Identifying mineralization patterns using auto-correlation and weights of evidence: Mount Isa Eastern Succession, NW Queensland, Australia.

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1. Introduction

Australia's Mount Isa Inlier in NW Queensland contains major copper +/- gold and Pd-Zn-Ag resources, making it one of the world's premier mineral provinces.

Understanding the structural controls on regional-scale ore localisation is an important aid to mineral exploration.

This poster aims to define the regional structural controls on ore localisation in the eastern Mt Isa Inlier using a 3 phase analysis:

1. Literature Review: Deposit-scale structural controls
2. Auto-correlation: analysis of mineralisation trends
3. Weights of Evidence: spatial associations of mineral deposits

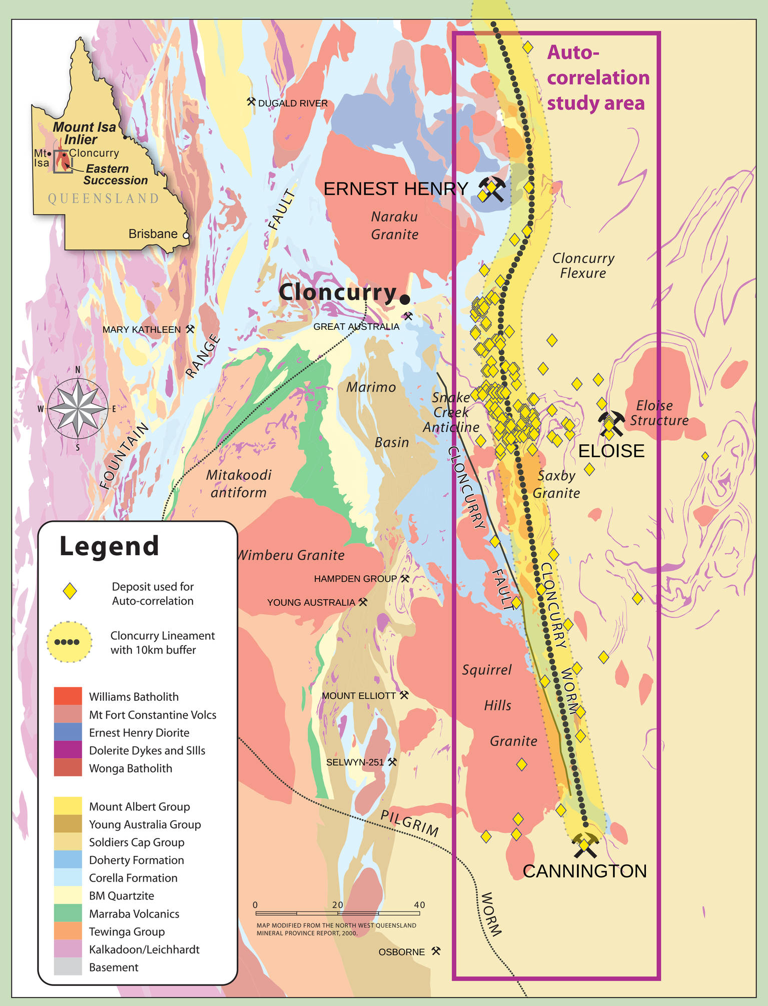


Figure 1: The geology of the Mt Isa Eastern Succession showing; study area, mineral deposits and the Cloncurry Worm (see panel 2). A weights of evidence study shows that 65% of deposits in the study area occur within 8km of the CW.

2. Background

1. The Isan Orogeny which occurred from ~1.61-1.5 Ga left a record of complex deformation and a range of mineral deposits. It consists of several shortening episodes, the major ones are; D1: ~1610 Ma N-S thrusting, D2: ~1585 Ma ENE-WSW folding and peak metamorphism, D3: 1527 Ma ESE-WNW folding, brecciation and pluton intrusion (ages summarised from Rubenach, 2005).

2. The timing of mineralization in the inlier is largely accepted to have occurred during two periods: 1.67-1.60 Ga for Pb-Zn-Ag; and 1.60-1.50 Ga for Cu-Au mineralization (Mark et al, 2005)

- Cu-(Au) deposits formed during reverse faulting/shearing after the ca. 1585 Ma metamorphic peak and have a genetic relationship with 1.55-1.50 Ga A-type magmatism. (Mark et al, 2005)
- Hatton and Davidson, (2004) suggest that iron oxides (+ Pb-Zn-Ag) were deposited on the sea floor during deposition of the 1675-1650 Ma Soldiers Cap group.

3. Carter (1961) and Laing (1998) propose that N and NW faults host both Cu-Au and Pb-Zn-Ag deposits while "North-east faults are generally barren." Carter (1961) also suggests that NE+NW & NNW+NNE faults are two conjugate fault sets that formed as a result of two successive stages of East-West shortening.

4. A prospectivity analysis by Mustard et al. (2004) identifies the Doherty Formation-Soldiers Cap Group contact (a NNW tectonic feature) and NE trending strike-slip faults to be highly prospective to Cu-Au mineralization. These structures are interpreted to be two main components of a major geophysical lineament referred to here as the Cloncurry Worm (CW).

3. Structural controls / settings - deposit scale

Structural information can be found for 26 deposits in the study area (see table). Structural controls are sourced directly from the references (see figure 3) or inferred from 1:100k geological mapping where information is inadequate.

Structurally, there are three main types of deposit and several unique / more complex deposits.

1. North trending, iron formation-associated deposits that are Pb-Zn-Ag rich.

2. North trending, iron formation-associated deposits that are Cu-Au rich.

3. Copper or gold dominated deposits that occur along, or at the intersection of syn-post-orogenic, variably oriented faults. This may be evidence of copper / gold remobilization.

NB: The three largest deposits (e.g., Cannington, Eloise, Ernest Henry) have more complex fault geometries than smaller deposits.

DEPOSIT NAME	SIZE	DEPOSIT TYPE	LODE ORIENTATION / STRUCTURAL CONTROL	REFERENCE
Ag-Pb-Zn +/- Cu Deposits				
Cannington	Giant	Ag Pb Zn	N-NNE - BIF	Chapman & Williams 1998; Walters and Bailey, 1998.
Pegmont	Medium	Pb Zn Ag	NE - BIF	Blake et al,1983, Vaughan & Stanton, 1986
Cowie	Small	Zn Pb Ag	NNW - BIF	Blake et al,1983
Maramungee	Small	Zn Pb Cu	N - BIF	Williams and Heinman,1993
Fairmile	Very Small	Ag Pb Zn Cu	N- BIF	Donchak et al, 1983
Maronan	Very Small	Pb Ag Cu Au	N - BIF	DeJong, 1995 (PhD Thesis)
Black Rock	Very Small	Pb Zn Cu Ag	N - BIF	Blake et al,1983
Dingo	Very Small	Zn Cu Au Ag	N - BIF	Nisbert & Joyce, 1980 (in Blake et al, 1983)
Cu-Au Deposits (brecciated)				
Ernest Henry	Large	Cu Au	Dilational jog in N-trending fault	Cleverley & Oliver, 2005, Mark et al, 1999,
Cu-Au Deposits hosted by iron formations in north trending faults				
Eloise	Medium	Cu Au Ag	North trending BIF	Baker & Laing, 1998, Baker et al, 2001
Mount Norna	Small	Cu Ag Au	North trending BIF	Hatton & Davidson, 2004
Monakoff	Small	Cu Au Ag Pb	North trending BIF	Hatton & Davidson, 2004
Weatherley	Very Small	Cu Au	North trending BIF	Hatton & Davidson, 2004
Cu-Au Deposits (remobilization along late / minor faults)				
Great Australia	Small	Cu Au	N / NE Fault Intersection	Carter, 1961; Cannell & Davidson, 1998
Gilded Rose	Small	Au	NNW / NE Fault Intersection	Oliver et al 2004
Barnes Shaft	Very	Cu	NNW / NE Fault Intersection	Blake et al,1983
Landsborough	Very Small	Cu	NE Fault	Donchak et al, 1983
Louise	Very Small	Cu	NE Fault	Donchak et al, 1983
Mount Arthur	Very Small	Cu	NNW / NE Fault Intersection	Blake et al,1983
Mount Kalkadoon	Very Small	Cu	ESE Fault	Donchak et al, 1983
White Cliffs	Very Small	Cu Au	Shear Zone	Blake et al,1983
Mount Carol	Very Small	Cu Sio	not observed	Blake et al,1983

4. Auto-correlation - regional scale

Auto-correlation is used to delineate patterns of mineral deposit distribution by defining the spatial relationship of each deposit to all others. MINOCC (2002) data was sorted into Pb-Zn-Ag, Cu, Cu-Au, Au-Cu and Au deposit types. Patterns of deposit locations are revealed by plotting the ends of vectors drawn from each deposit in turn at the centre of the plot to every other deposit. The resultant XY plots and rose diagrams are shown here ->

1. Cu-Au deposits show strong N-NNW trends as well as ~NE and SE trends.
2. Cu deposits have strong NNW and N-S trends
3. Pb-Zn-Ag deposits show strong N and NNE trends
4. Au+/-Cu deposits show 5 different trends: N-S, NE, ENE, ESE, SE; these correlate with a variety of late faults.

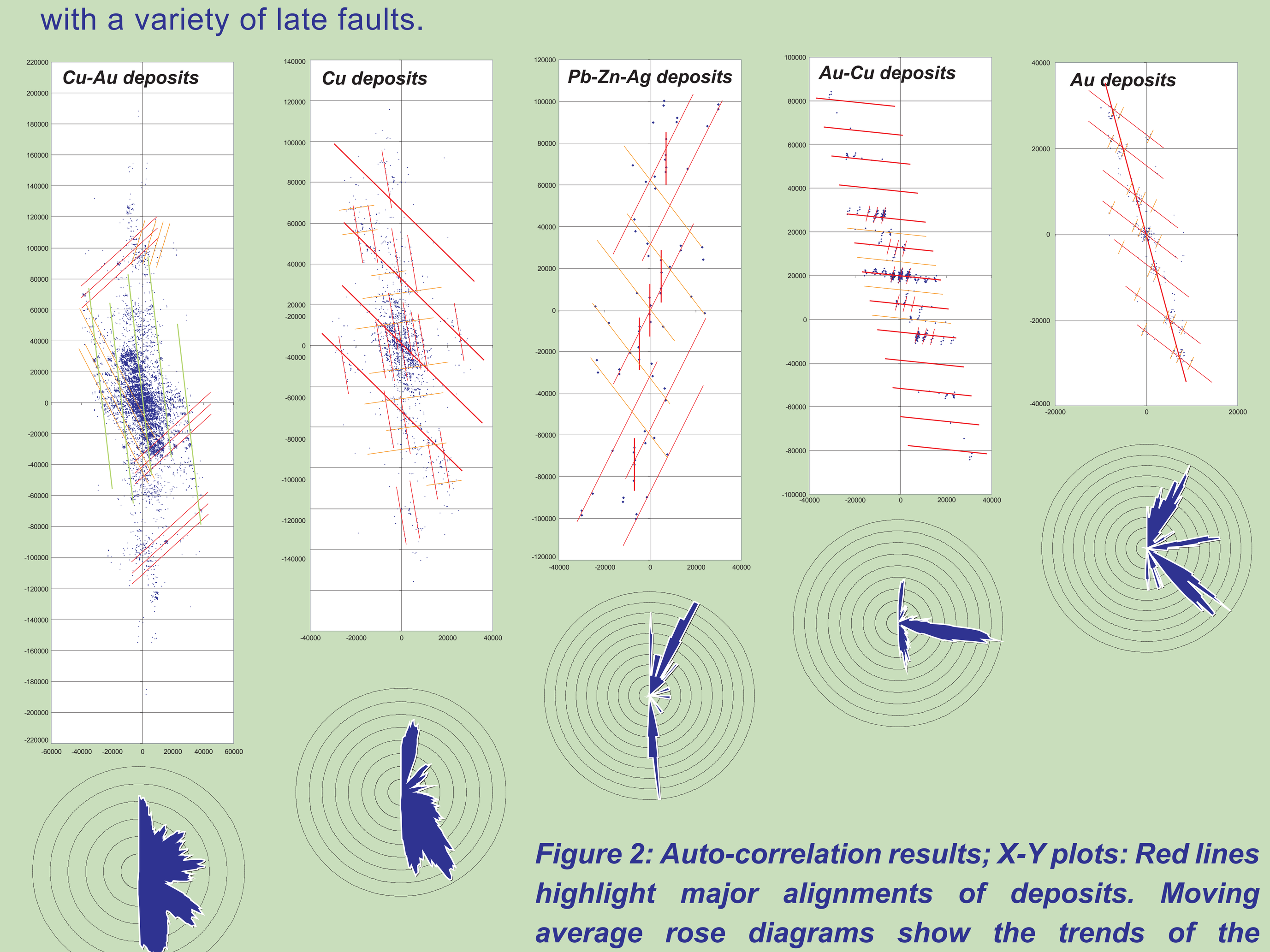
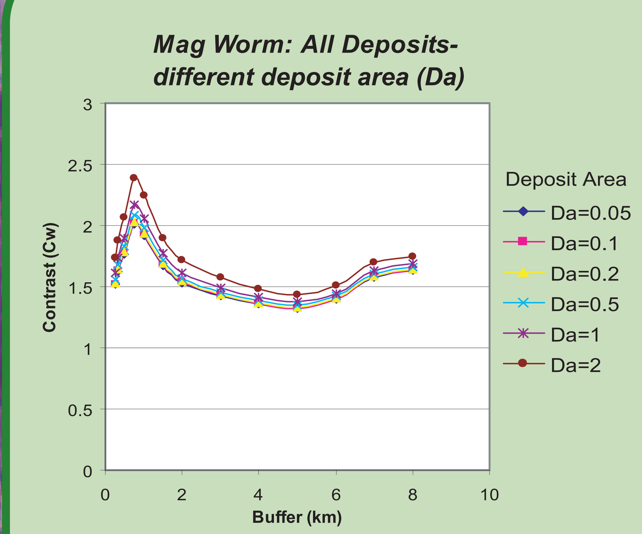
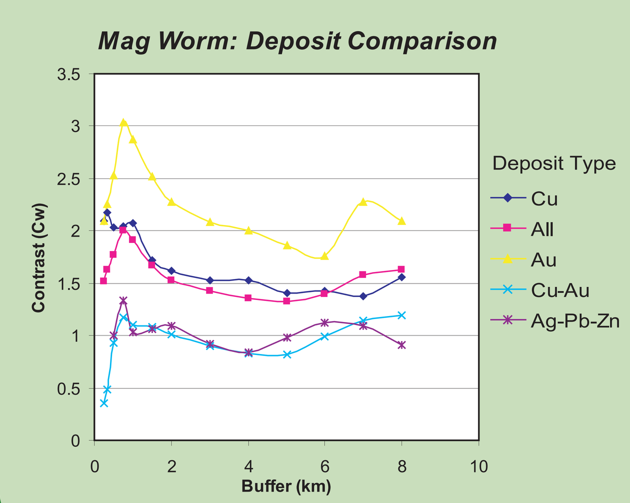


Figure 2: Auto-correlation results; X-Y plots: Red lines highlight major alignments of deposits. Moving average rose diagrams show the trends of the autocorrelation vectors for different deposit types.

5. Weights of Evidence





"Weights of evidence" is the degree of spatial association between deposits and a geological variable (e.g. buffer around fault). It is expressed by the Contrast (Cw); the natural logarithm of the ratio of the odds of a deposit given the presence of the geological feature to the odds of a deposit in the area without the feature.

Cw > 0.5 indicates a significant spatial association, thus there is a strong correlation between mineralisation and the Cloncurry worm.

Au and Cu deposit types have a stronger correlation with the worm than Ag-Pb-Zn deposits . This contrast could be explained by a 2-phase mineralisation history where:

1. Large, low grade, Ag-Pb-Zn & Cu-Au primary deposits formed first. The structural relationship of these deposits to the Cloncurry worm is inconsistent, however Cannigton (the largest of these deposits) sits directly on the worm.

2. Smaller, higher grade Au and Cu deposits formed on minor faults related to reactivation and a second phase of fluid flow along the Cloncurry worm. These fluids may have been basin fluids related to late syn-post-Isan extension.

6. Conclusions

- Weights of Evidence analysis indicates that mineral deposits in the study area have a strong correlation with the Cloncurry worm.
  - Cu and Au deposits have a stronger spatial association than Ag-Pb-Zn and Cu-Au deposits.
- Auto-correlation analysis shows N-NNW Cu-Au trends and N & NNE Pb-Zn-Ag trends, which correspond to north trending Iron formation deposits in table 1. There are Cu-Au rich and Pb-Zn rich end members.
  - These trends are generally bedding parrallel and probably reflect the stratiform nature of these deposits. It is also possible that the ironstones have formed in N-trending normal or dip-slip faults (e.g., the N-S Levuka shear zone).
- Au+/-Cu deposits have moderate NE, ENE, ESE, SE trends and have a strong spatial association with the Cloncurry worm. These deposits reflect secondary mineralisation along variably oriented late syn-post orogenic faults.
- Cu deposits have a strong NNW trend and have a strong spatial association with the Cloncurry worm in the weights of Evidence analysis, and thus appear to be structurally controlled by the Cloncurry Worm

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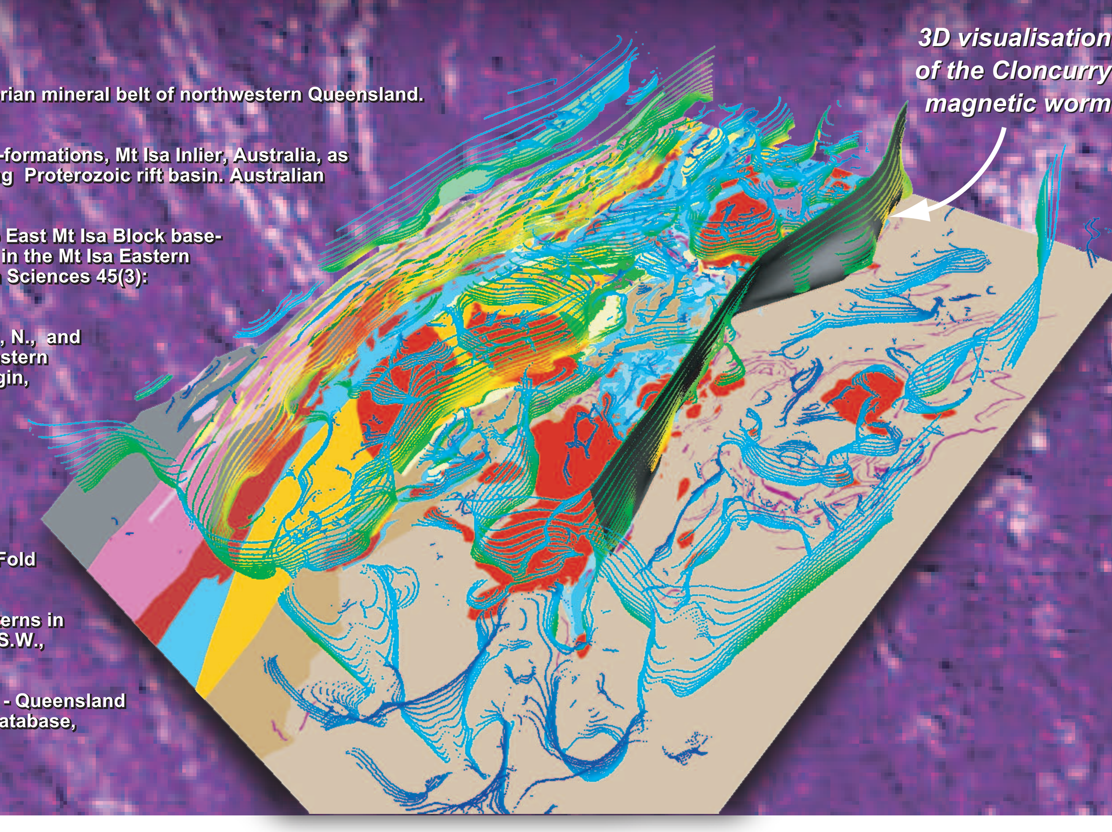

3D visualisation of the Cloncurry magnetic worm