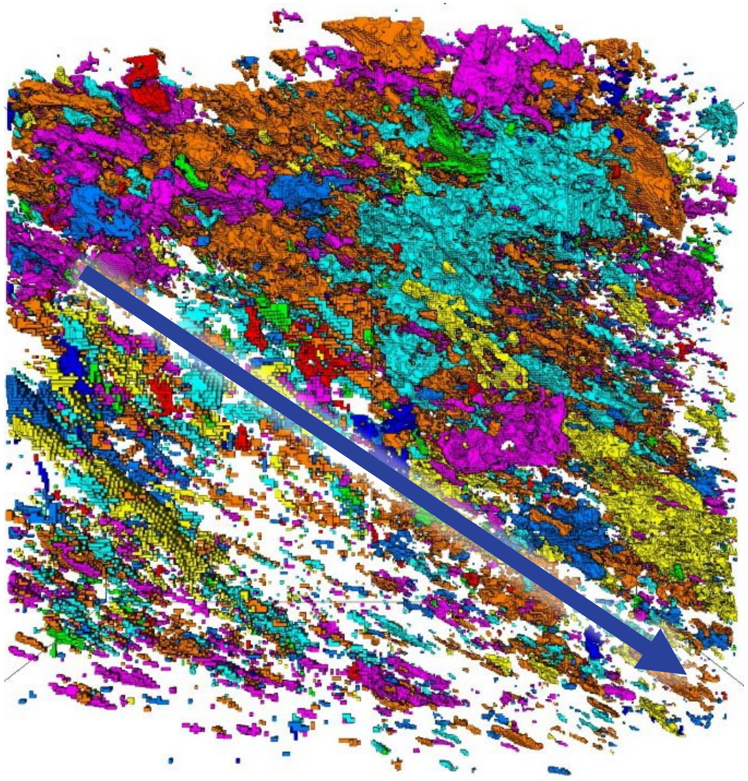


can be used to:

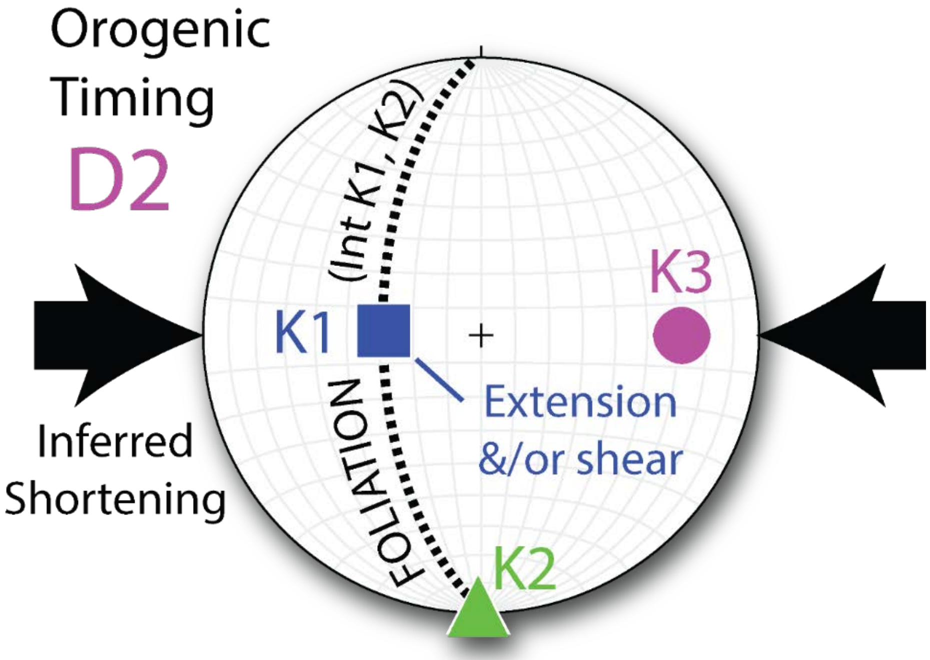
- Define strain distribution prior to mineralisation
- K3 is generally the shortening direction
- K1/K2 are perpendicular to shortening, define foliation



AMS (Anisotropy of Magnetic Susceptibility)

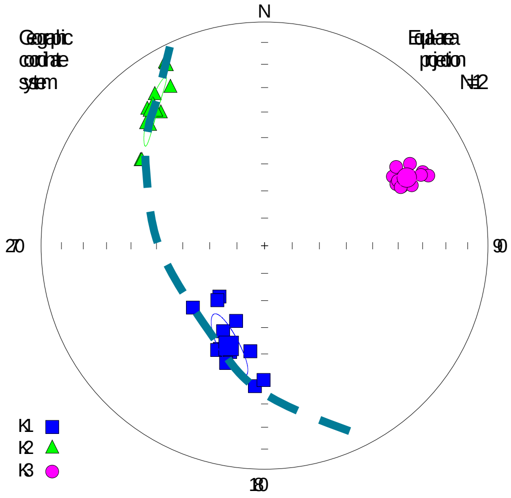


µCT image of Artemis (ART16C)



AMS can provide information about:

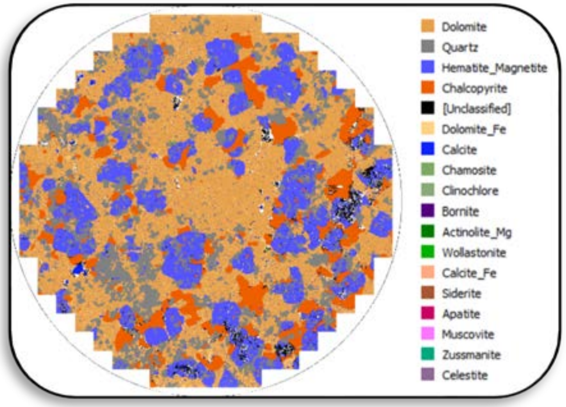
- **Strain Fabrics**
- **Shearing**
- Veining (Dilation)
- Sedimentary Banding
- Magma Flow
- Magmatic Settling
- So you need to know about the mineralogy and the texture to use it effectively



Correlating Structure with Fabric & Mineralogy

- The best way is to image the mineralogy of the same sample you've measured

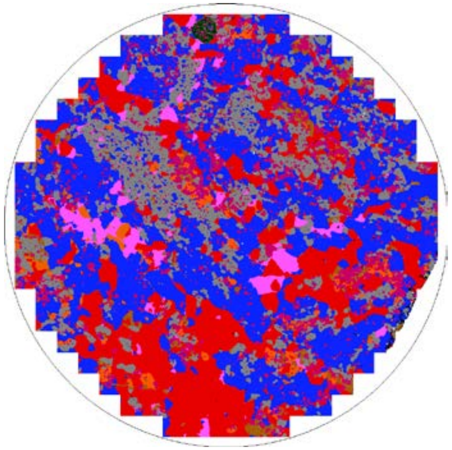
TIMA (Tescan Integrated Mineral Analyser)



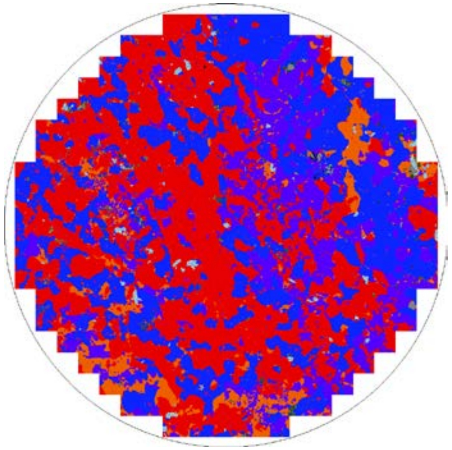
Cloncurry -> 750 samples from ~15 deposits

BHT/Sedex

Maronan Pb-Zn

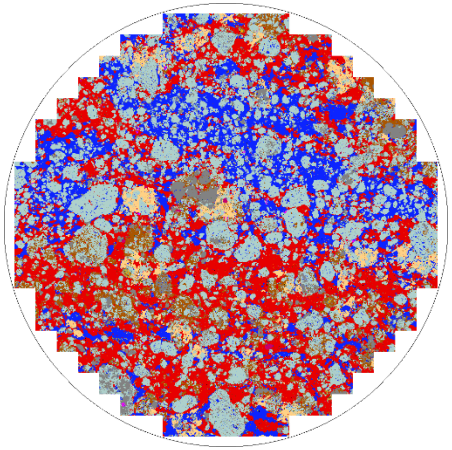


Artemis Cu-Zn

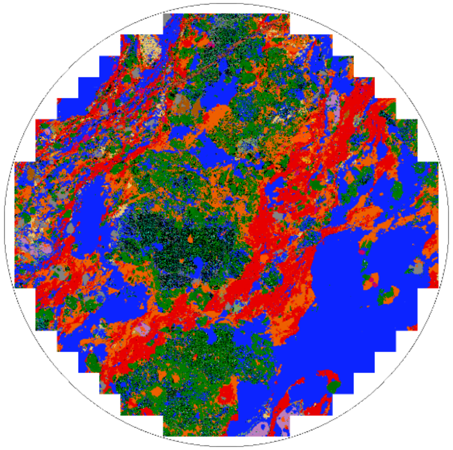


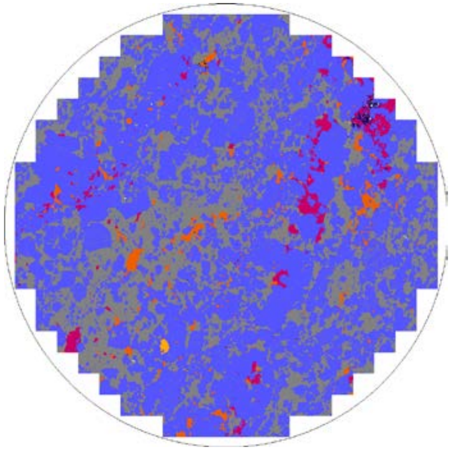
Calcite+Po SKARN

Canteen Cu-Au

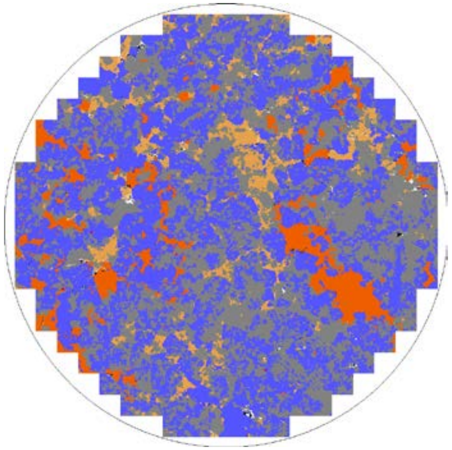


Mt Colin Au-Cu



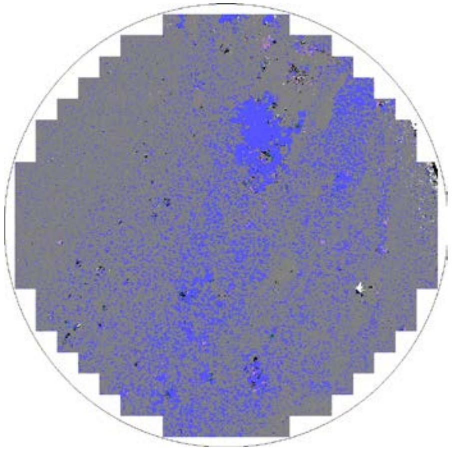


Osborne Cu-Au

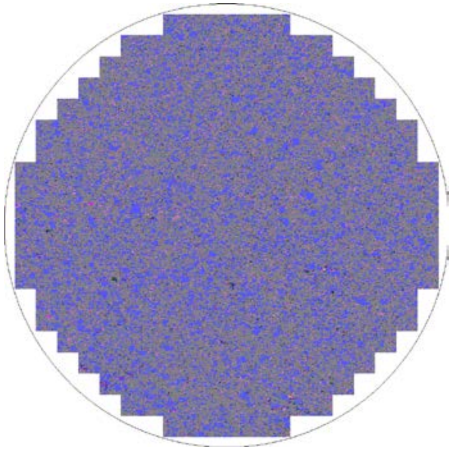


Starra Cu-Au

IOCG??



Monakoff Cu-Au

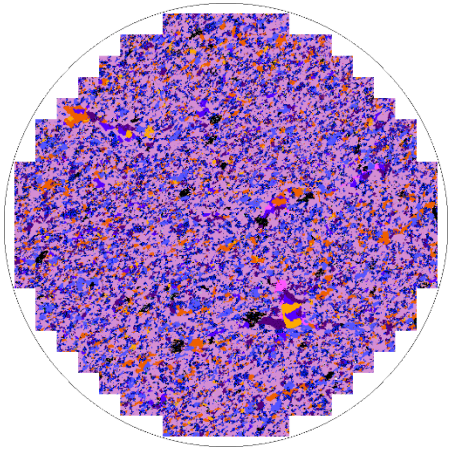


E1 Cu-Au

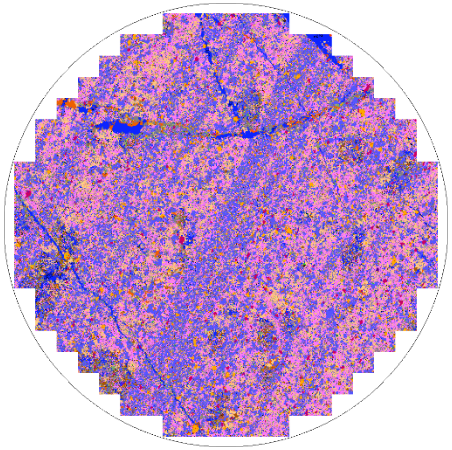
SEDEX (Distal)

Magnetite-Barite-Fluorite

Monakoff Cu-Au

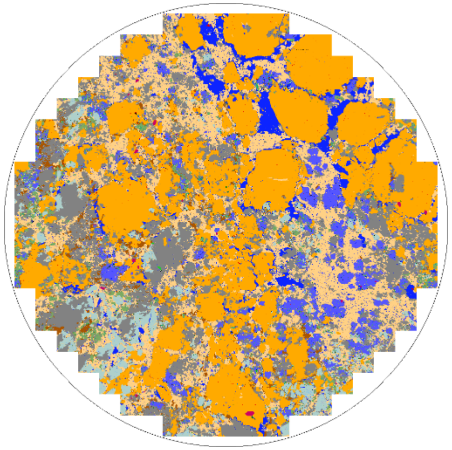


E1 Cu-Au

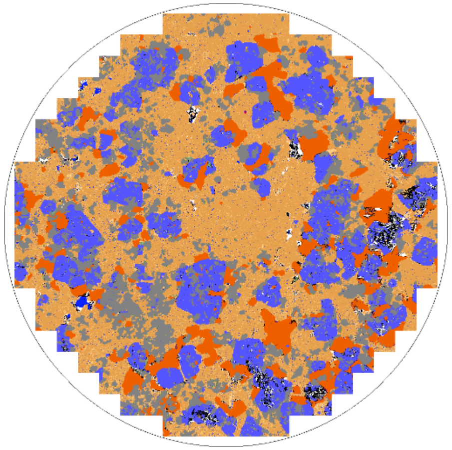


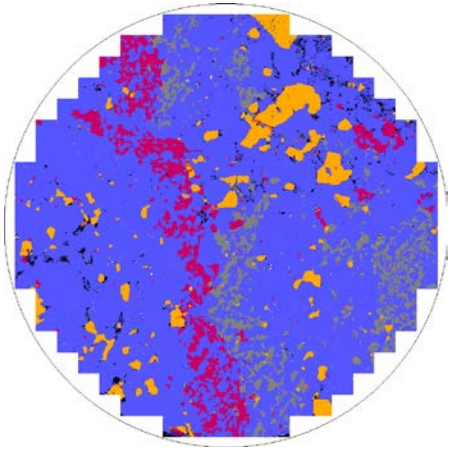
Dolomite-Pyrite-Mt-Qtz

Canteen Cu-Au

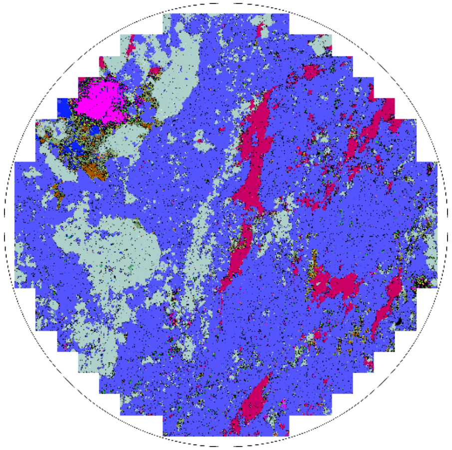


Starra Cu-Au



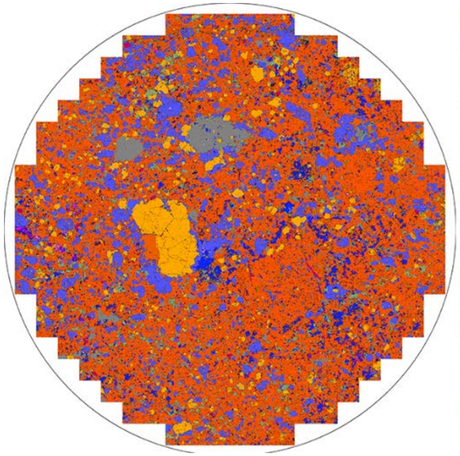


Osborne Cu-Au

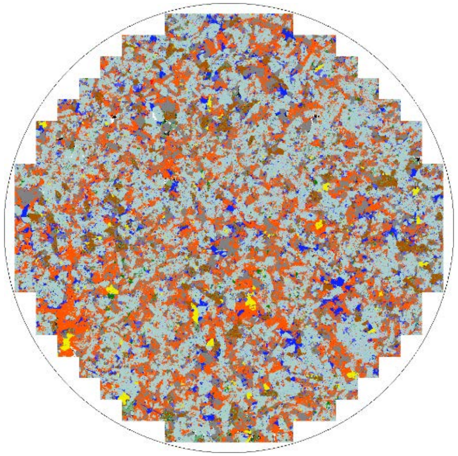


Ernest Henry Cu-Au

Magnetite-Apatite



Ernest Henry Cu-Au



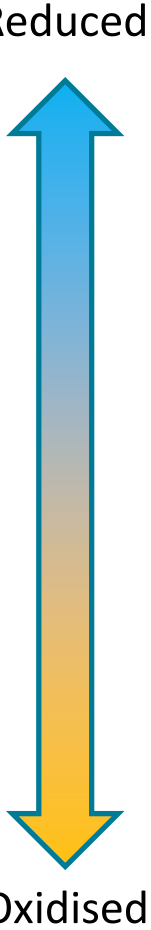
SWAN Cu-Au

Potassic Breccias

IOCG & ISCG alteration systems

- hydrothermal mineralization:
  - Highly variable
  - 50 Ma Post-peak metamorphism
  - Synchronous with felsic magmatism
  - Structurally controlled
  - Formed during transition from convergence to transpression then extension
  - Mineralization was associated with a number of different alteration types:

1. Pyrrhotite-Calcite Alteration
2. Pyrrhotite-Albite Alteration
3. magnetite-apatite
4. sodic (±calcic) alteration
5. Potassic Alteration
6. Quartz-Chlorite-Hematite alteration (retrograde)



Redox and Geophysics

Gawler IOCGs

Reduced ← → Oxidised

Associated
with Cu.

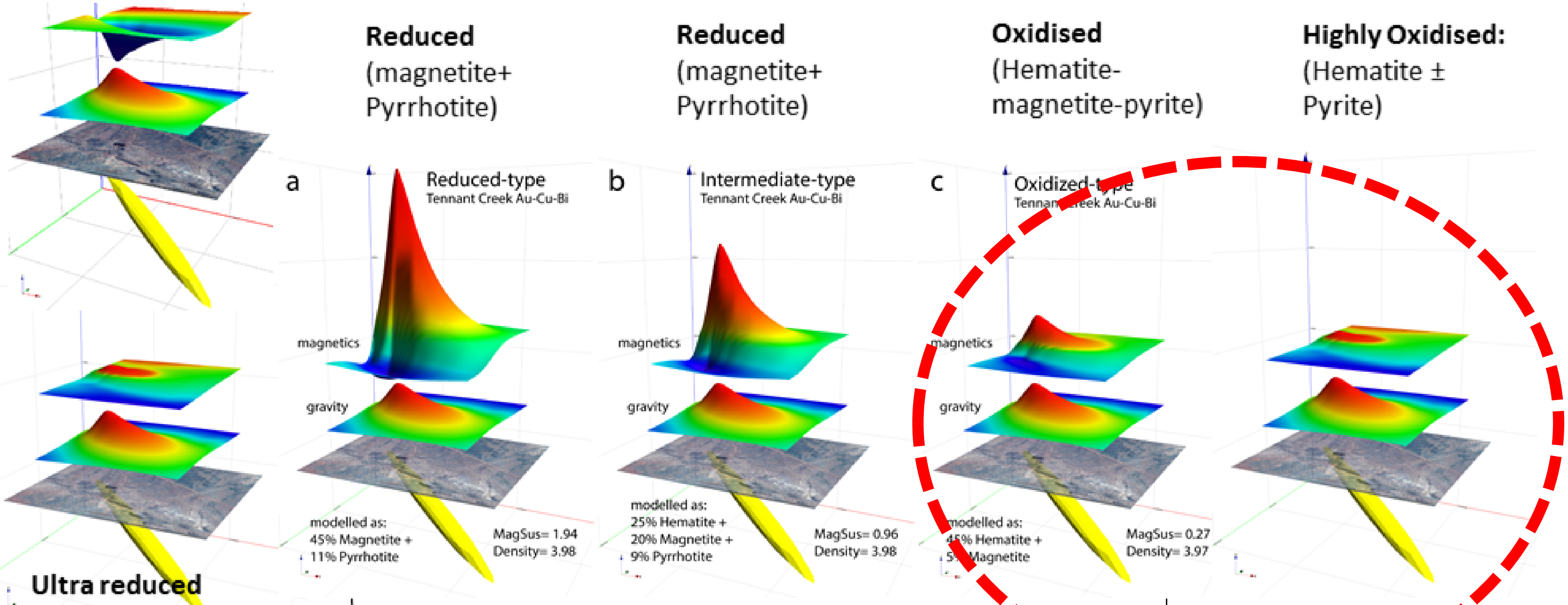
Ultra reduced
(magnetic
Pyrrhotite)

Reduced
(magnetite+
Pyrrhotite)

Reduced
(magnetite+
Pyrrhotite)

Oxidised
(Hematite-
magnetite-pyrite)

Highly Oxidised:
(Hematite ±
Pyrite)



Associated
with Pb & Zn

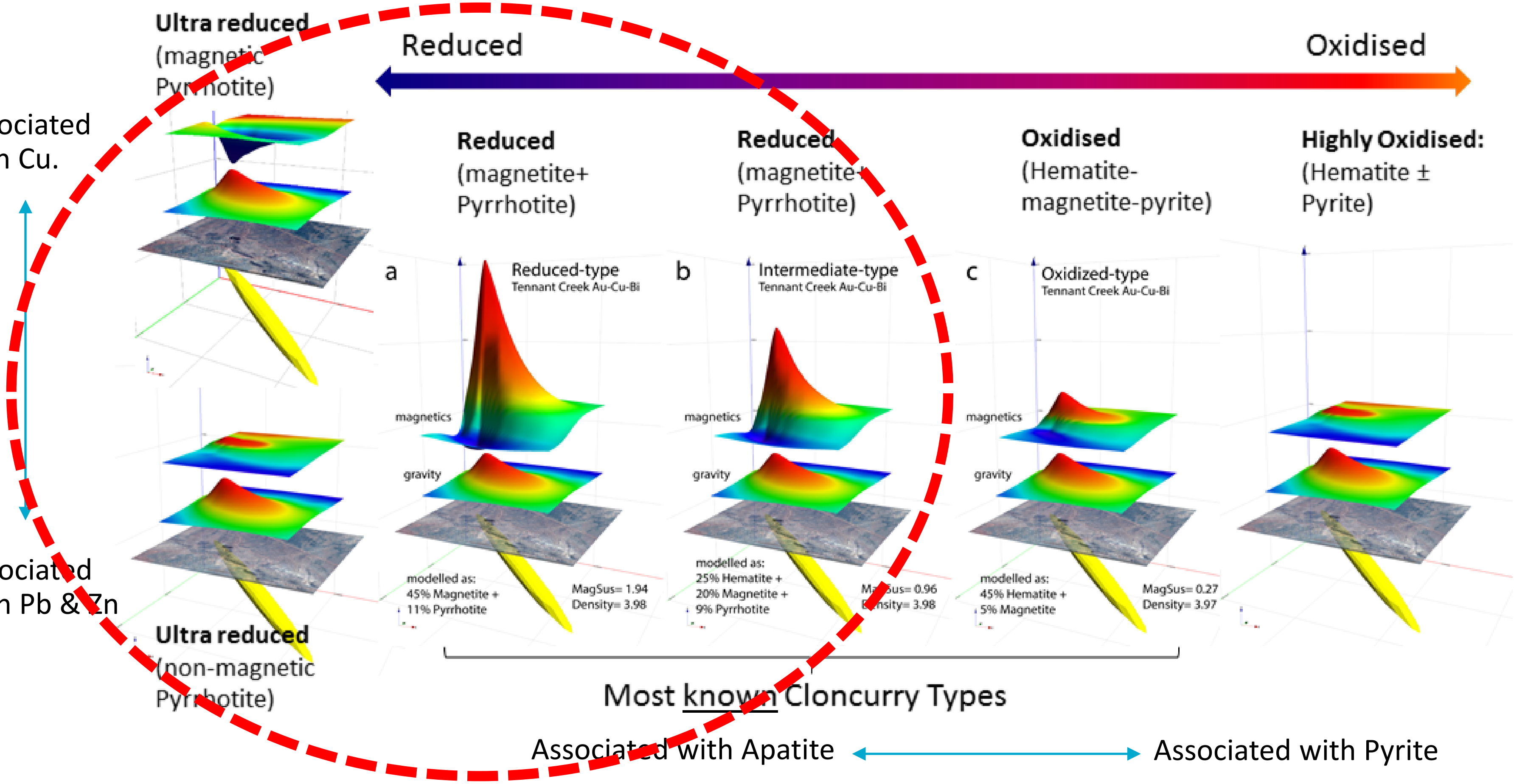
Ultra reduced
(non-magnetic
Pyrrhotite)

Most known Cloncurry Types

Associated with Apatite ↔ Associated with Pyrite

Redox & Geophysics

Cloncurry IOCGs



Reduced ← → Oxidised

Ultra reduced (magnetic Pyrrhotite)

Associated with Cu.

Associated with Pb & Zn

Ultra reduced (non-magnetic Pyrrhotite)

Reduced (magnetite+ Pyrrhotite)

Reduced (magnetite+ Pyrrhotite)

Oxidised: (Hematite-magnetite-pyrite)

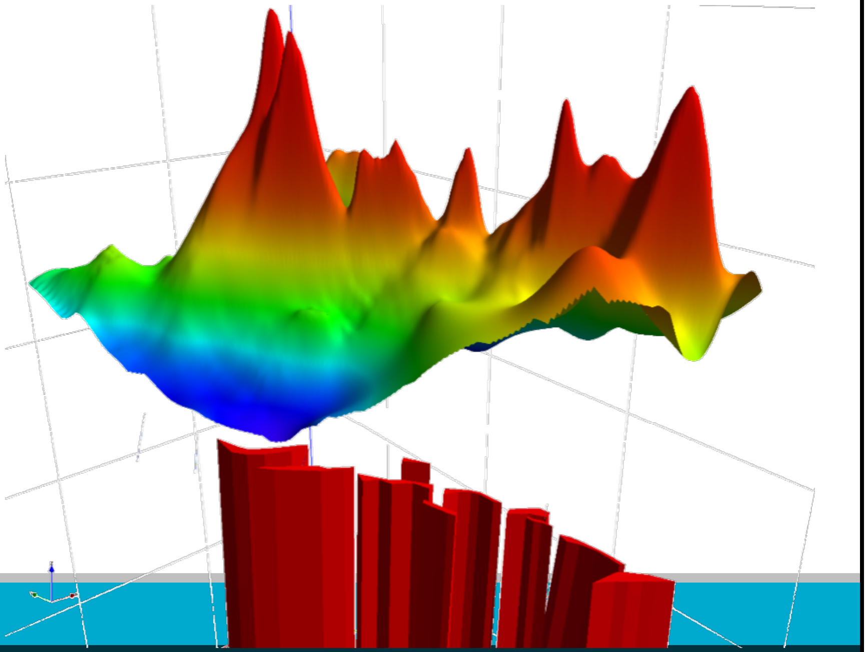
Highly Oxidised: (Hematite ± Pyrite)

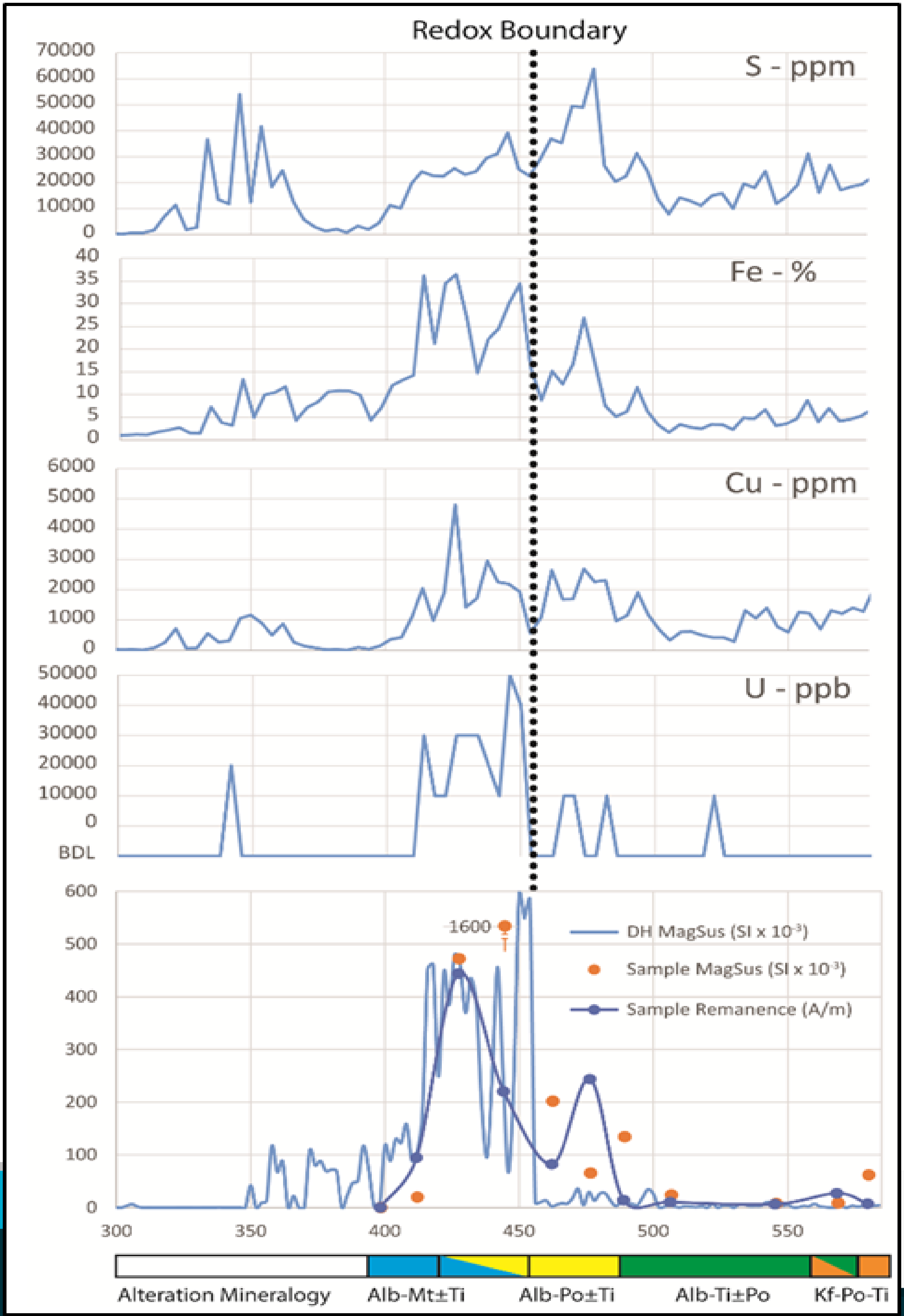
Most known Cloncurry Types

Associated with Apatite ↔ Associated with Pyrite

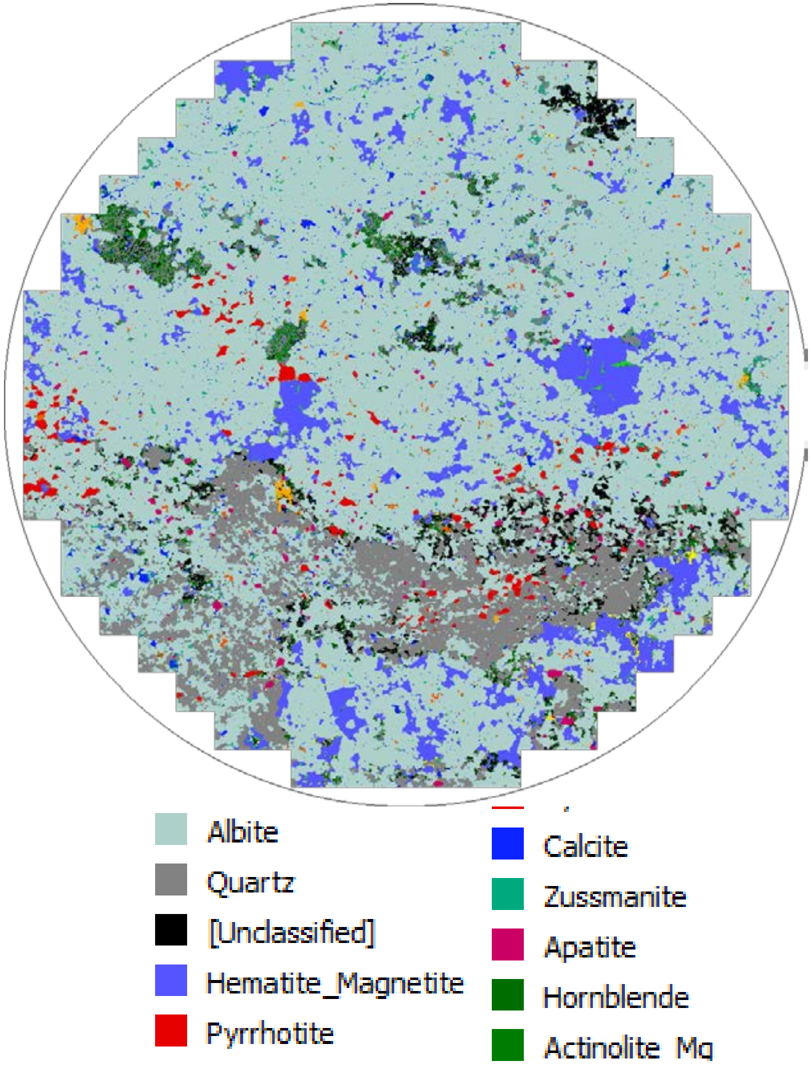
Redox Control on Cu

- Elevated Cu occurs either side of an apparent redox boundary
- transition from magnetite into magnetite-pyrrhotite
- U-rich alteration sits on more oxidized side

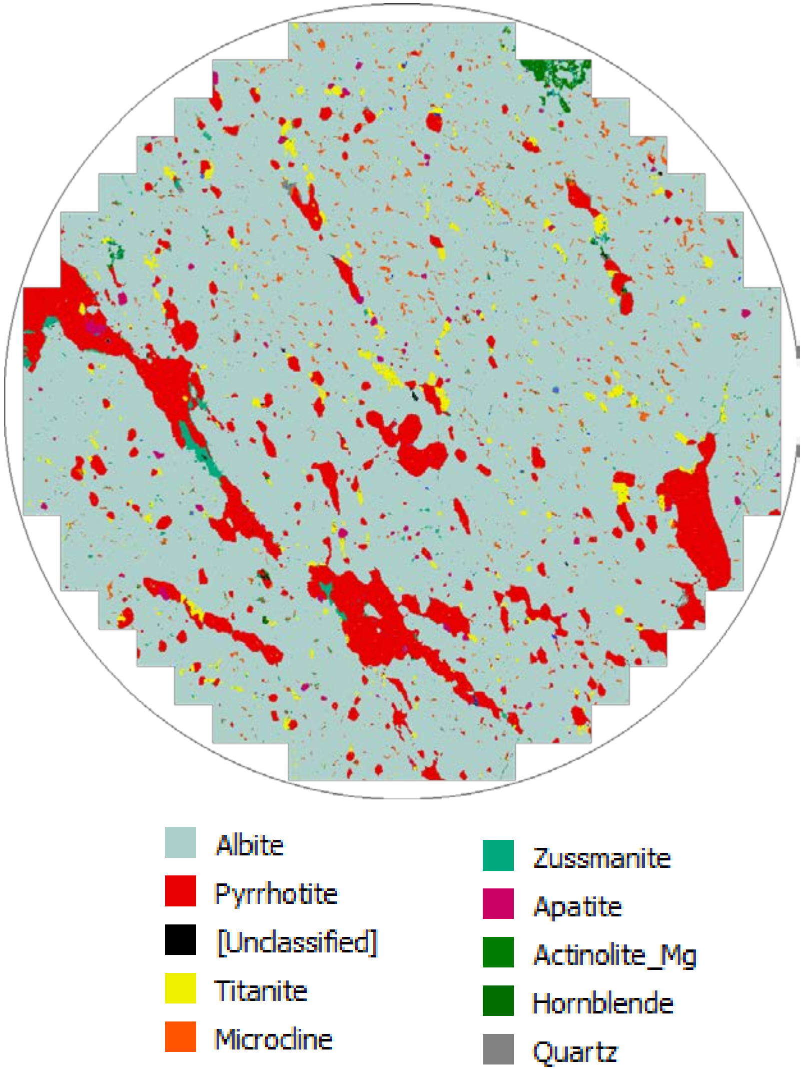




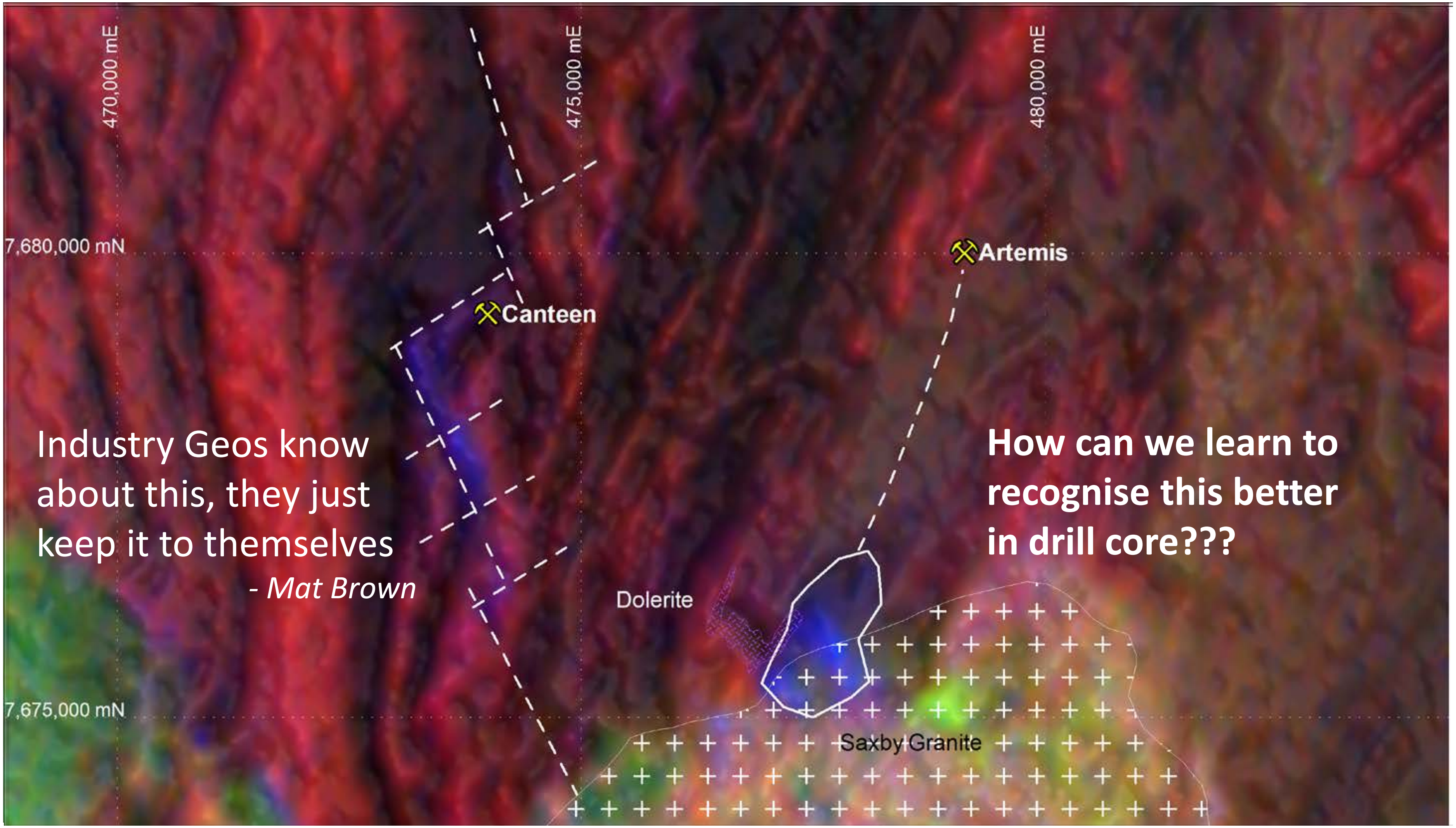
Uranium, assoc with Mt-dominant Sodic Alteration



REDOX BOUNDARY



Ternary KTU radiometrics



Industry Geos know about this, they just keep it to themselves

- *Mat Brown*

How can we learn to recognise this better in drill core???

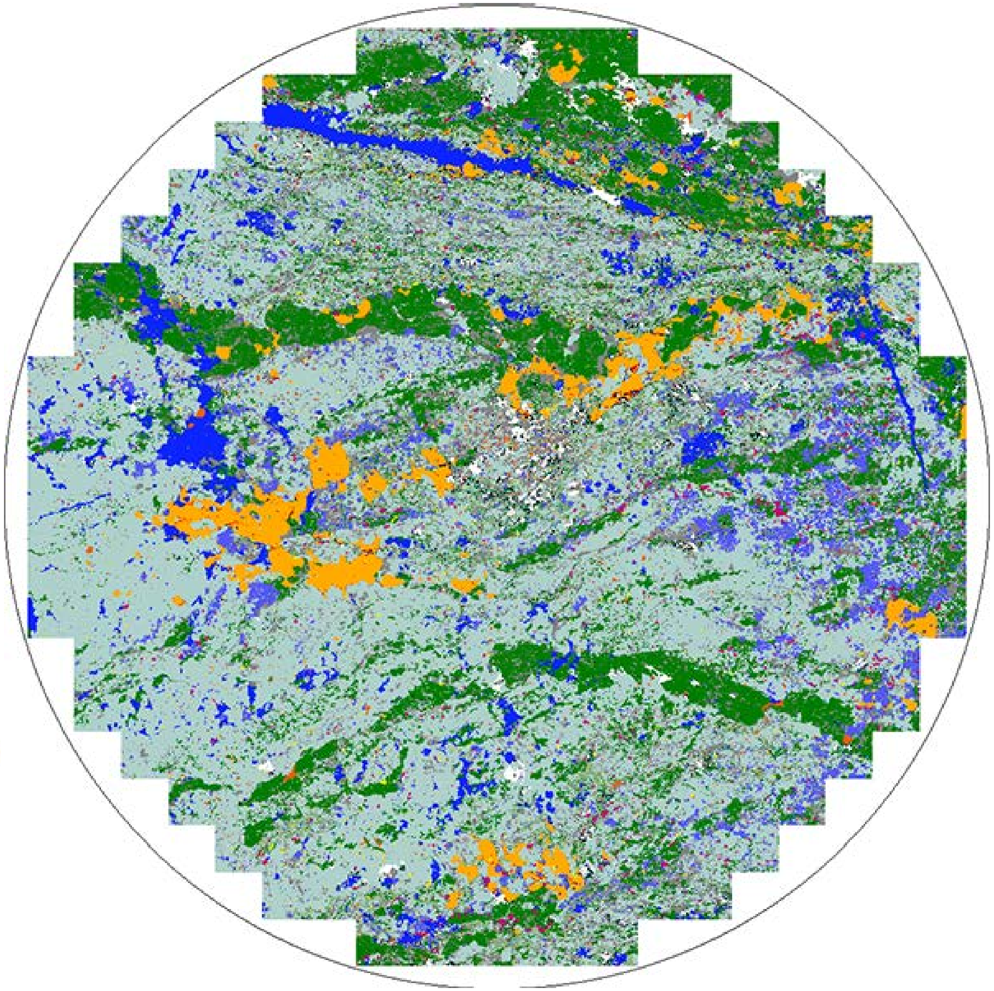
Case Study

1. Ernest Henry Cu-Au

(Iron-Oxide Cu-Au deposit)

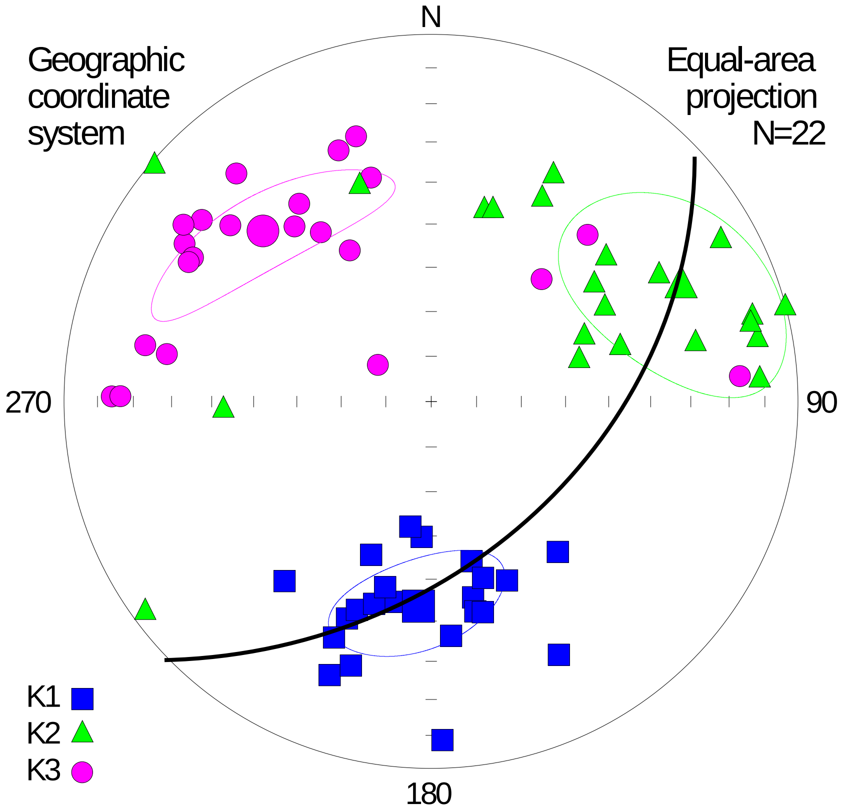
Sodic Alteration (albite-actinolite magnetite)

- albite-dominated lithologies
- variable amounts of coarse multi-domain magnetite as the phase.
- Associated with moderate to high susceptibilities



AMS - Hanging wall (Sodic Alteration)

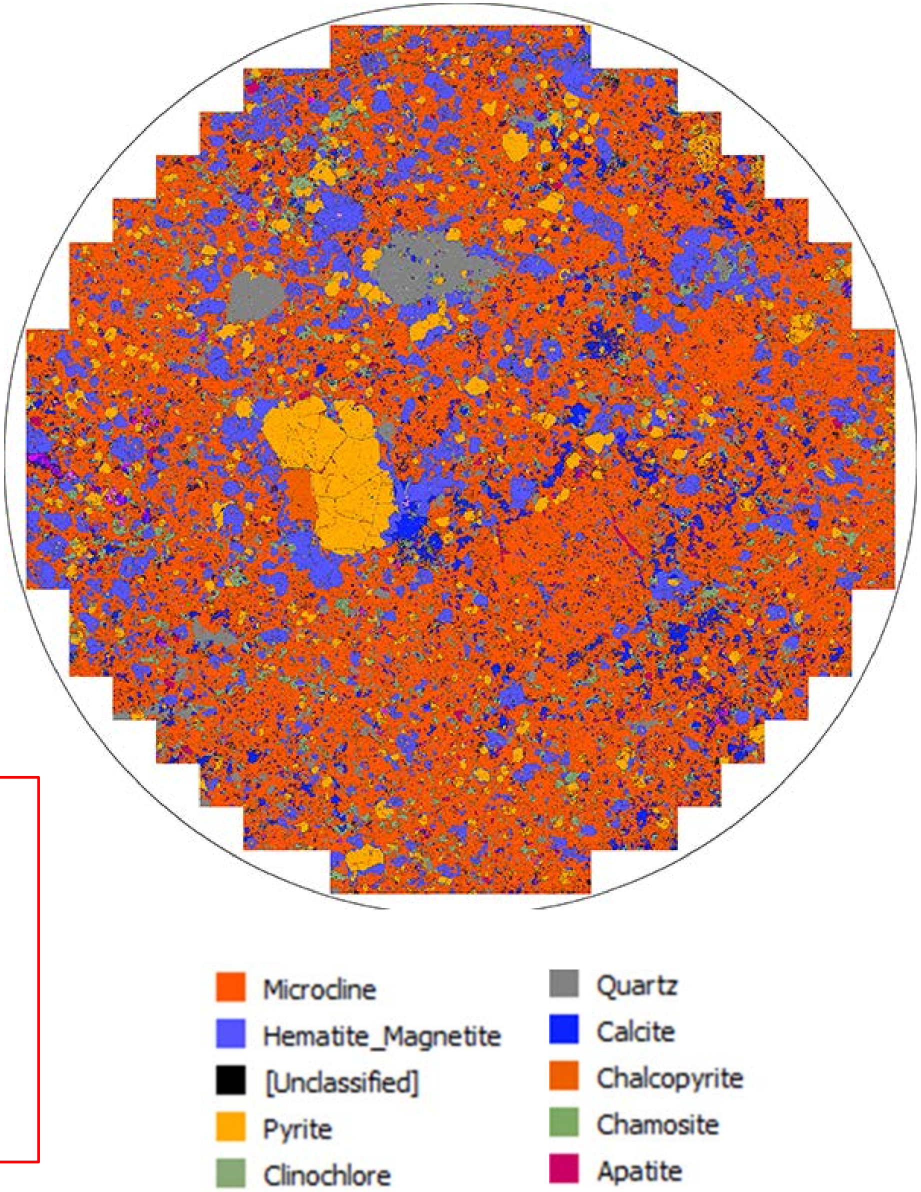
- SE- dipping shear zone
- South plunging lineation
- Indicating South over north movement
- Shear Fabric is Consistent with the thrust ± jog model (e.g., Valenta, 2000)



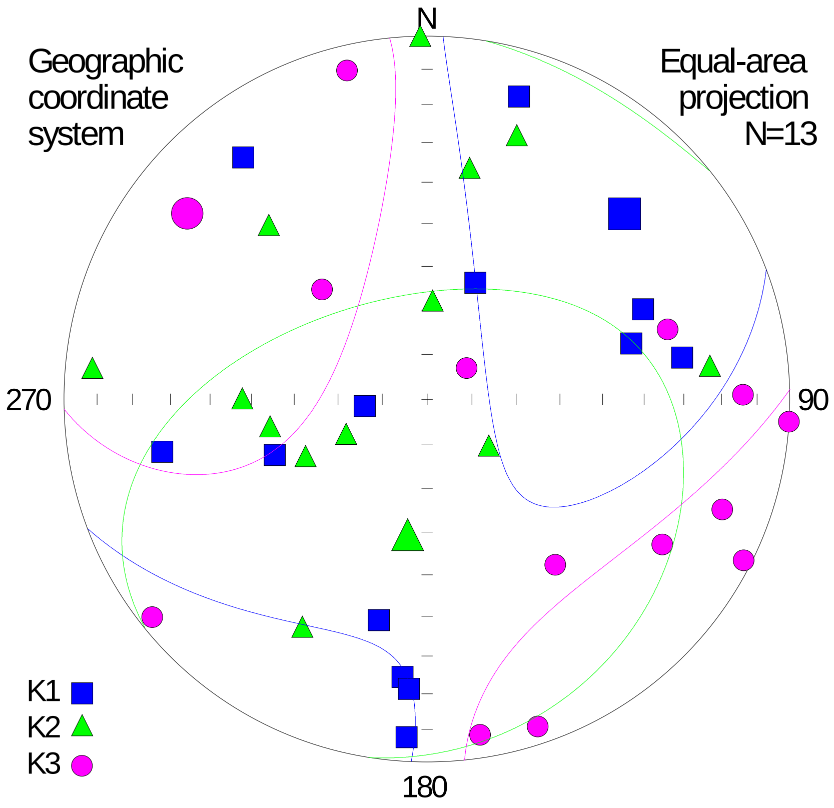
Potassic Alteration

- Replacement feldspars (e.g., Albite) by K- Feldspar
- Formation of Iron Sulphides reduces Susceptibility

- K-feldspar alteration is often thought to be associated with hematite (based on the reddish color of the K-feldspar).
- However, magnetite is the dominant magnetic phase.



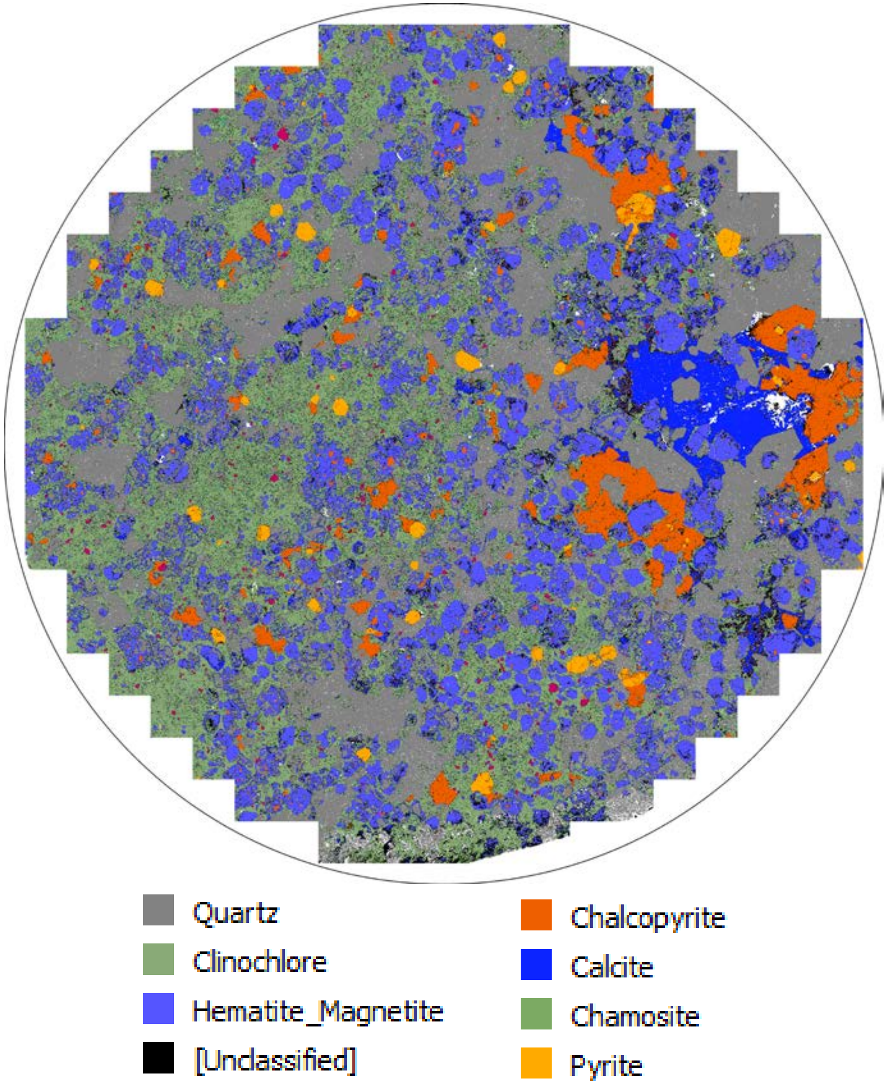
AMS – Breccia Zone (Potassic Alteration)



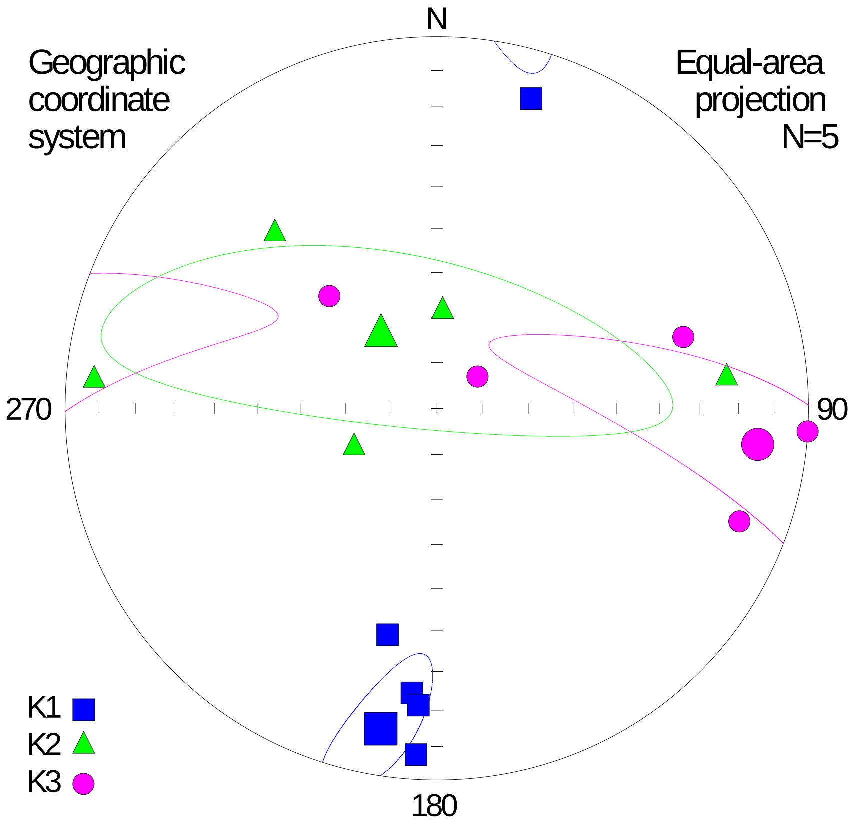
- Random AMS in breccia
- No fabric (Isotropic)
- It has destroyed the structural fabrics present
- Potassic alteration (Breccia) overprinted the sodic-calcic alteration
  - Structurally and
  - Metasomatically.

Quartz-calcite-chlorite-hematite alteration

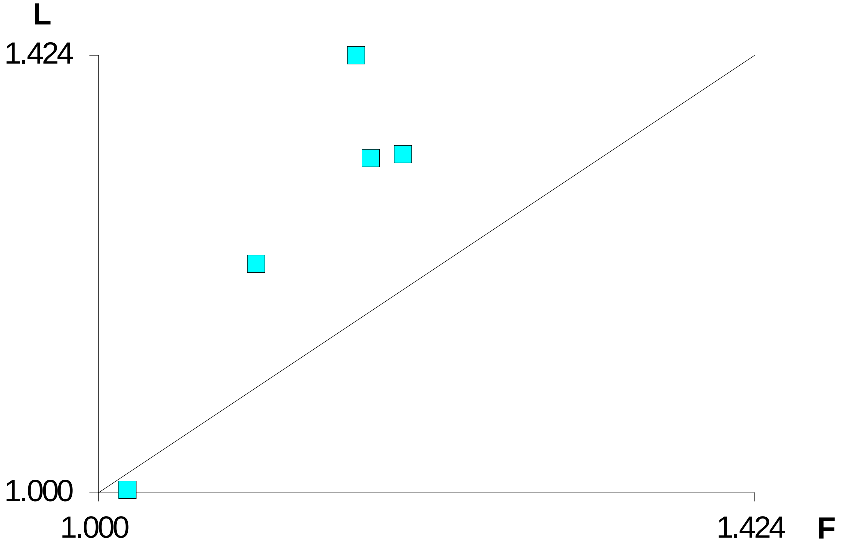
- Late quartz-calcite-chlorite-pyrite-hematite alteration is present in a number of deposits
- associated with copper and/ or molybdenum at Ernest Henry, Canteen, Kalman and Merlin
- most oxidized style observed in the Cloncurry district,
  - as indicated by the presence of pyrite and hematite,
  - rather than pyrrhotite and magnetite
- mineralized samples (with such alteration) sit below the Mt- trend on the density/sus plot.
- iron in magnetite is being converted to;
  - ferromagnesian minerals (e.g., chamosite),
  - chalcopyrite, pyrite and/or hematite during the late alteration history.



AMS – Quartz-Clacite-Chlorite-Hematite

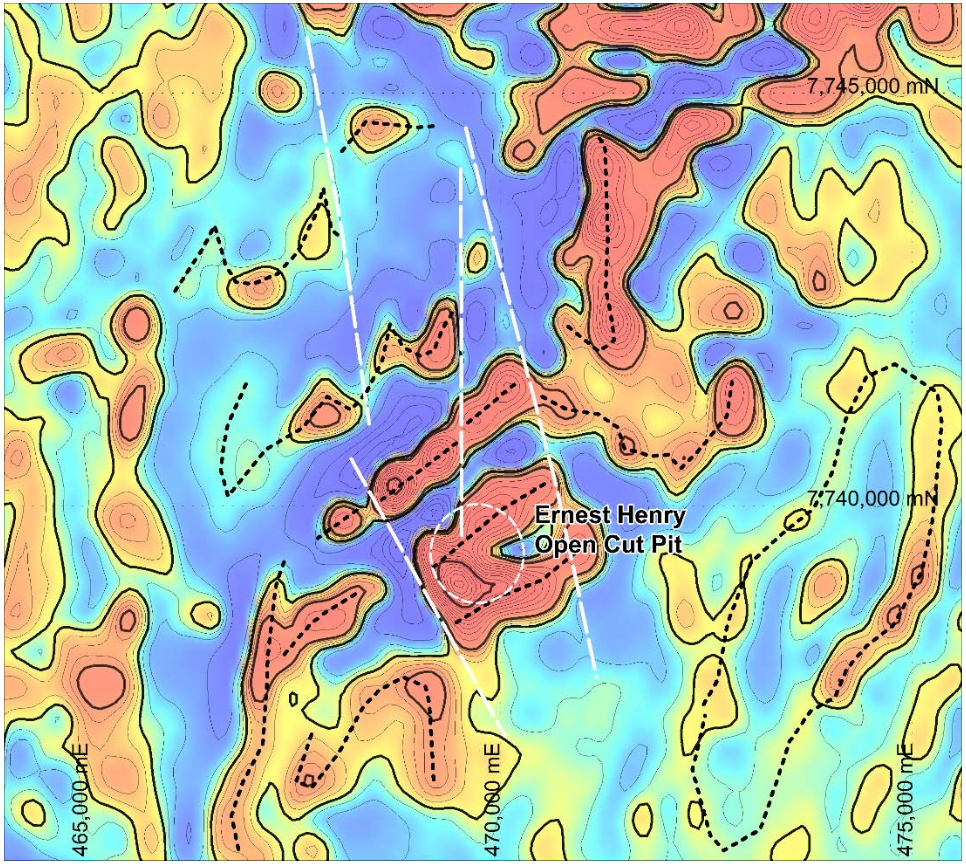


- Horizontal lineation
- Consistent with N-S strike-slip movement in a N-S upright fault.



Geophysical evidence

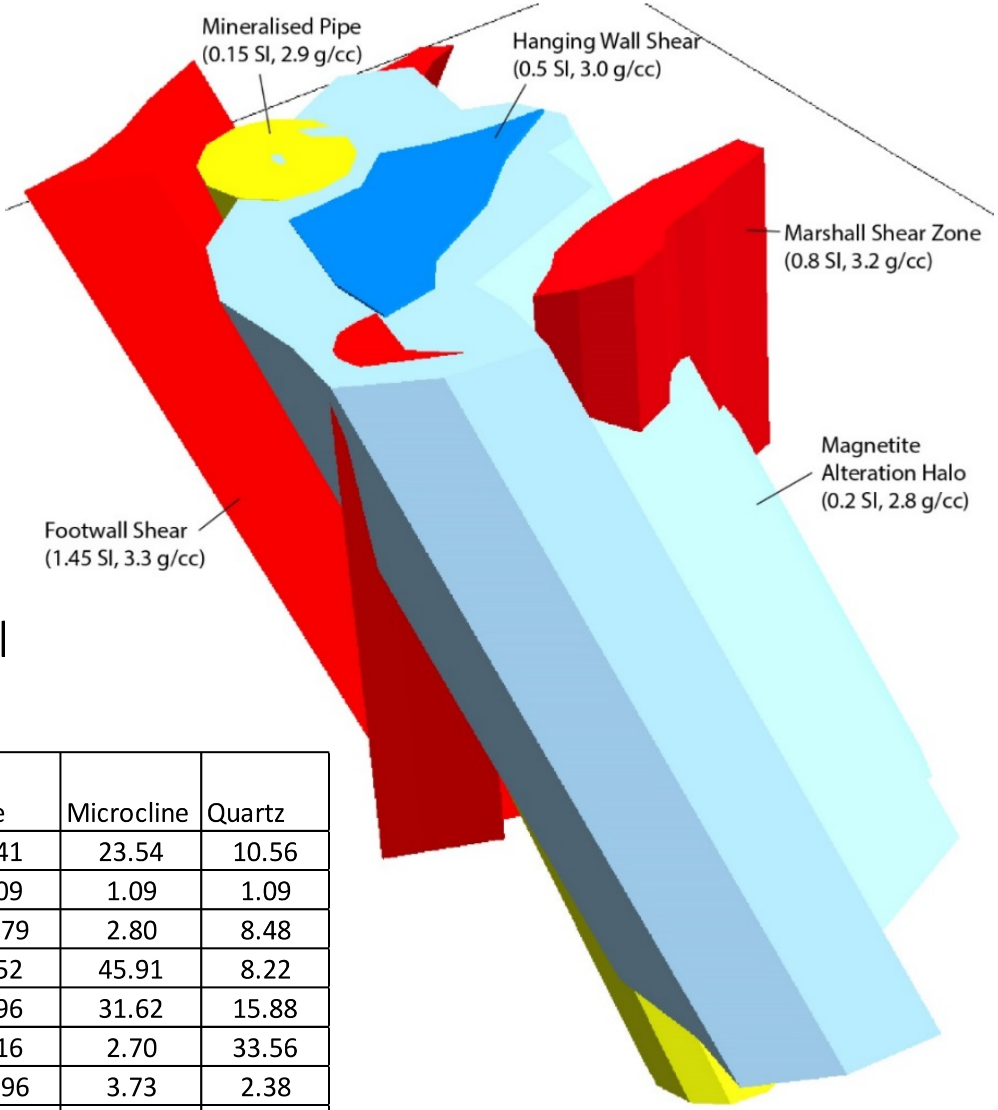
- Vertical derivative of RTP
- This shows 3 parallel magnetic zones coincident with NE-oriented shearzones.
- Bounded on each side by north to NNW oriented faults
- Mineralisation is coincident with the intersection of the N-fault and the NE-fabric



Magnetics 1st Vertical derivative of RTP

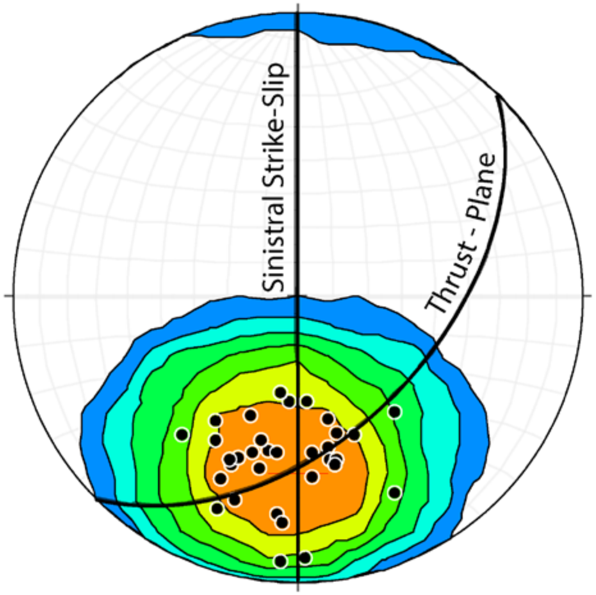
Inverse Bullseye

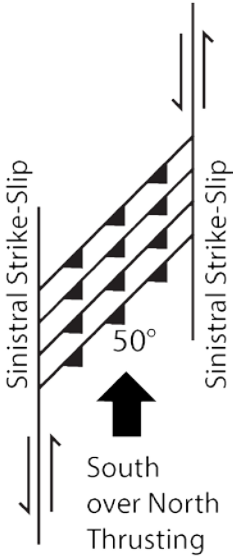
- Mineralisation increases on alteration gradient, from Sodic to potassic to hydrolytic alteration
- Mineralisation increases as rocks become more weakly magnetic
- Mineralisation related to oxidation l

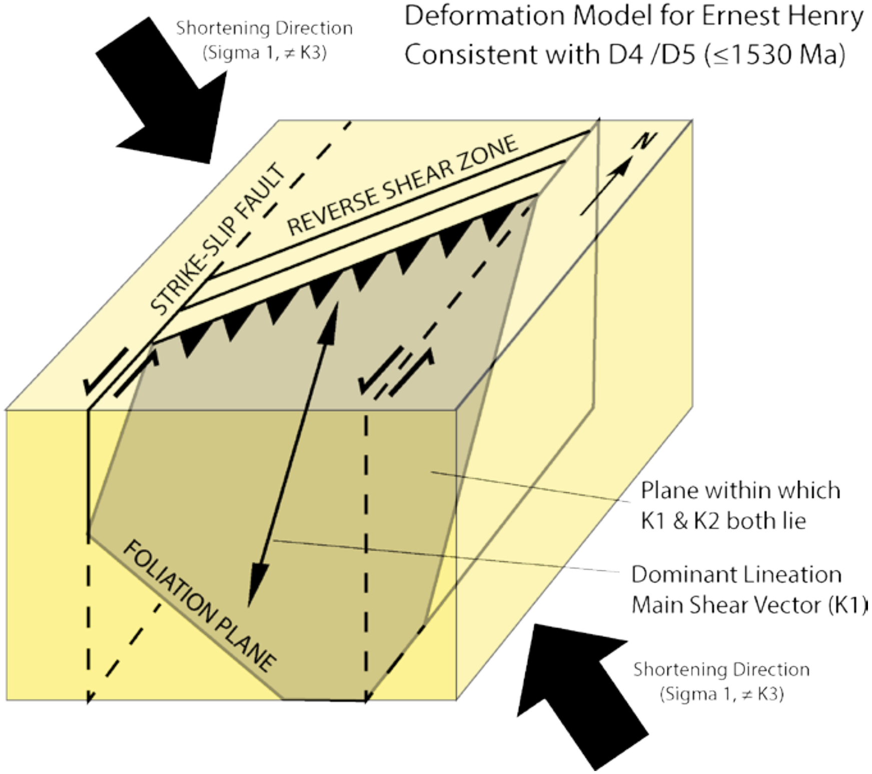


Alteration type	Chalcopyrite	Chamosite	Pyrite	Albite	Microcline	Quartz
And-Alb+Potassic+Calcic	0.00	0.82	0.27	7.41	23.54	10.56
Magnetite-Apatite*	3.80	1.84	1.09	1.09	1.09	1.09
Potassic (Bt)	0.00	0.29	0.07	58.79	2.80	8.48
Potassic (Kf)	0.25	2.27	3.38	2.52	45.91	8.22
Potassic+ Cal-Qtz-Py	2.00	1.19	4.03	0.96	31.62	15.88
Qtz-Cal-Chl-Py±Cpp±Hem	2.88	10.26	13.96	0.16	2.70	33.56
Sodic (Ab-Mt-Ti)	0.00	0.31	0.31	54.96	3.73	2.38
Sodic + Potassic (Bt)	0.05	1.12	0.27	20.11	20.00	10.03

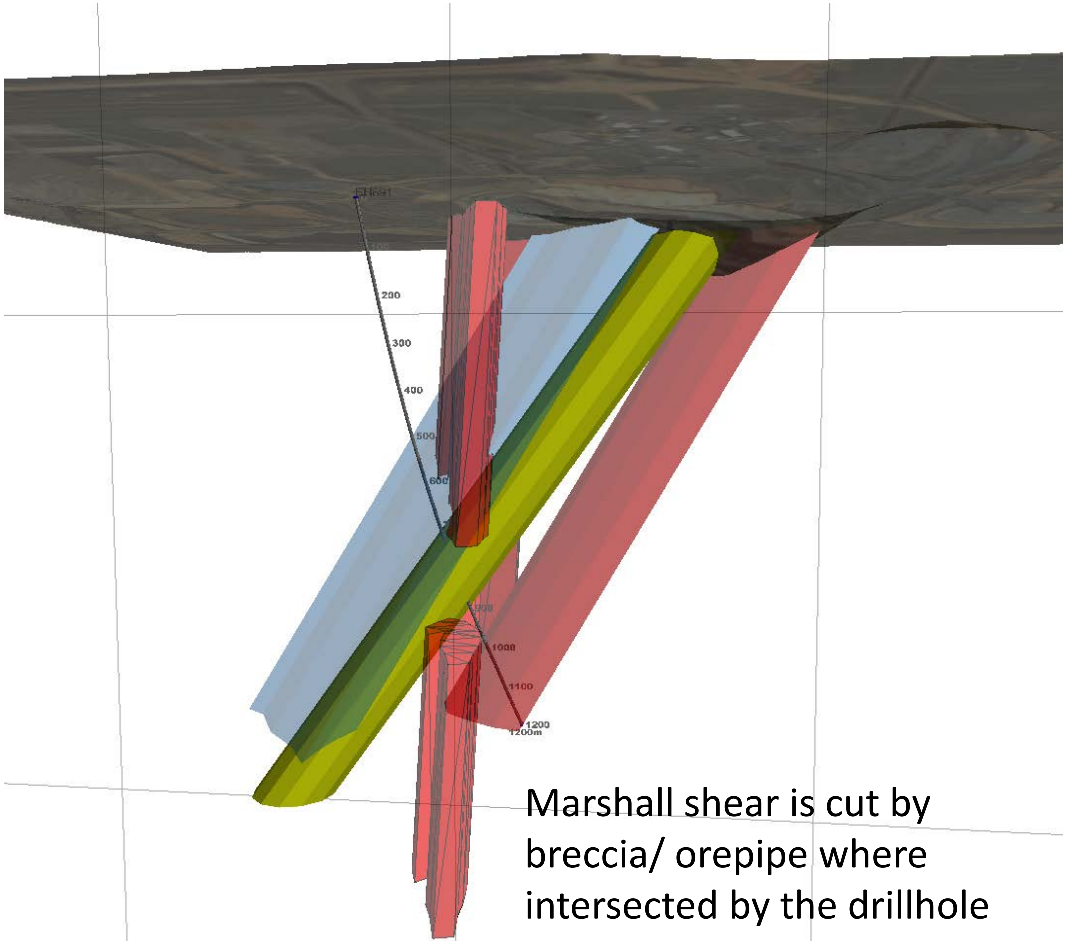
Thrust-Jog Model



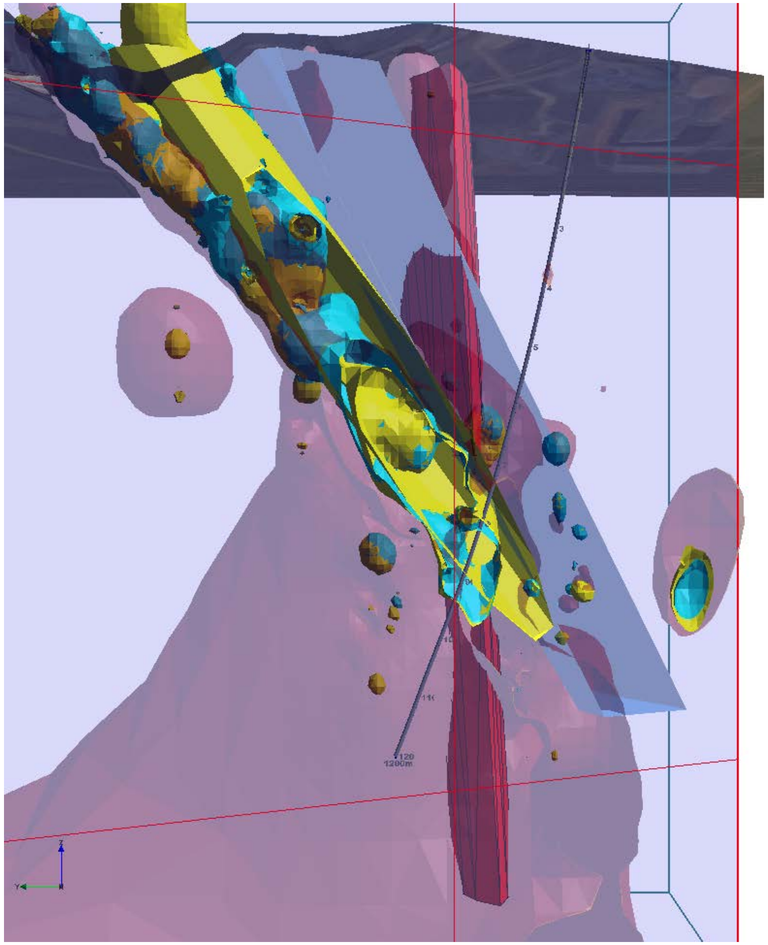



Deformation Model for Ernest Henry
Consistent with D4 /D5 (≤1530 Ma)

Structural-Geophysical-Geochemical Model



Marshall shear is cut by breccia/ orepipe where intersected by the drillhole

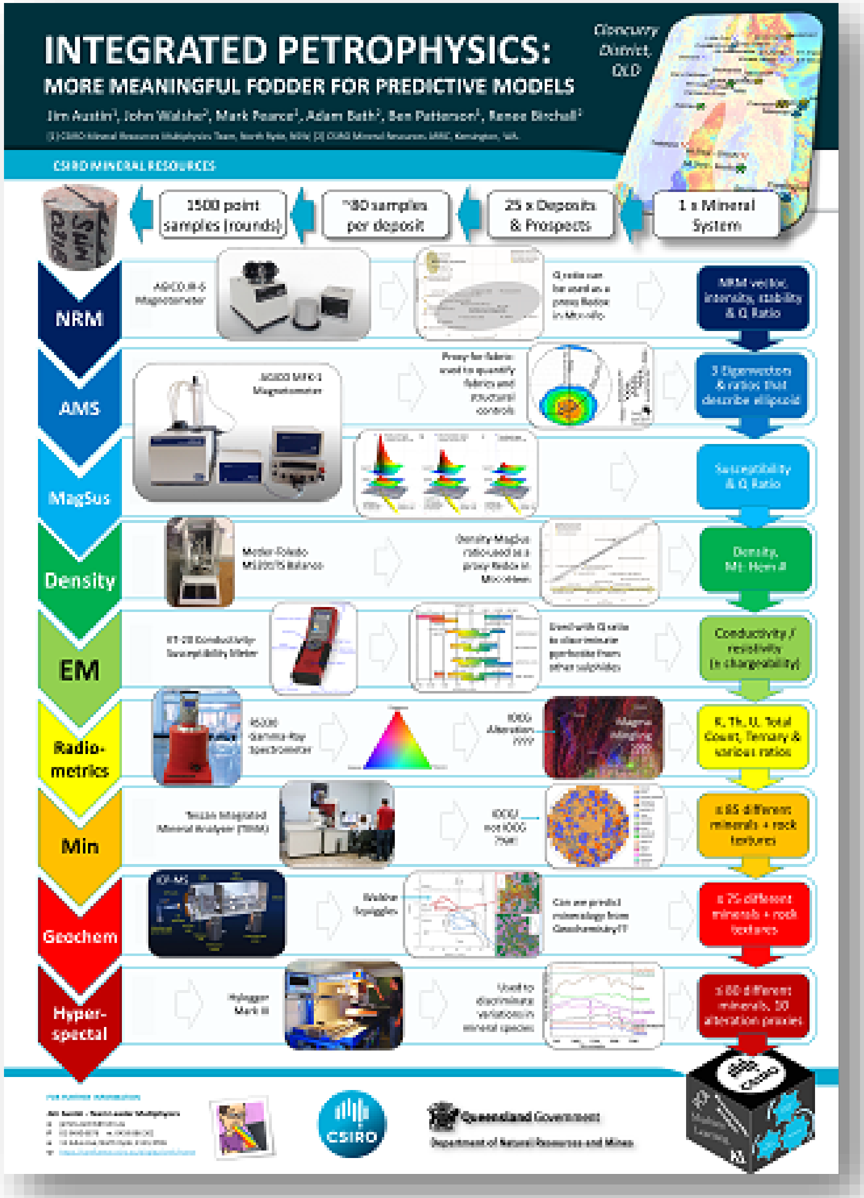


What else can we do??

After use samples can be also used for

Standard 1 inch paleomag cylinder

1. Mineralogy
2. Geochemistry
3. Hyperspectral
4. Conductivity
5. Density
6. Mag Sus
7. Remanence
8. Radiometrics



INTEGRATED PETROPHYSICS:
MORE MEANINGFUL FODDER FOR PREDICTIVE MODELS

Jim Austin[1], John Walshe[2], Mark Pearce[1], Adam Bath[2], Ben Patterson[1], Renee Birchall[2]

CSIRO MINERAL RESOURCES

What **WILL** we do??

Standard 1 inch paleomag cylinder

After use samples can be also used for

1. Mineralogy
2. Geochemistry
3. Hyperspectral
4. Conductivity
5. Density
6. Mag Sus
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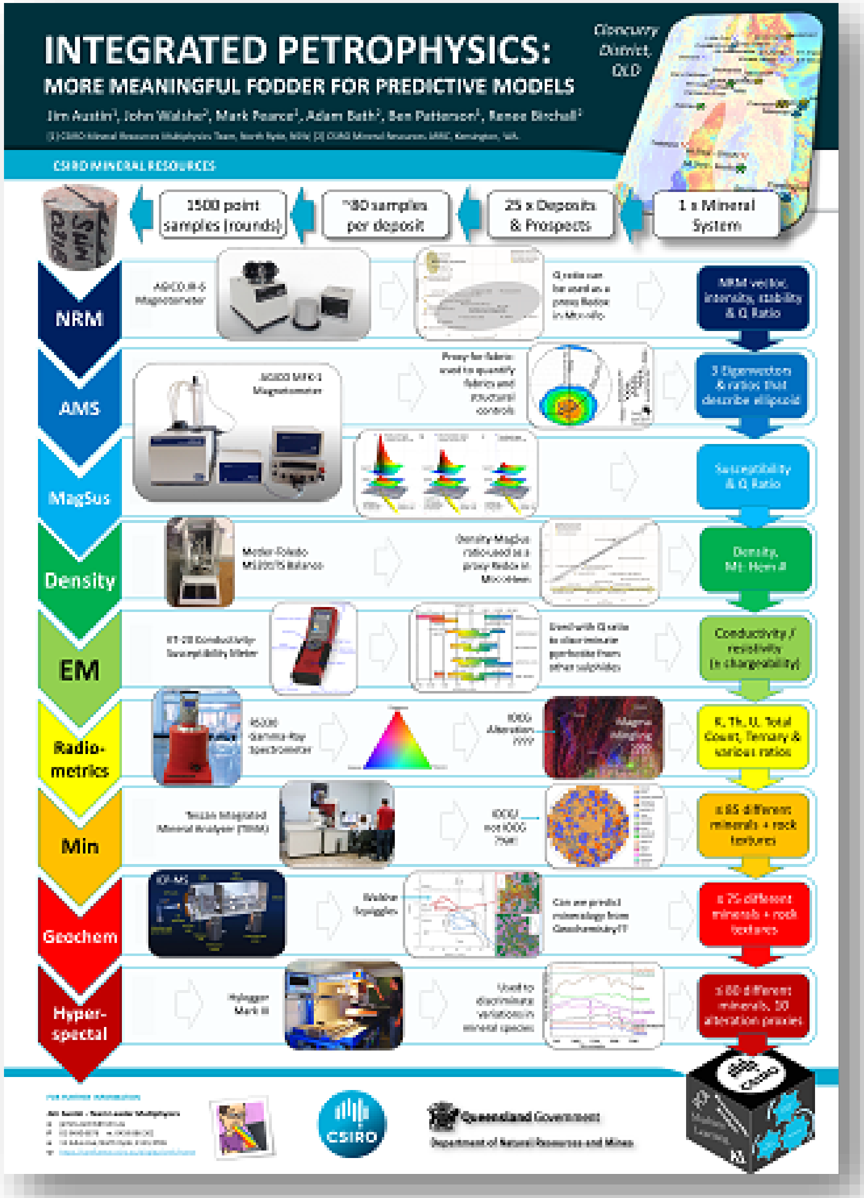
8. Radiometrics



INTEGRATED PETROPHYSICS:
MORE MEANINGFUL FODDER FOR PREDICTIVE MODELS

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Exploration significance

- Understanding Zonation can help us discriminate barren vs mineralised geophysical anomalies
- Understanding Redox can help us use geophysics to better map mineral systems
- Understanding the relationships between different geophysical signatures of alteration assemblages can help us target them indirectly
- All of this can help us recognise “near miss” signatures in core

“In theory there is no difference between theory and practice.

In practice there is.”

Yogi Berra