Structural Framework and Target Generation in the Osborne District, Mt Isa region, Queensland, through analysis of Aeromagnetic Multiscale Wavelets ("Worms").

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Executive Summary

This report concerns the interpretation of multiscale wavelet edges (worms) from aeromagnetic data in the Osborne region in Mt Isa. The objective is to derive a structural framework and to establish what correlations, if any, might exist between the wavelet edges and known mineralization that may be used in a predictive way to target ore systems of interest. The basis for this analysis comes from the perceived spatial relationship of the Barramundi Worm to Giant Ore deposits in the region, and from relationships derived between worms and deep tapping crustal scale structures (in other districts).

Worming is an edge detection technique that diminished ambiguity in potential field interpretation and provides critical 3D information on the shape and relative depth extent of edges (eg. faults, shears, intrusive contacts). The analysis of worms is based on numeric distributions of two variables, Z being the level of upward continuation, and W being the "amplitude" of the edge. A key aspect of the analysis undertaken here lies in the projection or migration of the 3D worm data into a 2D exploration environment, with a focus on edge location, apparent penetration, and intersection geometries derived from the structural architecture.

A good correlation is seen between worm edges (Z) and mapped geology, which gives confidence to their interpretation undercover. Area selections using an intersection index (AI) derived from 2km buffered regions about 20km edges yields about 50 potential target areas, including Osborne. The spatial distribution of W shows a strong association between discrete regions of high magnetic intensity and with existing mineralization, eg. Osborne. A ranking of these regions yields 4 priority target areas, at least one of which is ore related, and 8 lower priority regions. These anomalous W regions are largely contained in regions outlined from the buffered migrated edge analysis (Z values).

Through the integration of these two variables, a useful first order, area selection filter can be derived. Second order filters of host rock potential and depth of burial need to be applied to effectively rank the regions of interest.

1. Introduction

This report concerns the interpretation of multiscale wavelet edges ("worms") derived from potential field data in the Osborne district of the Mt Isa region (Fig. 1). The objective is to derive a structural framework from the worms that allows an evaluation of the degree to which penetrative structures and intrusions exert control on existing ore body locations and, if so correlated, to form a basis for target area selection on a regional scale. It seeks to do this through integration and mapping of worm data sets, with respect to mapped or inferred geological features, and determining their spatial relationship to mineralisation.

This research contributes to the pmd*CRC I2/I3 project on "Total Systems Analysis of the Mt Isa Eastern Succession" (representing Module 1: Structural Framework), and to the I1 project on "Mt Isa Western Succession 3D architecture and ore systems". It seeks to build on the existing high level understanding of the region, as documented in the North West Queensland Mineral Province Report (NWQMPR 2000). This latter report represents a cornerstone in prospectivity analysis, and derives from the integration of a range of geological and geophysical data, mostly undertaken at 1:250,000 scale. The current work by the pmd*CRC incorporates new processing ("FracWorming") of similar geophysical data sets as those in NWQMPR (2000), and represents a more detailed scale of regional data integration, against the backdrop of Geoscience Australia's 1:100,000 digital solid geology map coverage (Fig. 1).

The concept that penetrative crustal scale structures provide a control on ore body location is not new (eg. O'Driscoll 1990), and is implicit in assessments of the deposit types contained in this region (eg. NWQMPR 2000, Large *et al*. 2002, Haynes 2002). It is critically demonstrated in the North Australian Proterozoic region by the spatial association of the deep "Barramundi Worm" (derived from gravity data) and "Giant Ore Deposits" proximal to it (Hobbs *et al.* 2000; Fig. 2). Initial assessments of such relationships using the Australian gravity field (Archibald *et al*. 2001) suggest a closer correlation of coarse scale worms with Pb Zn deposits than with Cu Au systems. This lends weight to the hypothesis that penetrative faults, and particularly fault intersections along them, may provide a first order control on the localization of ore systems. Such regions are, 'a priori', more permissive for ore localisation, through the ability to tap deep source regions for metal and/or magmatic fluids and thermal gradients, and to create volumes of high fracture density that can facilitate hydrothermal fluid flow. A second order filter, once such regions have been identified, is the existence or preservation of suitable host rocks. The objective of this analysis is to identify the more permissive regions (the first order filter).

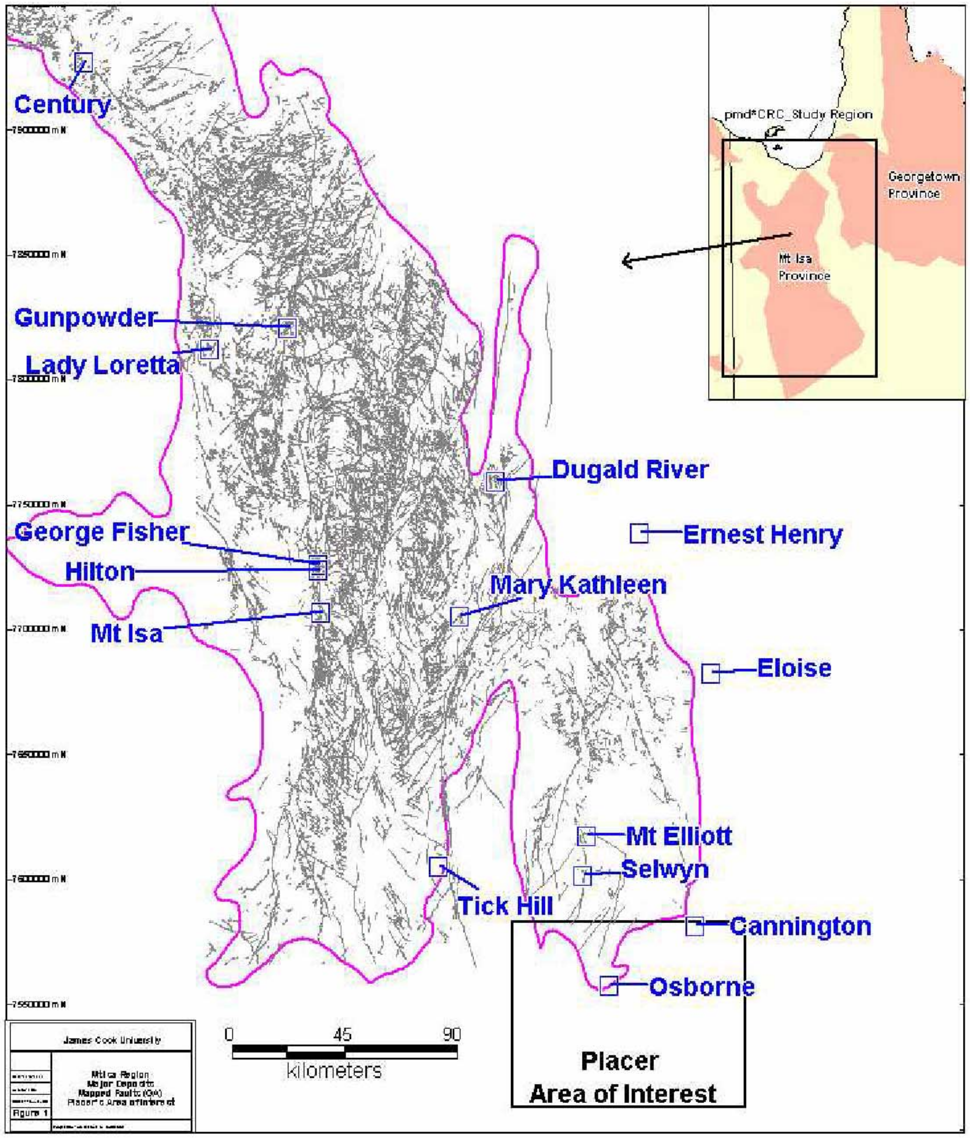


Figure 1: Regional location map of Proterozoic study area.

The power of the multiscale wavelet method of upward continuation lies in reducing the ambiguity in interpretation of potential field data by providing critical shape and depth information on edges in the data (Archibald *et al.* 1999, 2001). It is particularly useful for mapping faults and intrusive contacts (Fig. 3). The role that faults and intrusives have in the localization of IOCG and SHMS deposits in the district can then be addressed. Attributes of the worms are examined in the context of: a) the level of upward continuation (Z), being an indirect measure of relative penetration depth, b) the interpreted intersections of worm sheets, and c) other spatial features of the wavelets (e.g. W value). These attributes are evaluated using mapped geology where possible, to derive confidence in the interpretation, and become critical in the undercover environment.

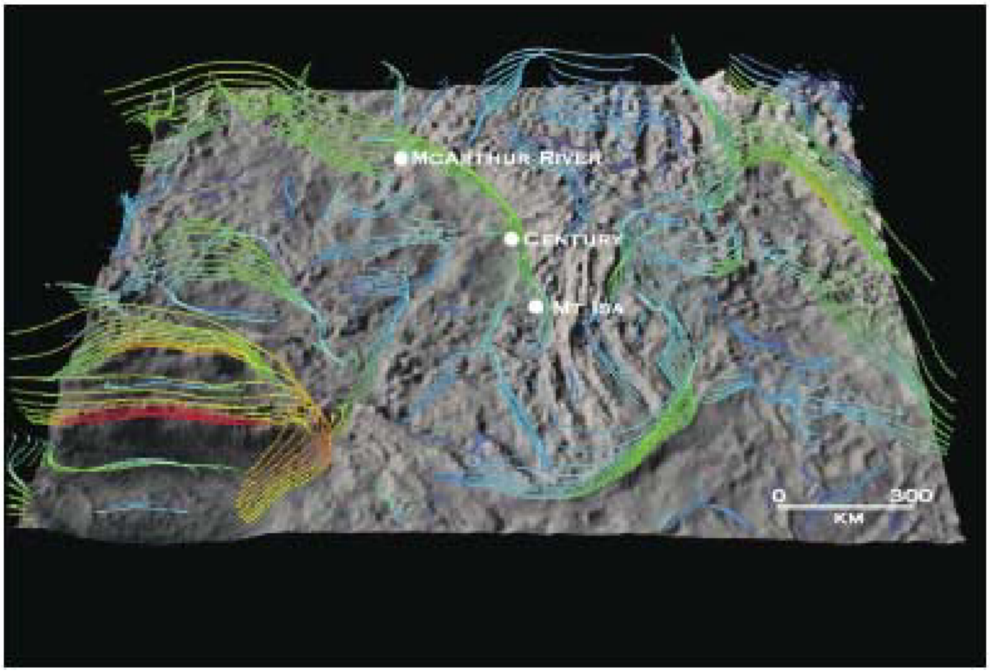


Figure 2: Oblique view of North Australian Gravity with upward continued worms to 220km. Major deposits spatially related to Barramundi Worm (Hobbs et al. 2000)

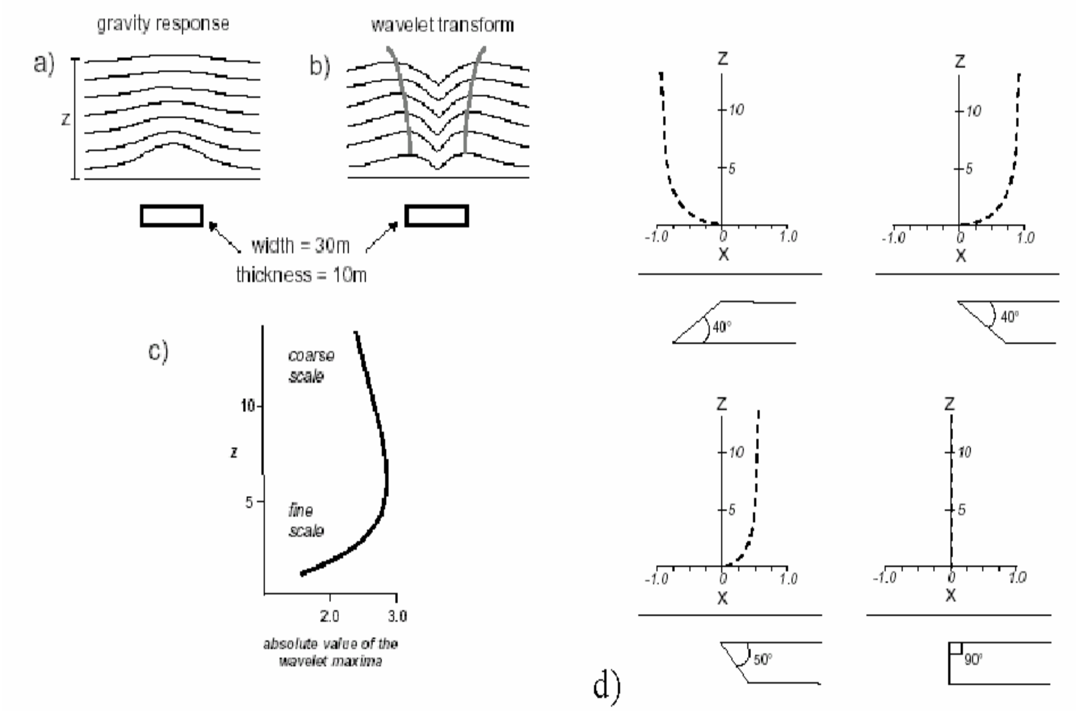


Figure 3: Synthetic models and their wavelet transformations for a) gravity source with increasing levels of upward continuation; b) Wavelet Transform of response; c) variation in Wavelet Maxima with increasing Z; d) models of Z migration in relation to direction of variably inclined edges (Archibald et al. 1999).

A methodology for migrating 3D worm data (Z values) into a 2D image of their near surface expression was developed by the author as a targeting tool in the Irish mineral province. A key aspect to the analysis is the up-dip projection of worm sheets into an "exploration" environment, where their geological context can be evaluated. The Irish case study indicated that intersections of crustal scale structures have a strong control on ore body location. This resulted in delineation of 11 target regions (of which 4 contain existing ore systems), and became the basis for Pasminco's area selection in the region – potentially, a cost effective, focused program. Based on this type of analysis, the pmd*CRC is seeking to apply similar techniques in the Isa region, one that is far more complex than the Irish setting. The application of this methodology to IOCG deposit styles is being trailed as part of this project.

Naturally, further work is needed to refine and test the interpretations contained here. In particular, the context of the edge features that are mapped have not been integrated or evaluated comprehensively with respect to their geological expression. A further limitation, through the reduction of the 3D data sets into a 2D framework, is that this has been done without recourse to a 3D viewing platform. As such, it is considered a first pass assessment of the region, and is an avenue for future research into the 3D architecture of the region and its ore systems.

2. Data Inputs and Processing

Multiscale wavelet data was supplied by Fractal Geoscience who processed ("FracWormed") the regional aeromagnetic data used in this analysis (Fig. 1).
The multiscale wavelets comprise ascii point files, with Easting, Northing, Z and W values. The Z value is a measure of the level of upward continuation (in meters) of detected edges or gradients. The worming technique (Fig. 3) involves the use of upward continuations to separate the potential field data into high frequency / short wavelength responses (near surface) and low frequency / long wavelength responses (possibly deeper sources). The W value is derived from the amplitude (or contrast) in the gradient at a particular Z value. Fractal's processing generated up to 32 levels of Z ranges. The aeromagnetic data was gridded to 200m and upward continued to approximately 30km. Two types of worms are produced for each upward continuation level. The "MAX" worms are the standard maximum horizontal gradient points derived from the either the magnetic or gravity fields. The "EFVD" worms are maximum horizontal gradient points derived from the enhanced first vertical derivative of either the gravity or magnetic fields. The EFVD worms provide additional spatial resolution at low levels of upward continuation and combined with the MAX worms can help determine approximate depth to source.

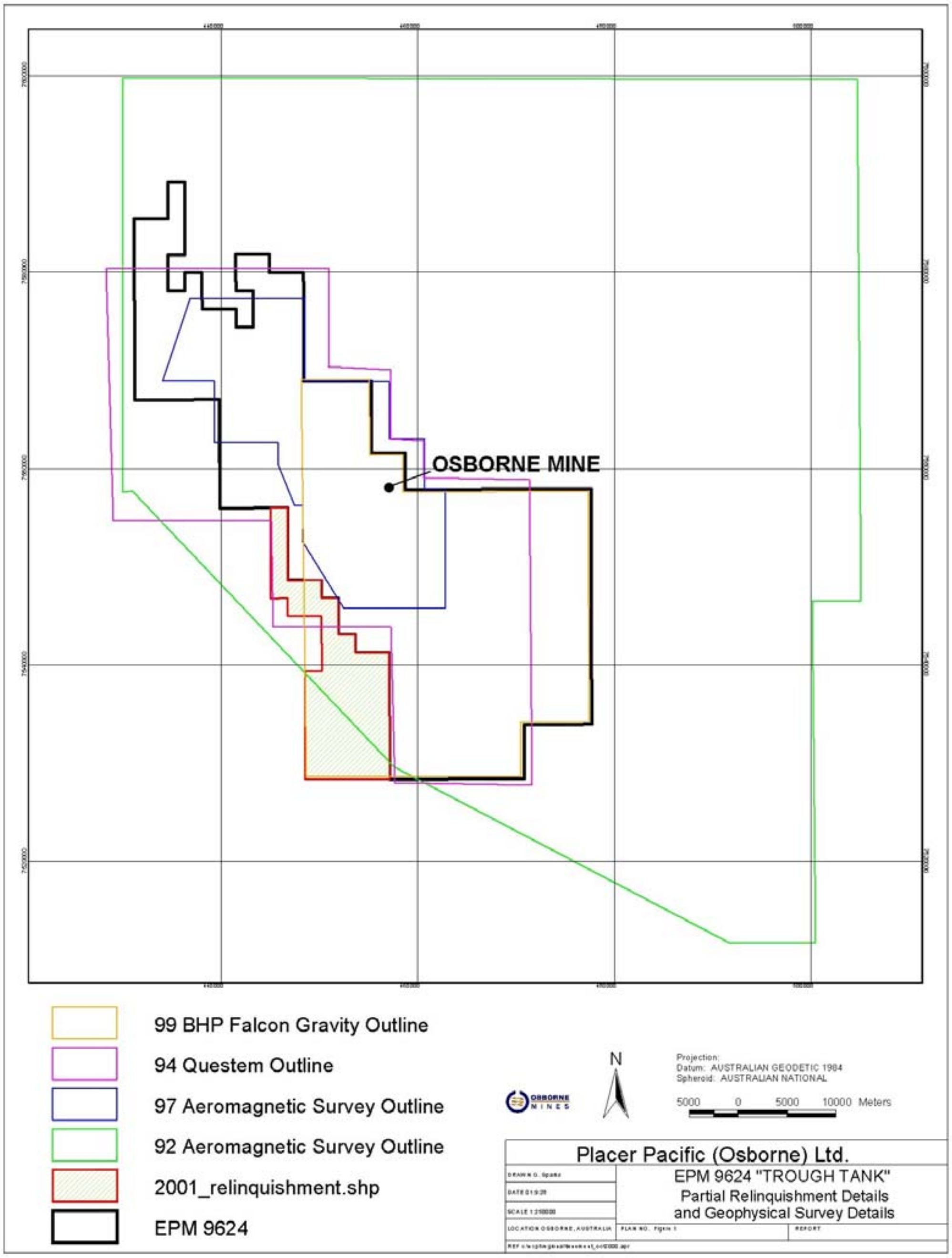


Figure 4: Placer Data Sets, Location of 1992 Aeromagnetic Survey.

3. Interpretation Methodology

Initial inspection of the EFVD and MAX data in Datadesk was performed to evaluate regional characteristics. This platform provides a "first pass" visualization from which a series of "cutoffs" in the numeric distributions for Z and W are determined. With two levels of processing and associated two derived values, results in 4 outputs to be considered (Appendix 1).

A key objective of the interpretation is to derive a 2D surface representation of the 3D worm sheets, while retaining attributes of apparent penetration depths (a function of the level of upward continuation, Z). This has involved developing a routine to reliably map the near surface expression of worm sheets and to attribute the near surface features with their depth dimensions. Three routes to this end product have been explored in the context of reliability, repeatability and time/cost effectiveness: a manual method (as in the original Irish case study), a semi-automated method (used here), and an automated routine (under development). For the magnetic data, the derived architecture is representative of features that are projected onto a 200-500m depth slice. Faults derived from the 1:100,000 GA geology were used as a backdrop to the interpretation. An updated fault file was initially created which attempts to create more linkages of faults than are shown in the original data (Fig. 1).

4. Results and Validation

There are two streams to the interpretation, involving Z and W respectively.

4.1 Z Distributions

- A series of "dot" maps are plotted at 1:250,000 scale to illustrate the worms, their relationship to the mapped fault architecture, and locations of the major deposits. (Maps 1-2). An example is shown here for the EFVD data (Fig. 5).
- In their geological context, where mapped faults and intrusive edges are known to exist, the spatial distribution of edges, particularly those that migrate to significant upward continuations, show a good correlation. The edge detection method appears to be remarkably sensitive to relatively minor mapped structures within the Proterozoic outcrop, and gives confidence that the worms are reflecting real features in the under cover environment.
- Many of the "deep" (high Z) worms shown in the magnetics (Fig. 5; Maps 1 & 2) outline large strike length features that include:
    - A major magnetic feature through the central part of the region. This is more coherent and shows up dip continuity in the SE while its surface manifestation in the NW is less evident, where it may have a ramp/flat topology,
    - Curvilinear edges and closures in places are related to granitoids.

A structural architecture has been derived through the up-dip projection or migration of the Z data. This is shown as a series of line interpretations (Map 3; Fig. 6). Individual lines are colour coded by the apparent penetration depth. The rectilinear fracture network derived in the interpretation is similar to other natural fracture systems seen at a range of scales. This data set is used for digital processing and area selection routines. Firstly, some criteria are derived in relation to existing mineralization.

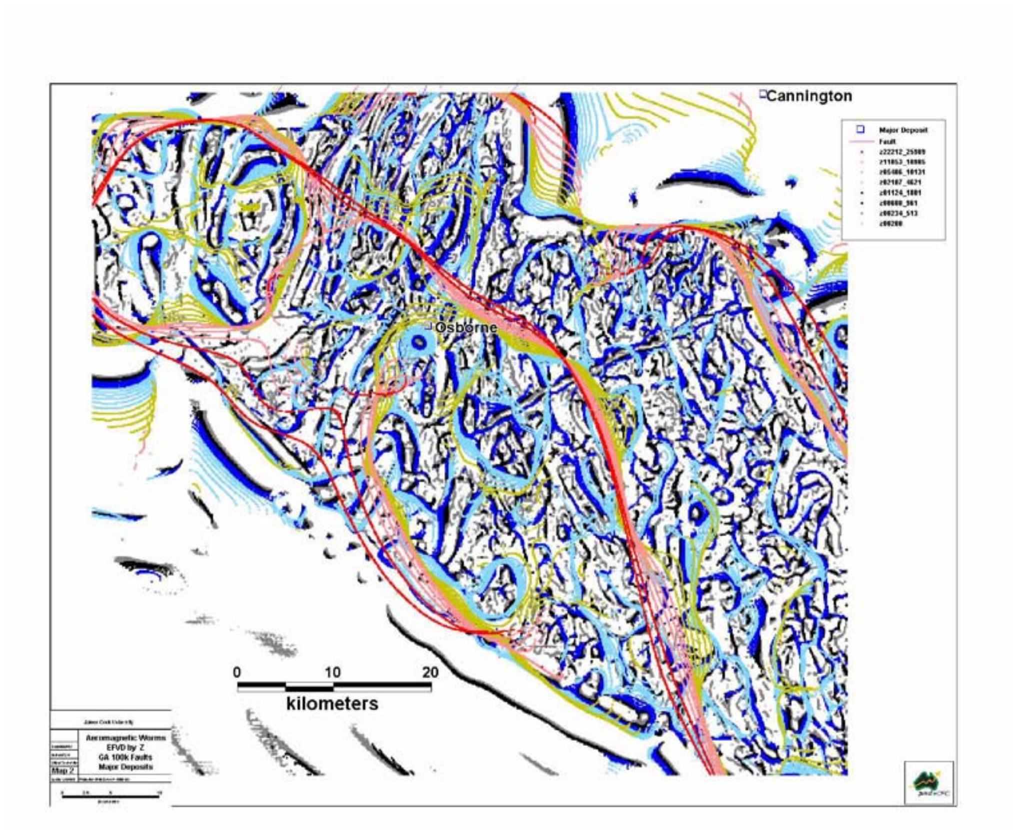


Figure 5: Aeromagnetic Worms, EFVD_Z, with Major Deposit locations.

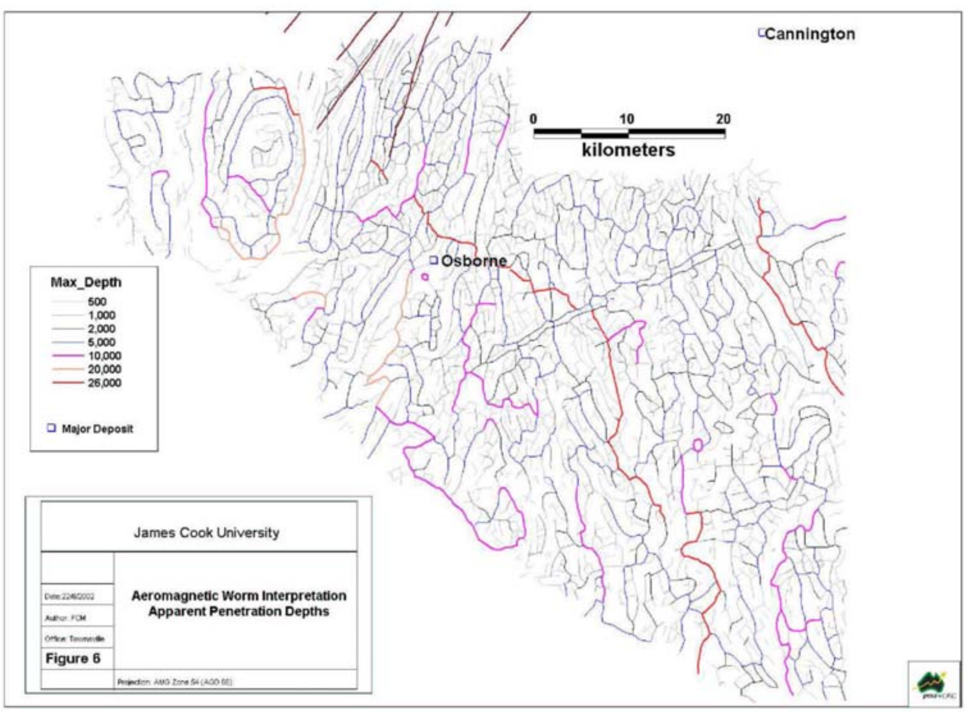
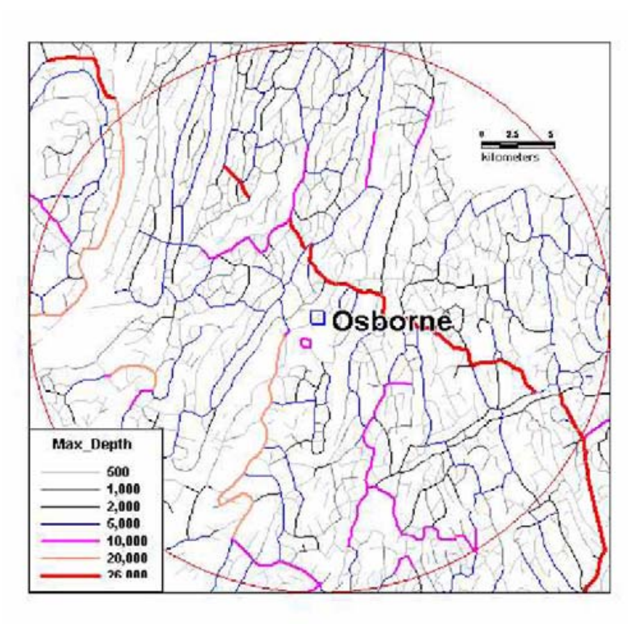


Figure 6: Depth migrated edge interpretation.

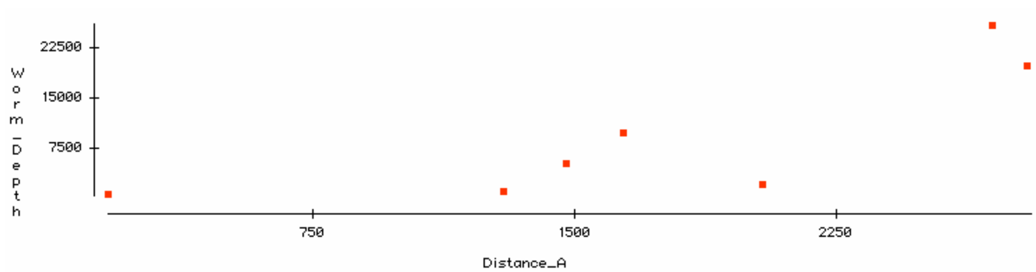
4.1.2 Deposit Analysis

The two related questions to be addressed are – what is the spatial relationship of worms to existing mineralization, and are there any criteria that derive from this that may provide a vector to areas where new mineralization might be found?

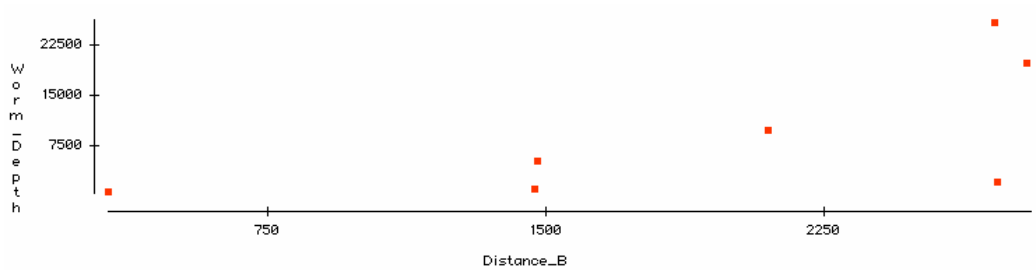
If the concept of proximity to deeply penetrative structures and intersections along them has a bearing on ore body location, then this may be evaluated in a semi-quantitative way against a structural framework derived from up-dip migration of Z values. The spatial analysis presented here takes no account of age or orientation of worm edge, nor its nature (eg. fault or intrusive contact), and is essentially a raw "Nearest and Deepest" analysis. Thus, within a radius of 20km, values (in km) for Distance A (to nearest worm line) and Distance B (nearest worm intersection) were calculated, and attributed according to Apparent Depth (in m) of the worm feature (Fig. 7). This gives an indication of the relationship of deposits to possible controlling edges, and provides a buffer or filter for subsequent regional scale area selection. The data indicates the presence of a 10km worm edge and intersection within 2km of the deposit, and it lies within 3km of an edge that migrates to 26km. This relative proximity to penetrative edges may be used as a regional buffer in area selection for such deposits. The underlying assumption here, that the genesis of the deposit is in some way related to penetrative edges, may or may not be a valid one.



a)



B)



C)

Figure 7: Deposit Proximity vs Edge Penetration Depth within 20km of Osborne, for a) Distance A - worm lines, and b) Distance B - worm intersections (values in m).

4.2 W Distributions

The spatial distribution of W values outlines a number of coherent relatively uniform domains. In addition, there are discrete areas highlighted in the most elevated or anomalous W values. There is a strong correlation (not necessarily 1:1) of high magnetic intensity with anomalous W values. Anomalous regions are plotted for MAX and EFVD magnetics respectively (Figs. 8 & 9) and ranked according to intensity.

- Both populations outline coherent areas, several of which are zoned concentrically, with a core enclosed by lower order values. EDVD regions are commonly nested within MAX regions.
- Both populations correspond with relatively shallow Z levels (Appendix 1, Fig. A2, A4). The source depths appear shallow.
- The spatial distribution of the outlined W regions (Figs. 8 & 9) show a strong correlation with worm edges with apparent depths of 5km plus.

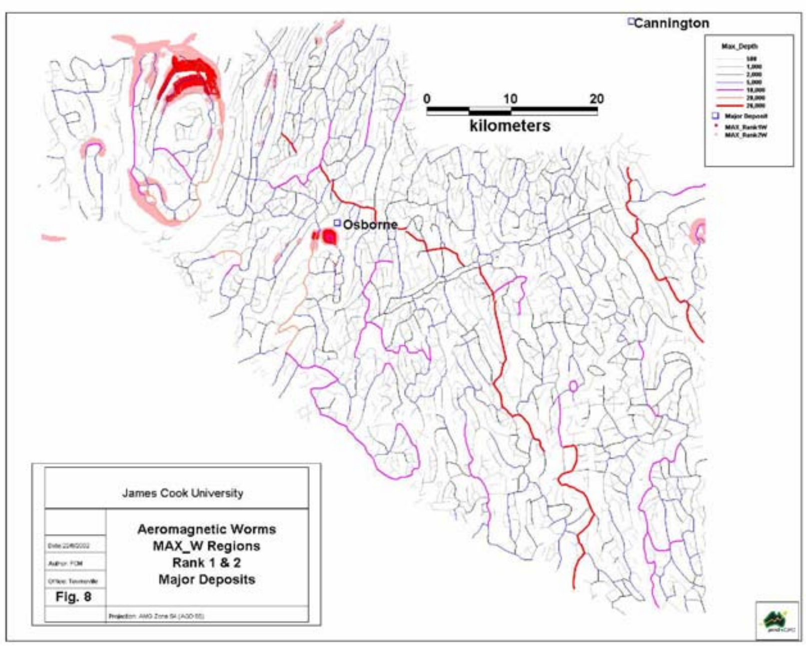


Figure 8: Anomalous W_MAX Regions, Depth migrated edges.

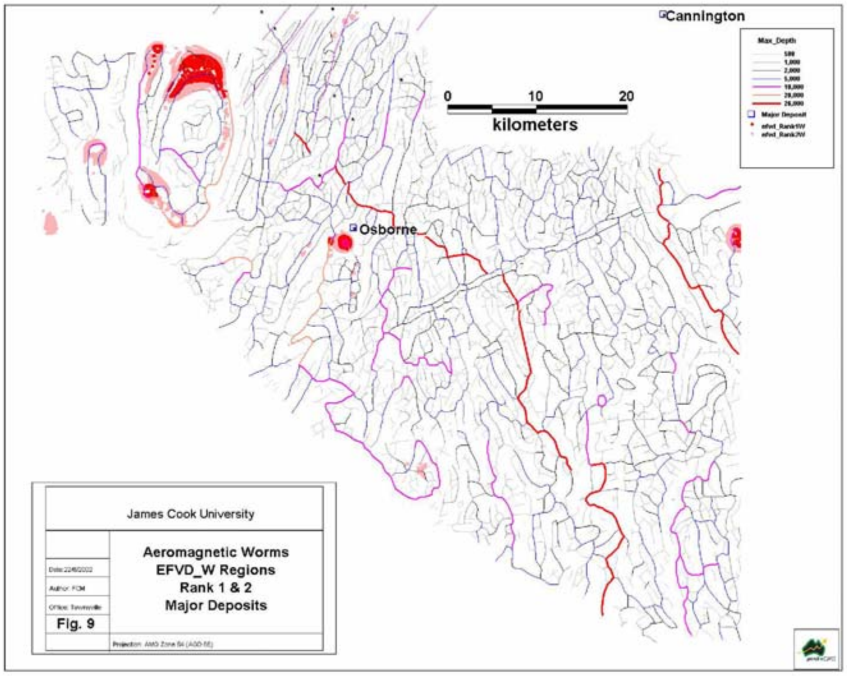
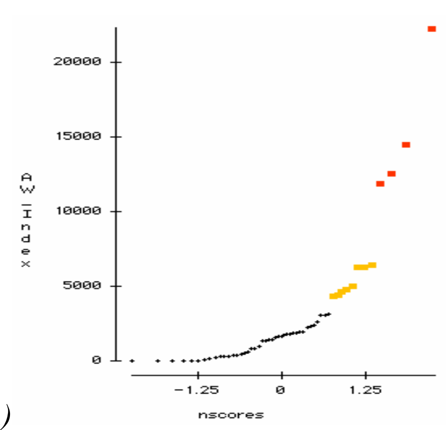
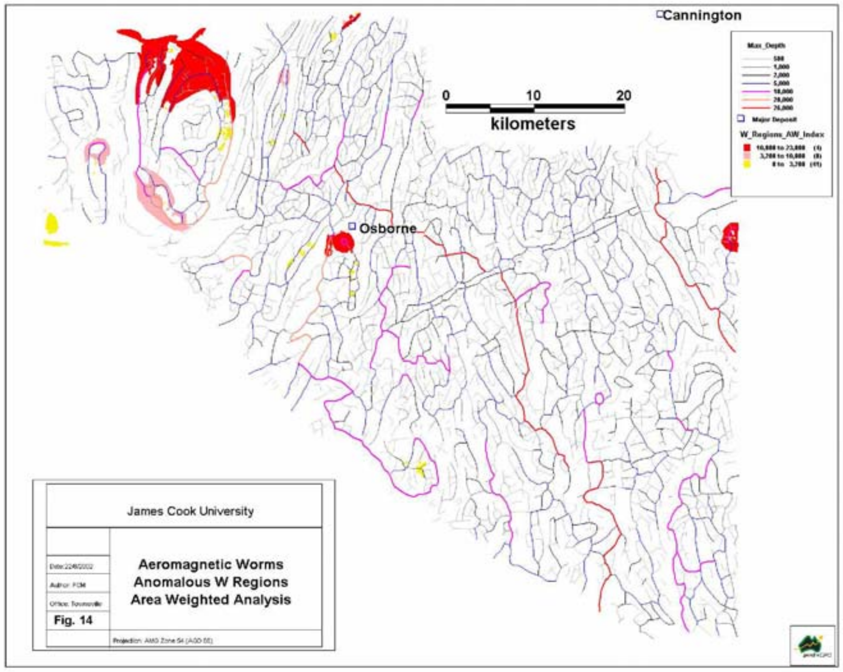


Figure 9: Anomalous W_EFVD Regions, Depth migrated edges.

The anomalous W regions (EFVD and MAX) have been normalized and conbined (Fig. 10). This outlines a number of regions of potential interest (Map 4). In order to derive a ranking of potential target areas, an Area Weighted index (AW; Fig. 10a) was derived based on size (km^2) and contained W values (sum of normalized values). The resultant population of 53 regions highlights a few with high intensity W values relative to their size. There are 4 highly ranked regions (red – one within 1km of Osborne) and 8 second order regions (orange). As Osborne lies just 1km outside a concentric anomalous region that occupies the 90th percentile, it is suggested that regions proximal to this subset of the W population offer high exploration potential.



A)



B)

Figure 10: Area Weighted index (AW) of Anomalous W regions, A) Normal Probability plot, B) Map of AW Regions.

5. Target Area Selection

The interpreted worms have been image processed in order to derive some regional spatial relationships for target assessment. Two types of output have been prepared from the migrated Z data, one based on values of apparent penetration depths of interpreted worm lines ("Edge Penetration" image; Fig. 11), and the other based on depth weighted values of intersecting worm lines ("Edge Intersection" image; Fig. 12; Map 5).

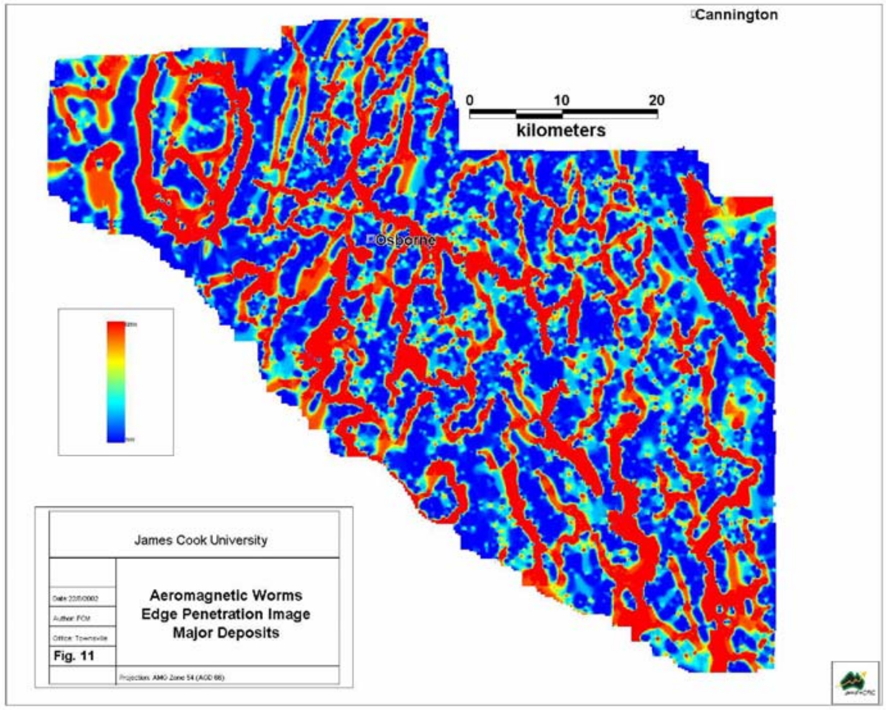


Figure 11: Edge Penetration Image

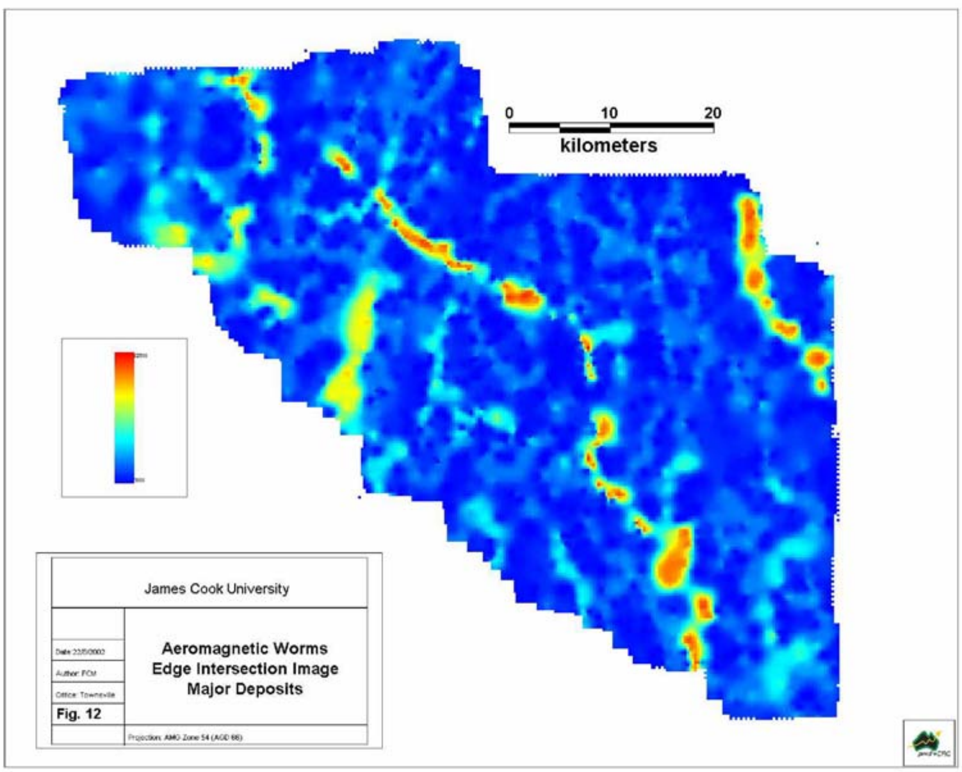
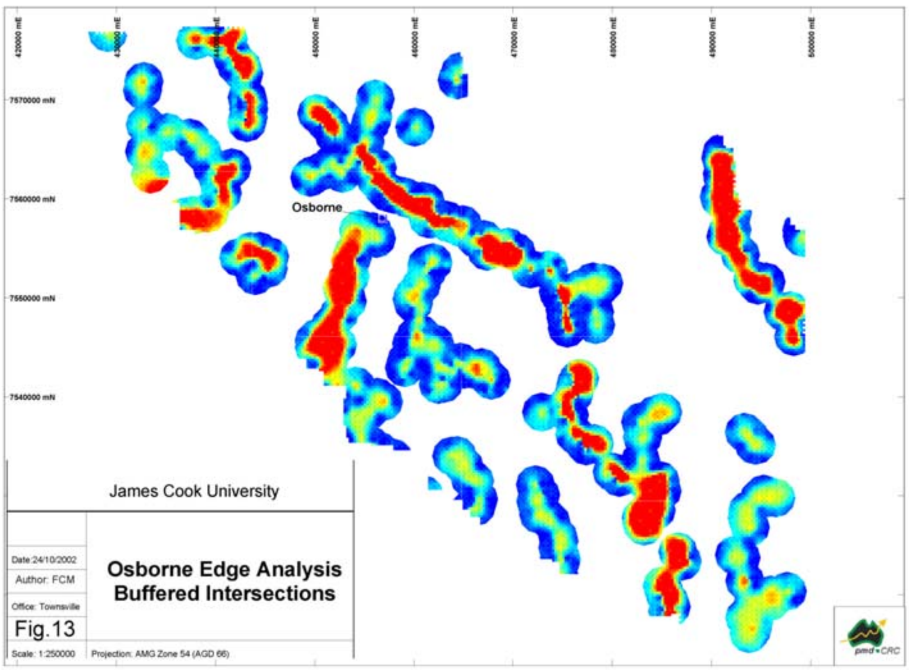
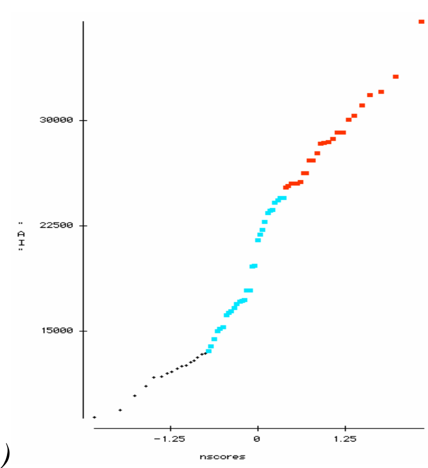


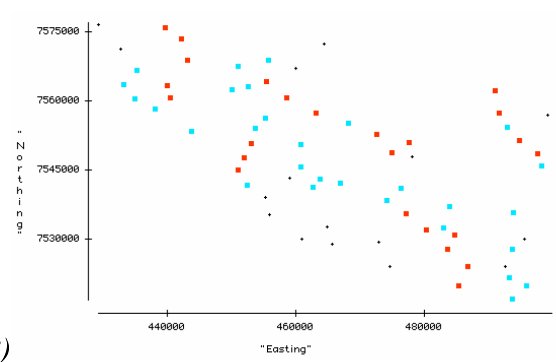
Figure 12: Edge Intersection Image

Although it is not firmly established that the Osborne deposit is ultimately controlled by proximity to a deep tapping structure, a buffer of 2km on >20km edges appears relevant to the deposit. Applying this criterion on a regional scale generates a number of regions that could be considered "permissive" (Fig. 13a). Regions have been defined based on the clustering of buffered points and, for each region, an Area Intersection index (AI; Fig. 13b) has been calculated based on the size and sum of all node values contained in the buffer. This outlines two main populations, the higher of which (35 regions) is largely related to the apparent deeper penetrating structures (Fig. 13c). There are 19 lower order regions (in blue), one including the Osborne deposit.





A)



B)

Figure 13: a) 2km buffer on 20k+ Intersections, b) Normal Probability plot of Area Intersection Index (AI), c) Scatterplot of Region centroids.

This area selection using the intersection index (AI) is shown in Map 6, together with overlapping AW indexed regions.   Note that the anomalous AW regions are largely contained within the buffered AI regions. Area selections based on an integrated analysis of the two values are considered the most fruitful approach to take. The apparent spatial association of CuAu deposits with anomalous W vales is, in its own right a persuasive indicator. These areas in particular need to be assessed in terms of the "permissive" AI index and serves as a first order area selection filter.

6. Conclusions and Recommendations

The application of multiscale wavelet edges from potential field data to defining the structural framework and targeting ore systems in the Osborne region shows promise. The structural architecture derived from migration of worm edges to a near surface environment shows good correlations with mapped fault and intrusive edges, and gives confidence to interpretation of those edges under cover.

Proximity of deposits to penetrative edges (based on the migrated Z values) goes some way to defining regions that are considered more permissive for mineralization. The application of fairly simple relationship buffers generates upwards of 50 such regions. There is considerable scope to apply other buffer selections to the data. Much work remains to be done in evaluation these regions in terms of their host rock potential.

Of more predictive value, in relation to CuAu deposits, are anomalous W values. An area weighted analysis of these regions yields 4 priority targets (one of which is ore associated, Osborne). In combination with the permissive Z regions, this provides tightly constrained anomalous W regions that offer direct and tangible exploration targets.

There is further research required, particularly in attributing worm edges with respect to mapped geology. An important adjunct to this analysis would be worming of the detailed gravity in the area, aspects of which have been undertaken at a region scale by the pmd*CRC, but would benefit from a finer scale study.

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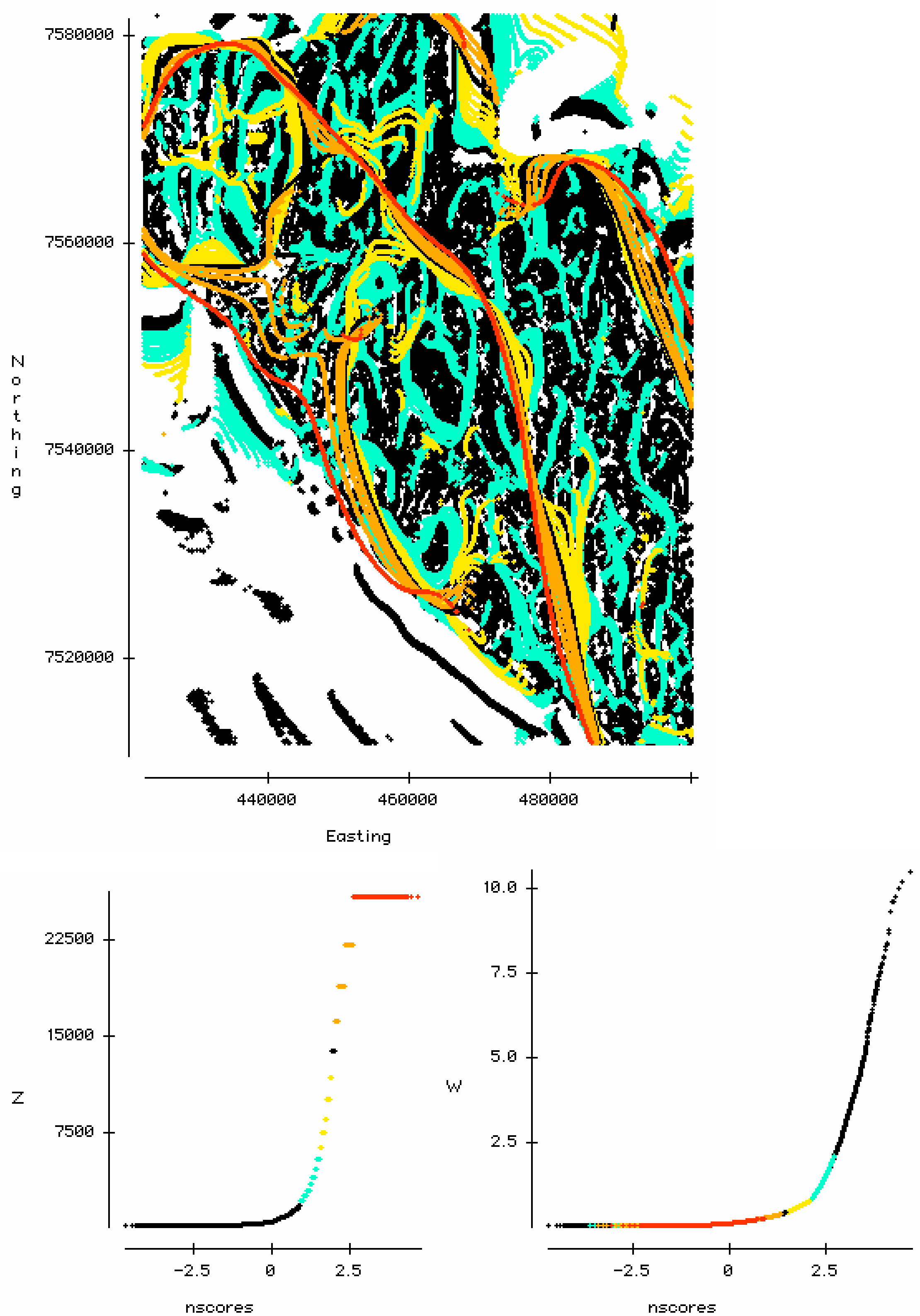
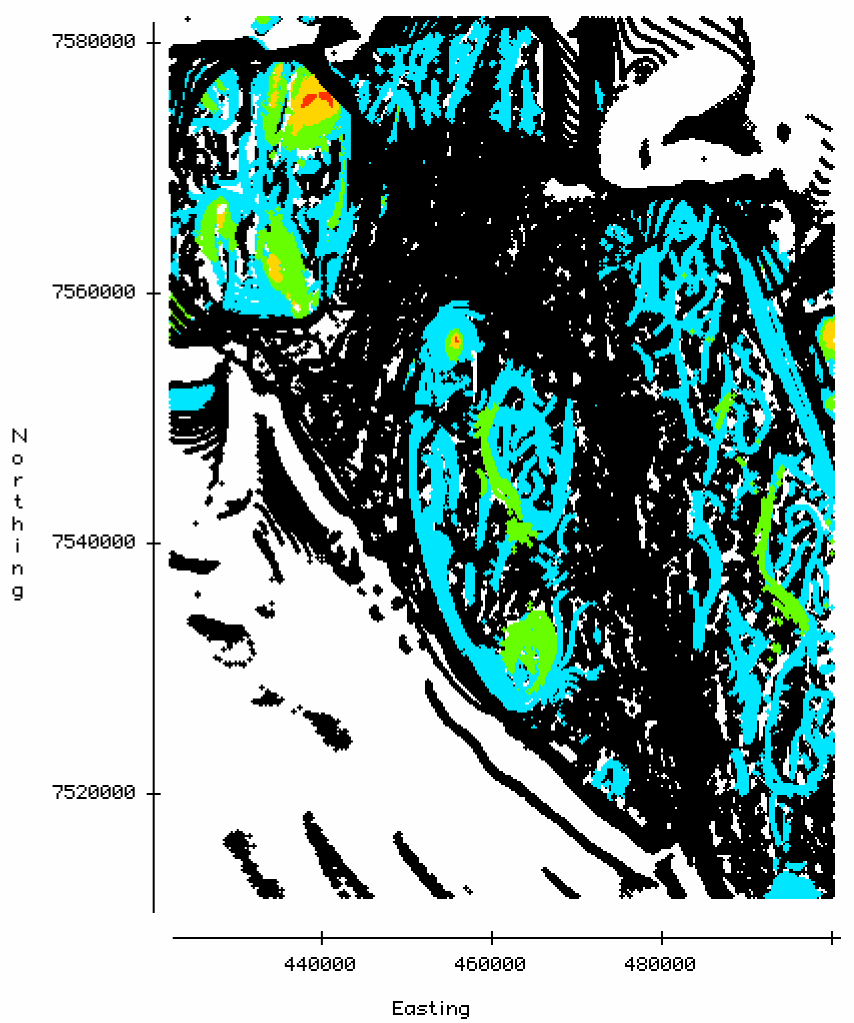
Appendix 1: Statistical analysis of Worm data sets

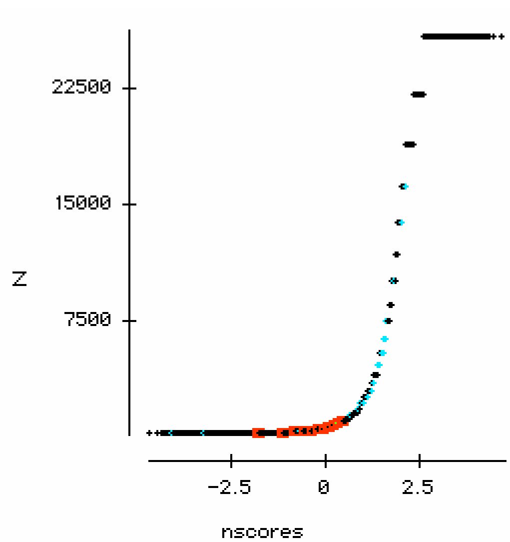
XY Scatter plots of Z and W values per EFVD and MAX processing of Aeromagnetics, showing Normal Probability plots of each population.

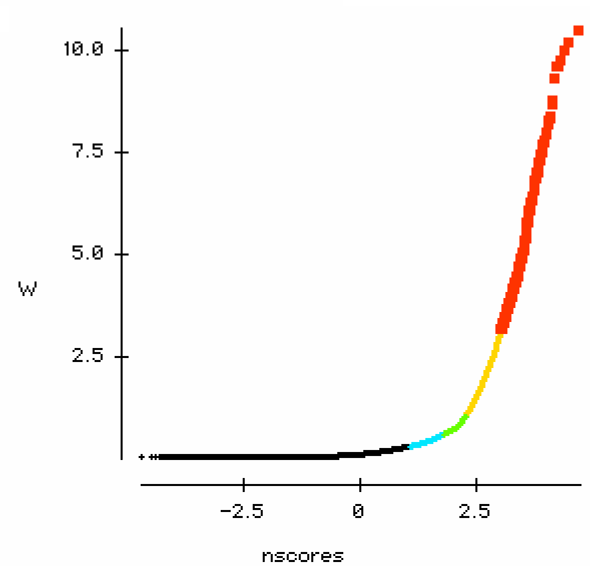
A1: Placer Magnetics _ EFVD _ Z
A2: Placer Magnetics _ EFVD _ W
A3: Placer Magnetics _ MAX _ Z
A4: Placer Magnetics _ MAX _ W



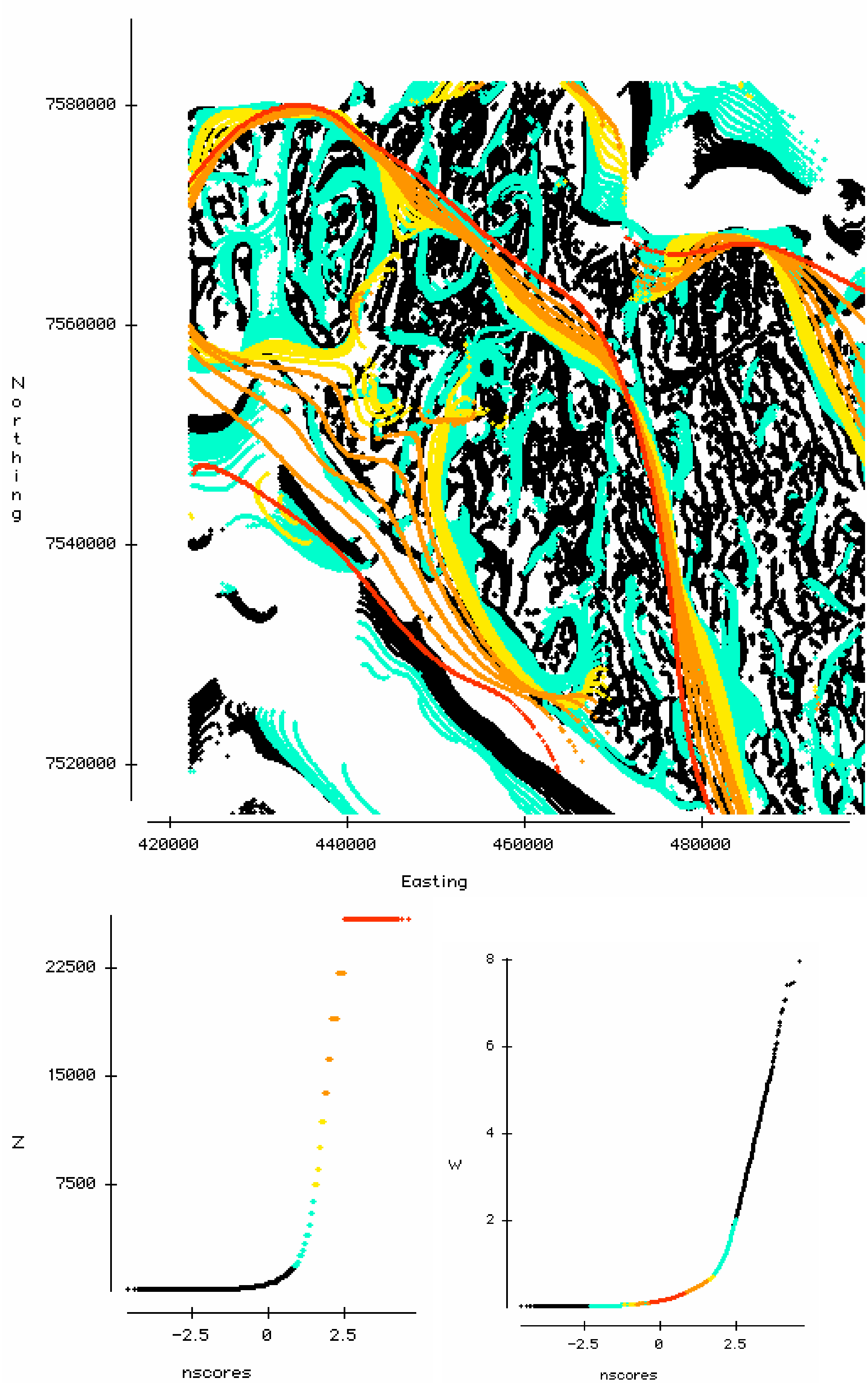
A1.1: Placer_Mag_EFVD_Coloured by Z



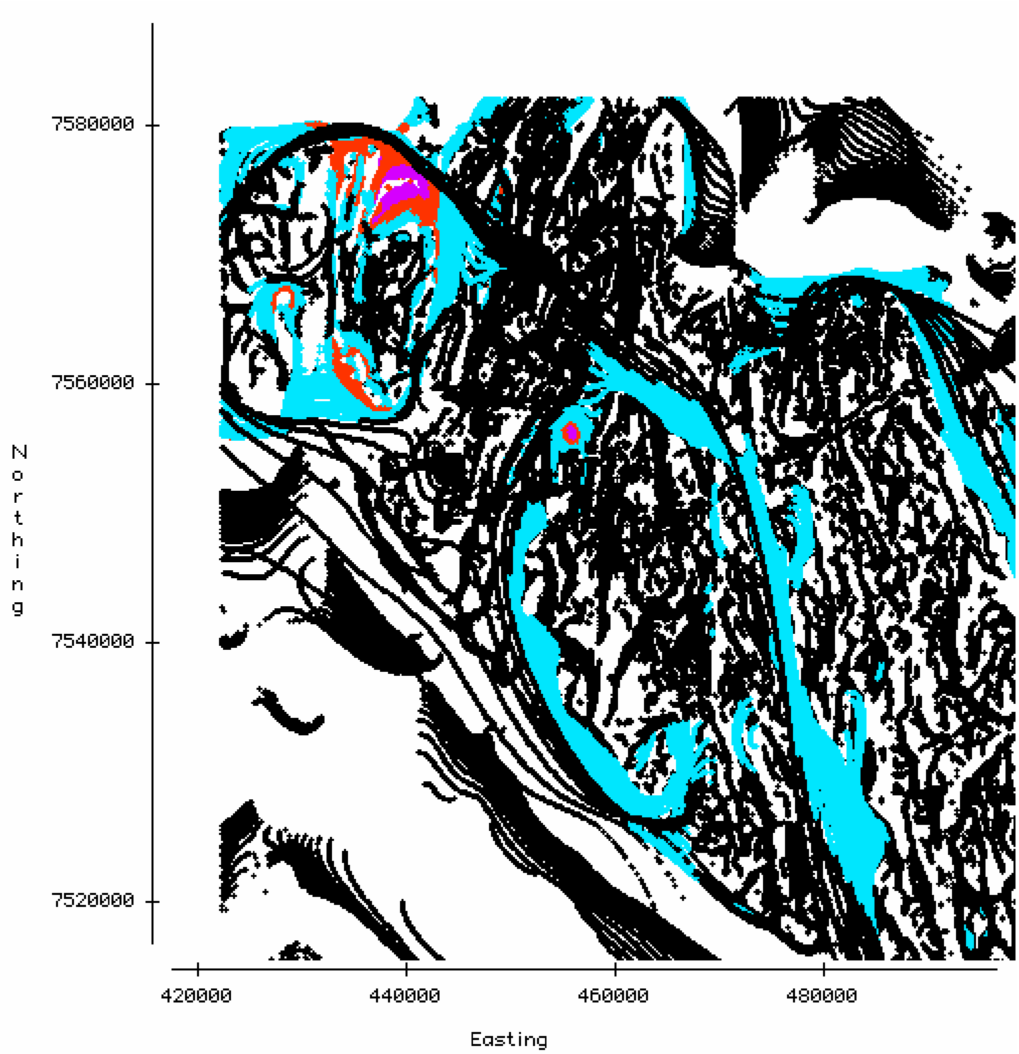


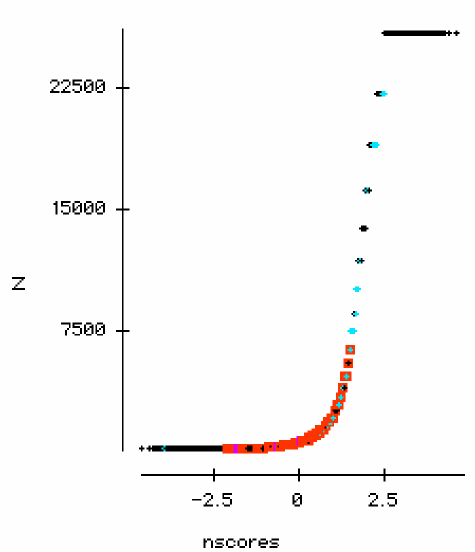


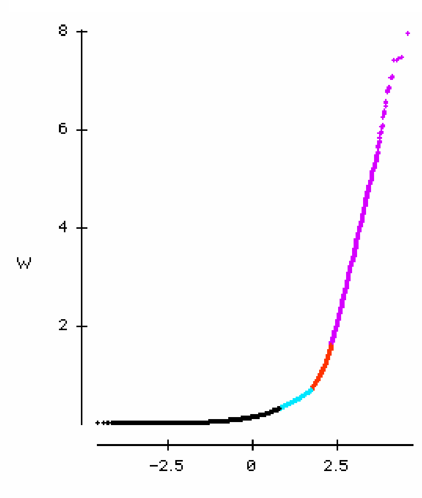
A1.2: Placer_Mag_EFVD_Coloured by W



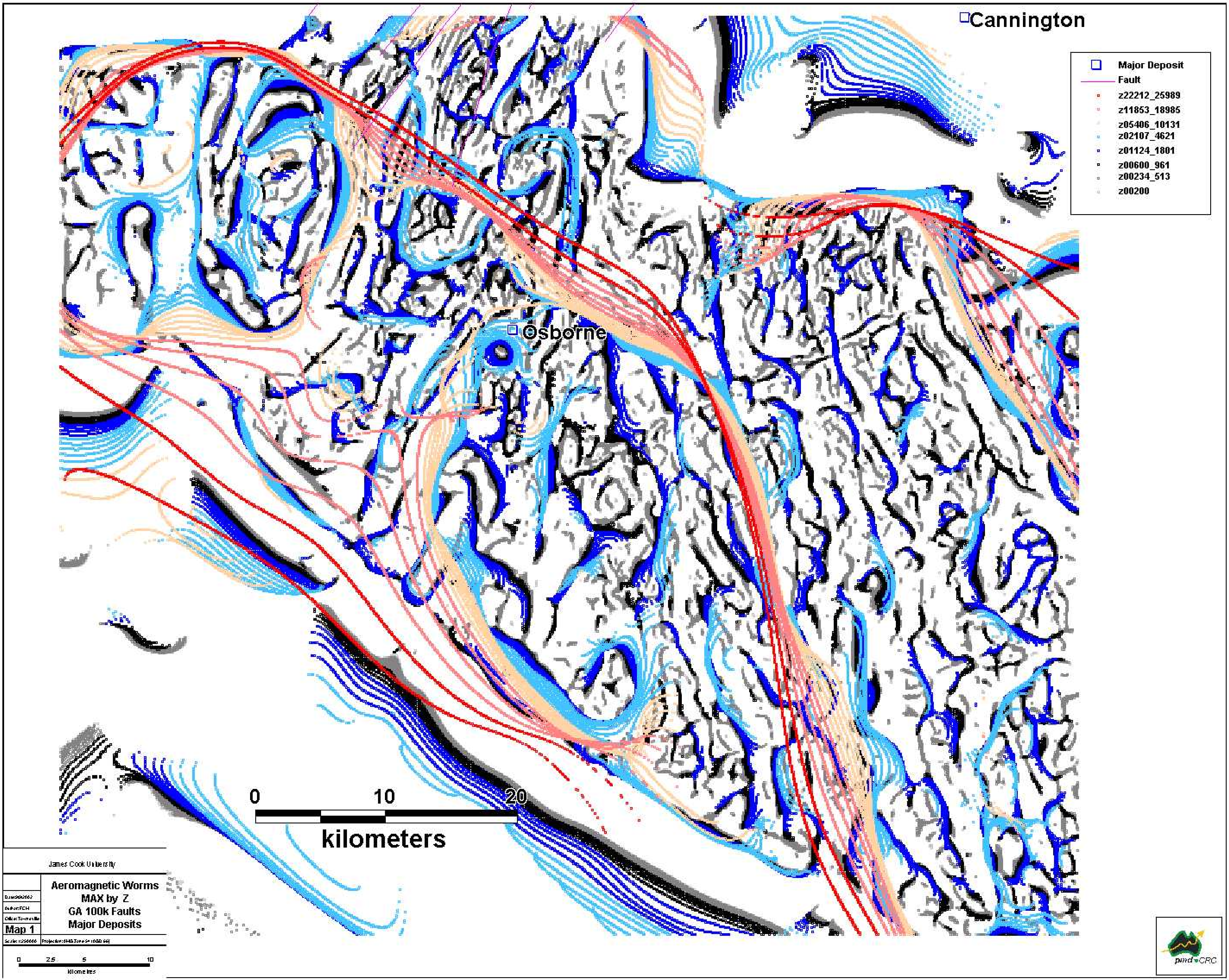
A1.3: Placer_Mag_MAX_Coloured by Z







A1.4: Placer_Mag_MAX_Coloured by W



Cannington
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20
kilometers
James Cook University
Aeromagnetic Worms
MAX by Z
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Major Deposits
Map 1
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kilometres
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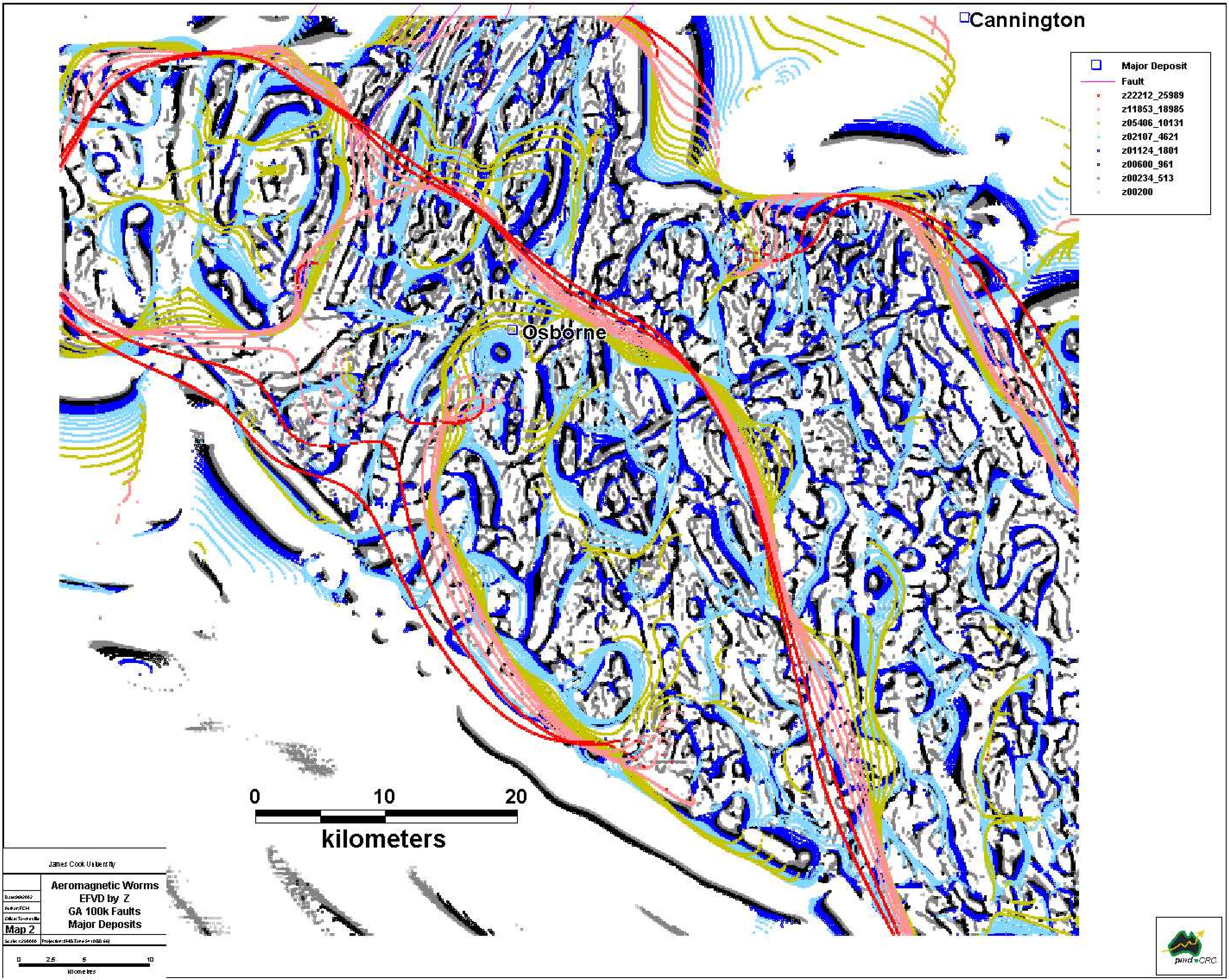
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James Cook University
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EFVD by Z
GA 100k Faults
Major Deposits
Map 2
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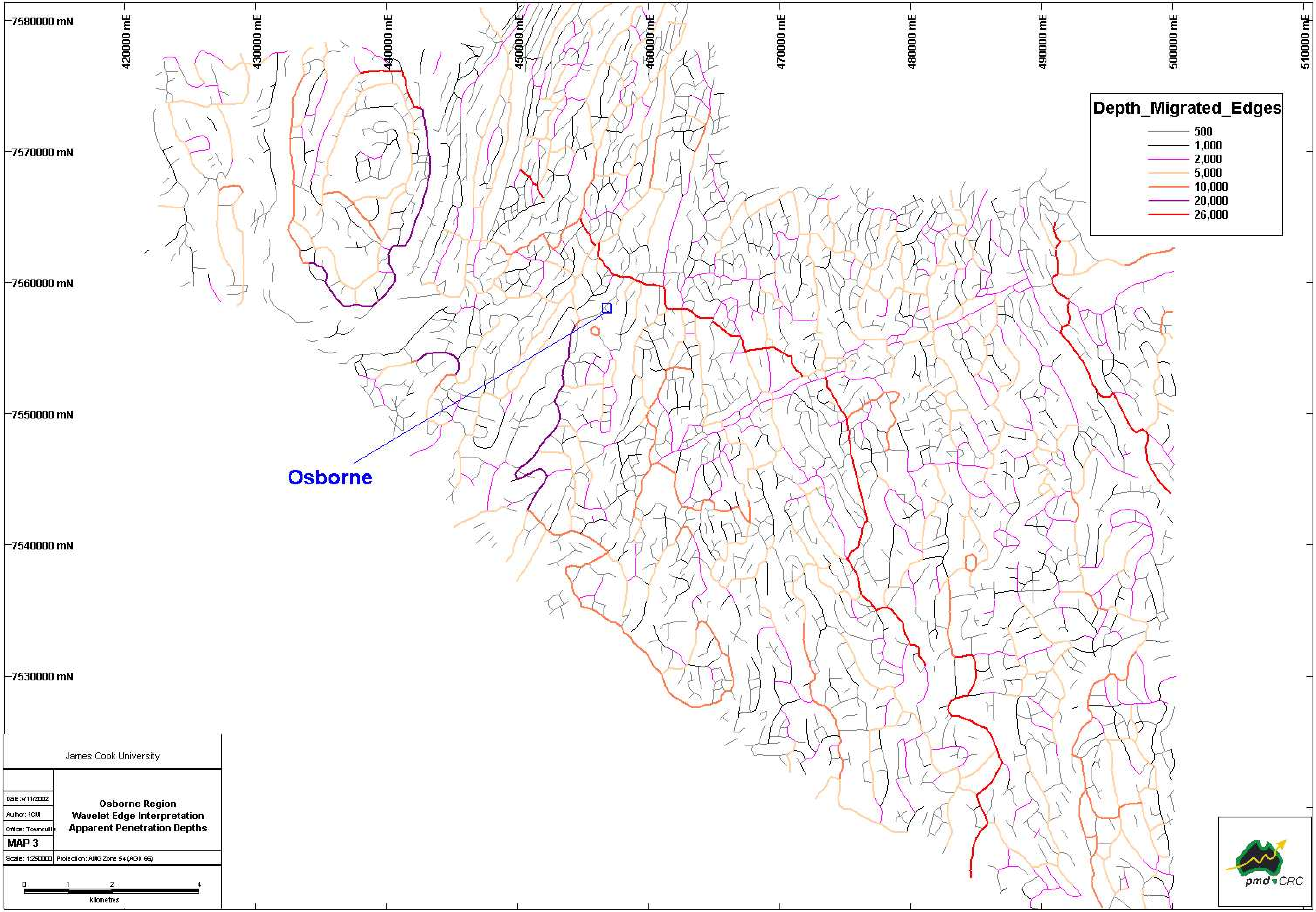
5
10
kilometres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7570000 mN
7560000 mN
7550000 mN
7540000 mN
7530000 mN
420000 mE
430000 mE
440000 mE
450000 mE
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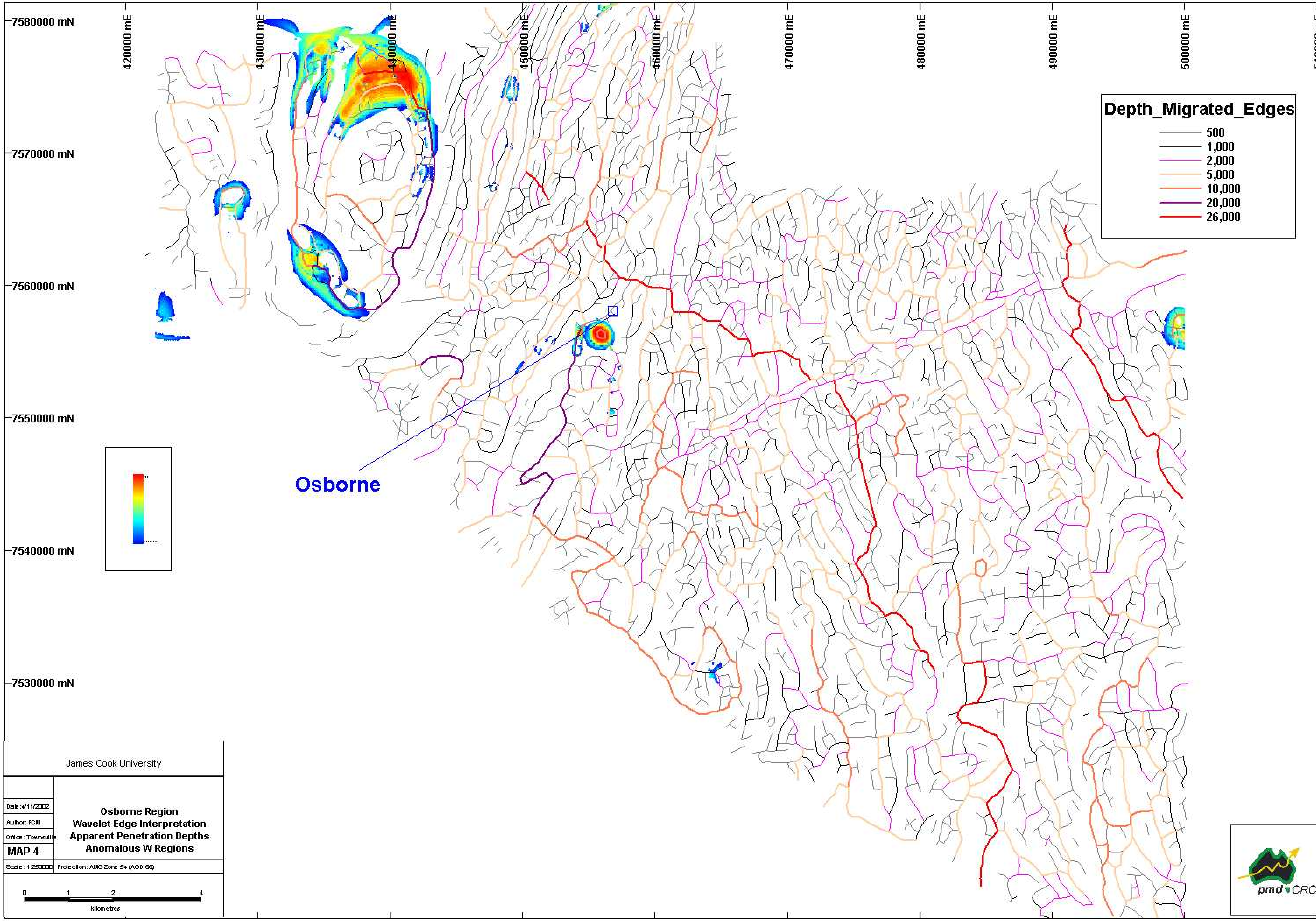
470000 mE
480000 mE
490000 mE
500000 mE
510000 mE
Depth_Migrated_Edges
500
1,000
2,000
5,000
10,000
20,000
26,000
Osborne
James Cook University
Date: 4/11/2002
Author: FCM
Office: Townsville
MAP 3
Osborne Region
Wavelet Edge Interpretation
Apparent Penetration Depths
Scale: 1:250000
Projection: AMG Zone 54 (AGD 66)
0
1
2
4
kilometres
pmd CRC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7560000 mN
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7530000 mN
420000 mE
430000 mE
440000 mE
450000 mE
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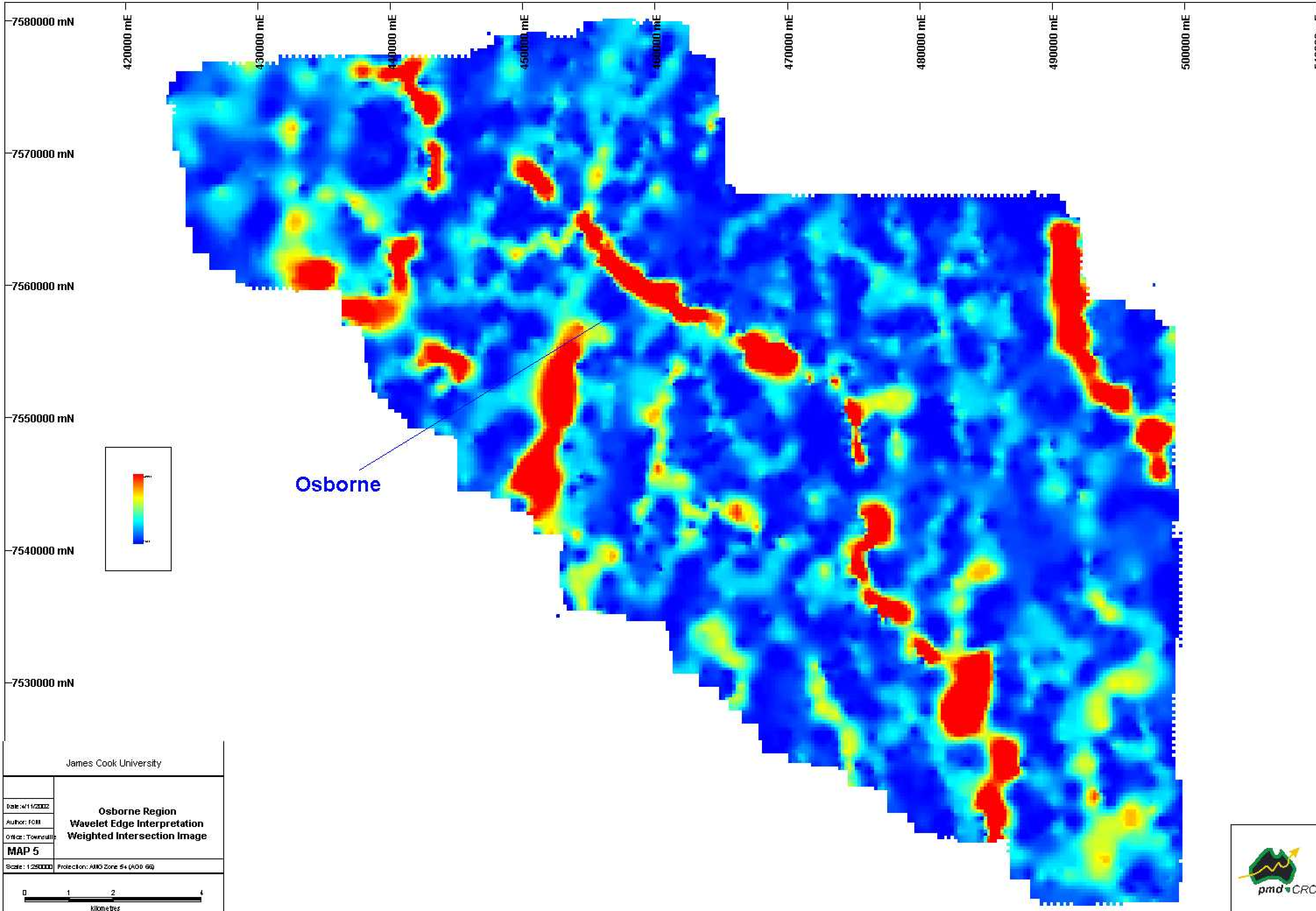
470000 mE
480000 mE
490000 mE
500000 mE
510000 mE
Depth_Migrated_Edges
500
1,000
2,000
5,000
10,000
20,000
26,000
Osborne
James Cook University
Date: 4/11/2002
Author: FCM
Office: Townsville
MAP 4
Osborne Region
Wavelet Edge Interpretation
Apparent Penetration Depths
Anomalous W Regions
Scale: 1:250000
Projection: AMG Zone 54 (AGD 66)
0
1
2
4
Kilometres
pmd CRC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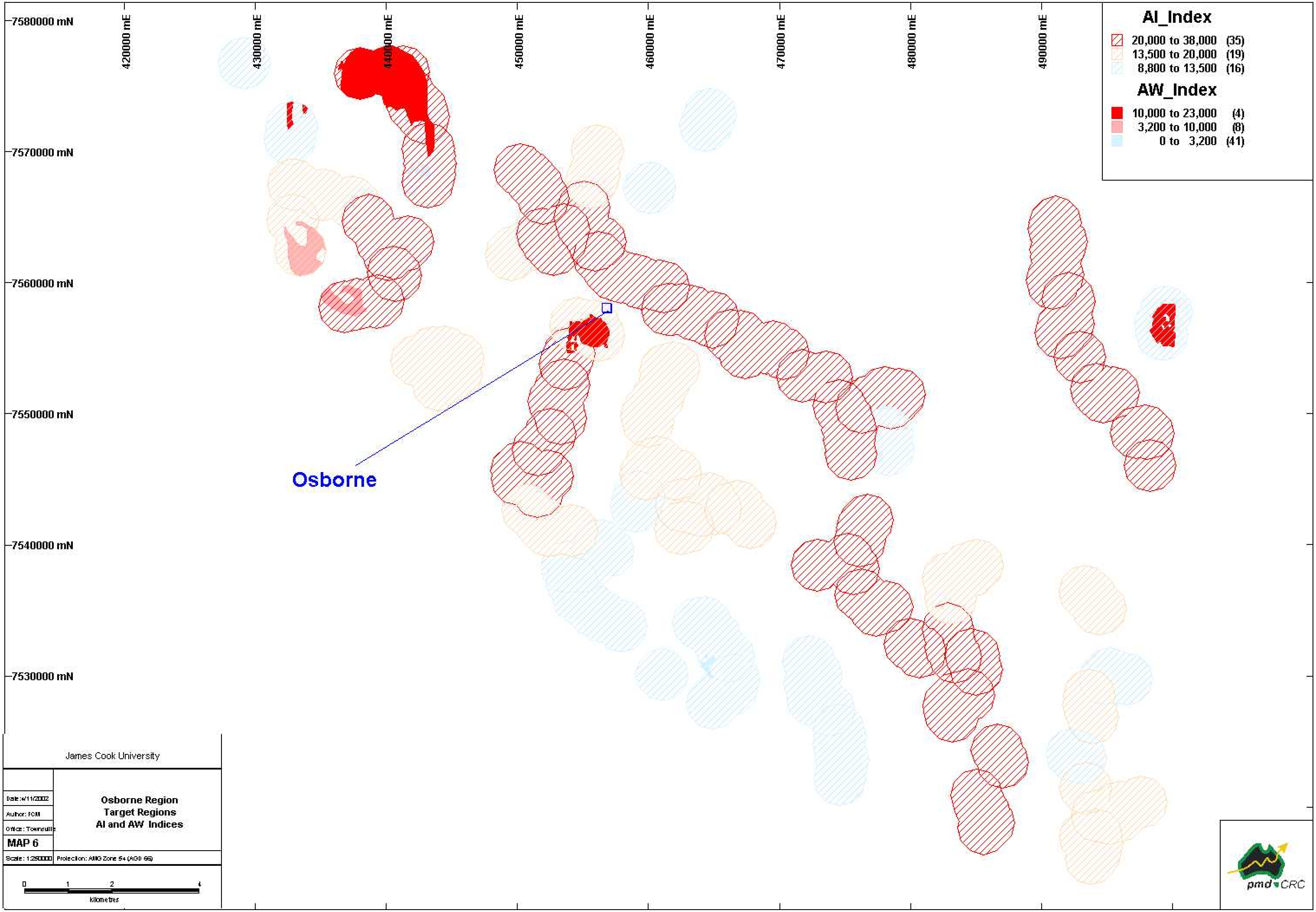
460000 mE
470000 mE
480000 mE
490000 mE
500000 mE
510000 mE
Osborne
James Cook University
Date: 4/11/2002
Author: FCM
Office: Townsville
MAP 5
Osborne Region
Wavelet Edge Interpretation
Weighted Intersection Image
Scale: 1:250000
Projection: AMG Zone 54 (AGD 66)
0
1
2
4
kilometres
pmd CRC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7540000 mN
7530000 mN
420000 mE
430000 mE
440000 mE
450000 mE
460000 mE
470000 mE
480000 mE
490000 mE
AI_Index
20,000 to 38,000 (35)
13,500 to 20,000 (19)
8,800 to 13,500 (16)
AW_Index
10,000 to 23,000 (4)
3,200 to 10,000 (8)
0 to 3,200 (41)
Osborne
James Cook University
Date: 4/11/2002
Author: FCM
Office: Townsville
MAP 6
Osborne Region
Target Regions
AI and AW Indices
Scale: 1:250000
Projection: AMG Zone 54 (AGD 66)
0
1
2
4
kilometres
pmd CRC