

# Uncovering with magnetics

Clive Foss

MINERALS DOWN UNDER FLAGSHIP  
[www.csiro.au](http://www.csiro.au)



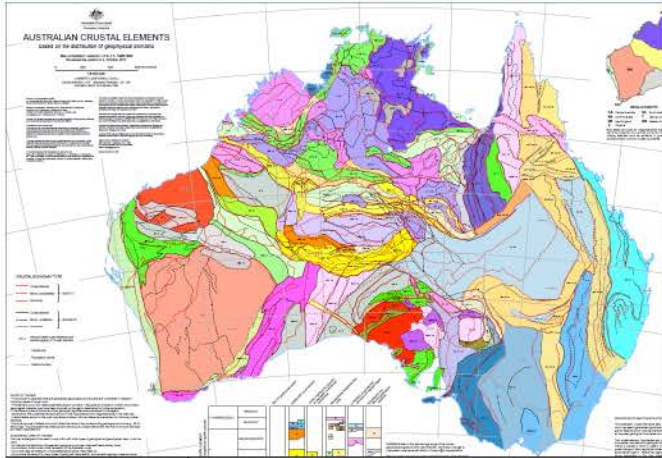
# Directions

1. Introduce the geophysical method in mapping cover thickness down to 1 km over a 5×5 km area
2. Discuss resolution of the method
3. Discuss how uncertainty is assessed
4. Provide an overview of the strengths and weaknesses of the method through case study examples

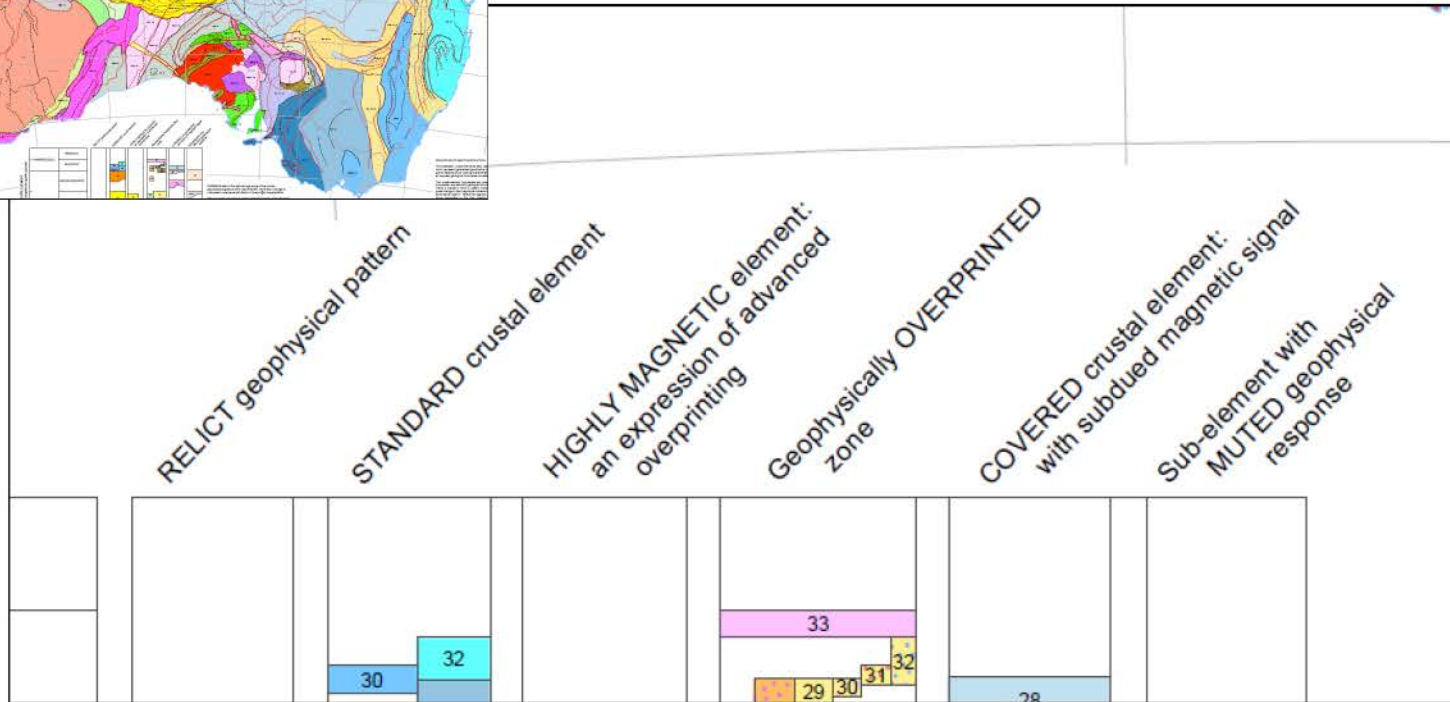
# 1) The Magnetic Method

# Magnetics ~~Reveals~~ Australian Geology

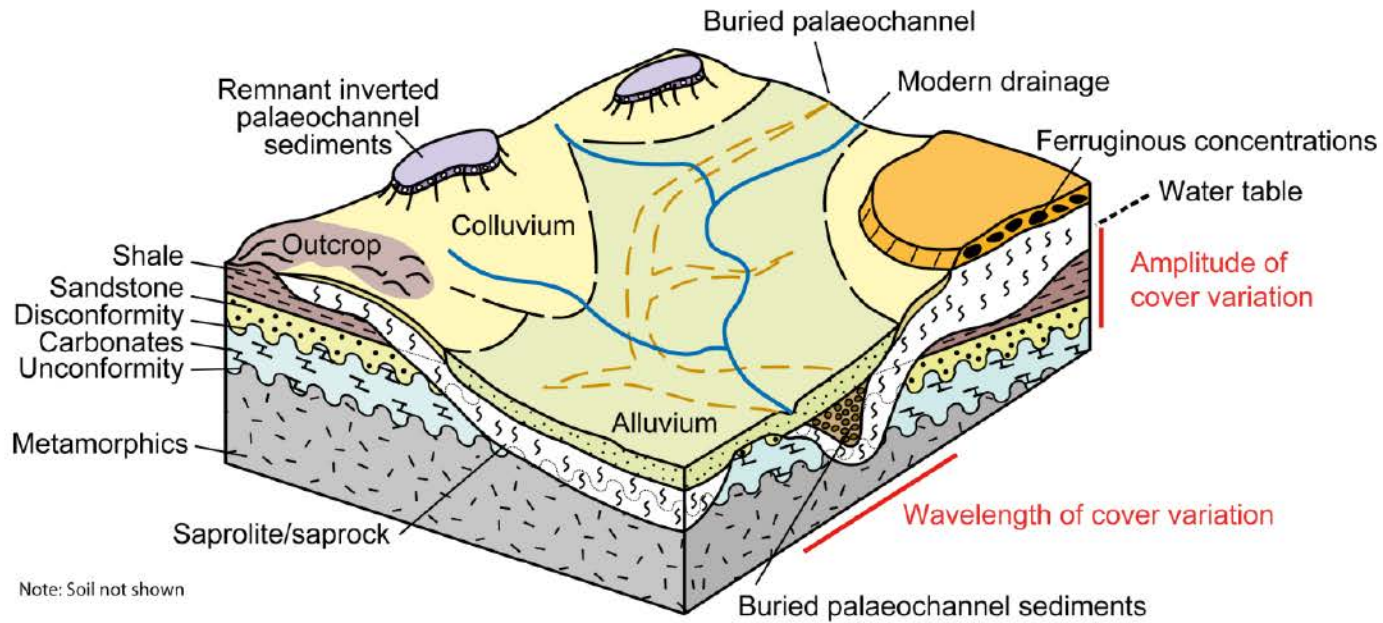
## Defines



Australian Crustal Elements Map  
by Geoscience Australia

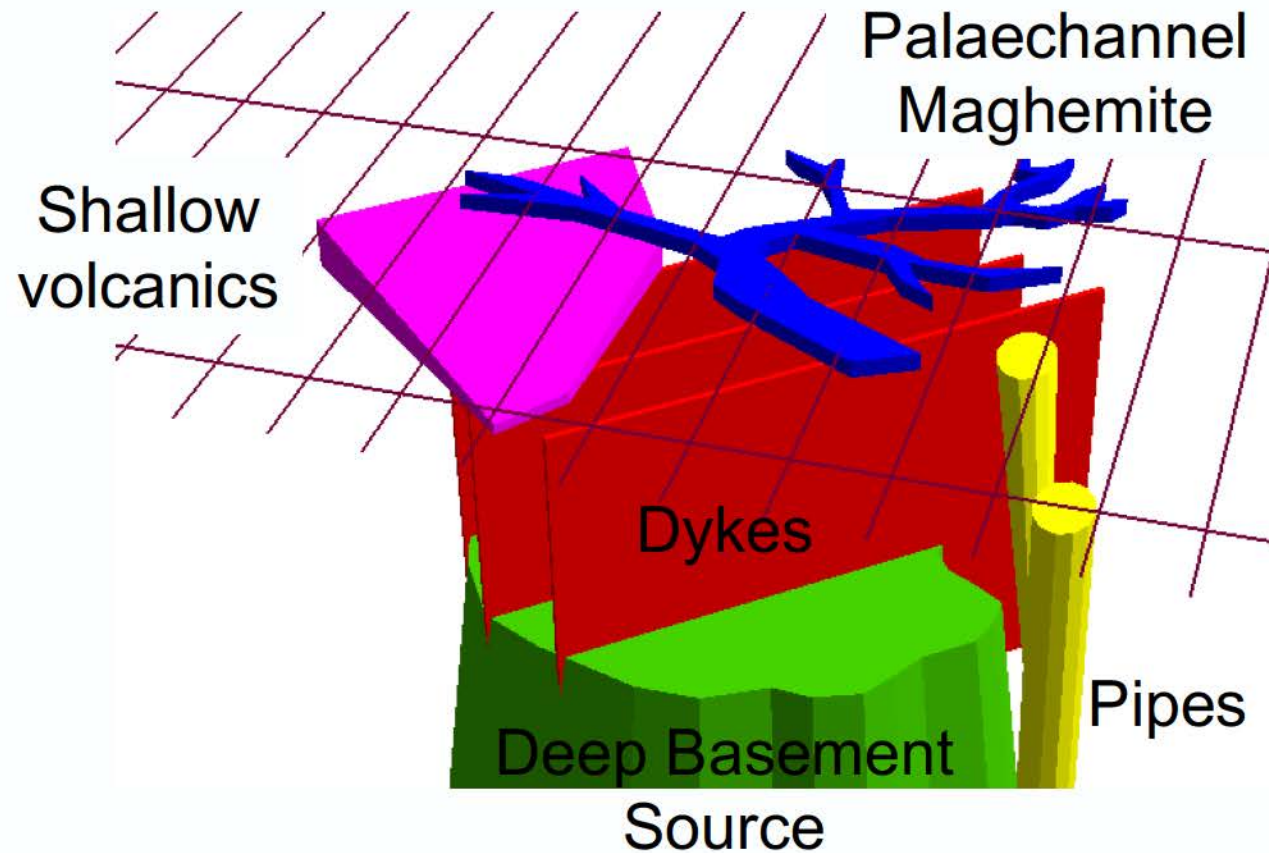


# Shallow Geology Schematic

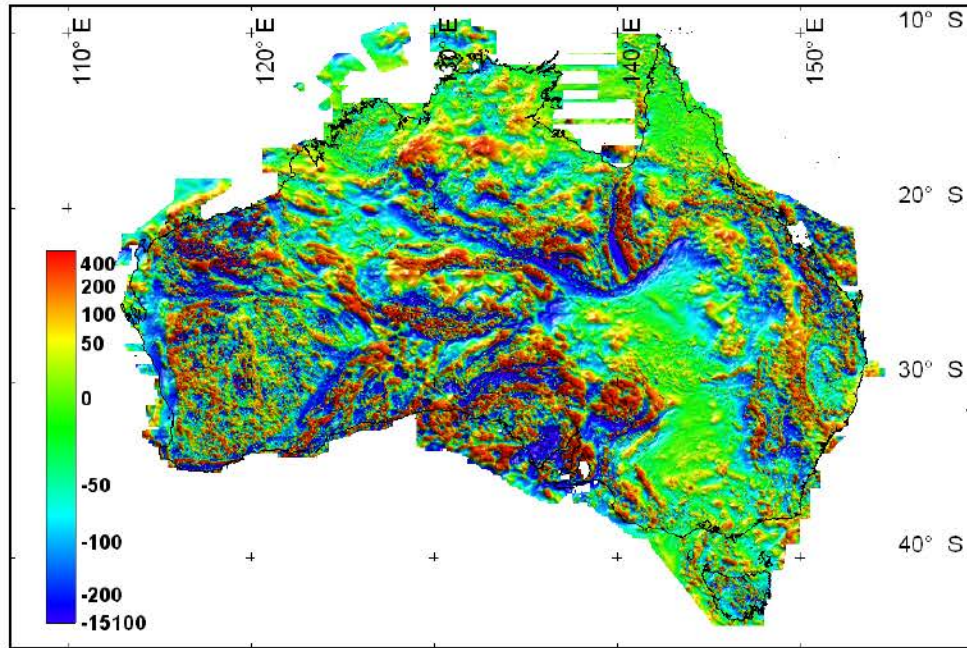


Most of these features can produce magnetic field variations detectable by low-level hi-resolution aeromagnetic and ground magnetic surveys. In any area generally only the strongest magnetizations can be mapped.

# Most Common Magnetic Sources



# GADDS – Australia's Geophysical Crown Jewels



### Geoscience Australia Data Delivery System

Define your area of interest

The screenshot shows the Geoscience Australia Data Delivery System interface. It features a map of Australia with a grid overlay. To the right of the map is a form for defining the area of interest, including fields for N Lat., S Lat., W Long., and E Long. Below the map is a scale bar and a small inset map of Australia. To the left of the map is a list of additional layers with checkboxes. To the right of the map is a 'Quick Start' section with a '1:250k Map Sheet' dropdown and a 'Proceed to Download' button. Below the map is a 'Load checked layers' button.

**Let/Long Rectangle**

N Lat.

S Lat.

W Long.

E Long.

[Use decimal degrees (e.g. 137.821)]

**Quick Start**

1:250k Map Sheet  
[Choose Map Name/Number]

clear form

Proceed to Download >

**Instructions**

**Detailed help:** HTML or PDF [700kb]

**Option 1:**  
Enter the extents in the Lat/Long Rectangle form as decimal degrees (e.g. 137.821) then click the 'proceed to download' button below it.

**Option 2:**  
Use the map query tool (📏) to define your area of interest. The Lat/Long rectangle form will be automatically populated with the extents of the area you define, then click the 'proceed to download' button below the form.

**Option 3:**  
Use the 'Quick Start' menu to choose an area of interest based on a 250k map sheet. Choosing a map sheet will populate the Lat/Long Rectangle form, then click on the 'proceed to download' button below it to find data in that area.

**Additional Layers:**

- Digital elevation model
- Magnetics
- Gravity
- Geological Regions
- Population centres
- Roads
- Railways
- 1:250 000 map sheets
- 1:100 000 map sheets

0 500 1100 1650 2200 km

Show all of Australia

Start again

Load checked layers

# Wing Tip Gradiometry

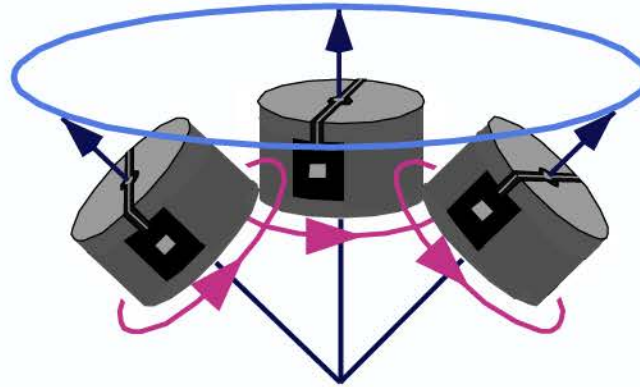


- Slight incremental cost to reduce effective line spacing
- Use of wing-tip gradiometry is a cultural issue
  - Canada – the default choice
  - Australia – rarely used **FOR NO GOOD REASON**
- The advantages are similar for regional and detailed surveys



# Airborne Magnetic Tensor Gradiometry

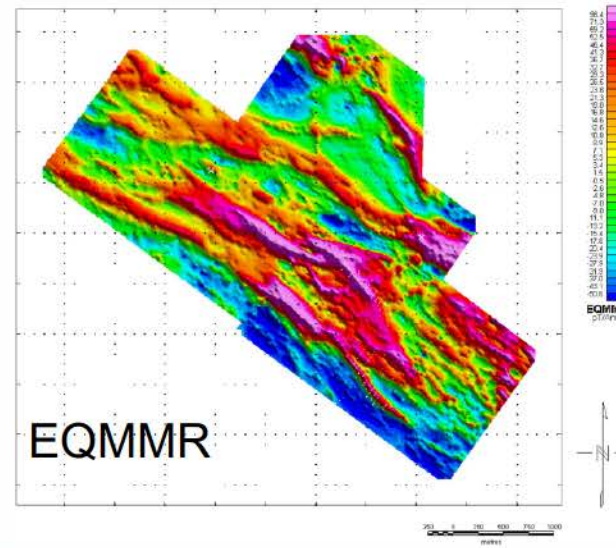
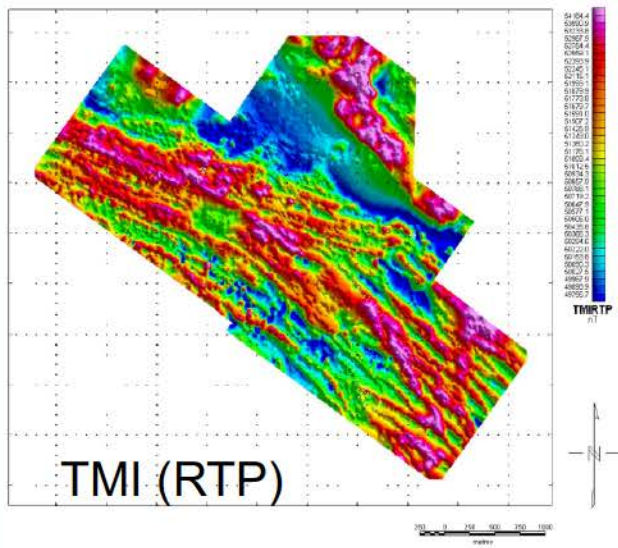
- Anglo and De Beers are flying magnetic tensor gradiometry using low-temperature SQUIDs



- CSIRO has a 2/3<sup>rd</sup> developed high-temperature SQUID magnetic tensor gradiometry (developed largely with defence funding for submarine detection)
- Magnetic tensor gradiometry is unlikely to displace TMI as the ‘work-horse’ aeromagnetic method – but may find application in high-resolution mapping

# SAM – Sub-audio Magnetics

Developed by GAP Geophysics <http://www.gapgeo.com/>



- Ground or heli- surveys
- More expensive than standard magnetics – but provides new mapping of an independent physical property

# Ultra-lights and Drones

- Do we want ultra-lights? - they may provide a cheap survey platform but can safety levels be ensured?
- Drones are an inevitable development and should provide lower cost aeromagnetic surveys



Medium size drone to fly tenement scale surveys (and possibly larger)



Small scale drone for brown-fields and production applications monitoring stockpiles or mapping mine benches

# Ground surveys



There will always be a place for high resolution ground surveys  
(by foot or quad-bike)

# Boreholes



- Down-hole Susceptibility Logging
- National Physical Property Database
- Down-hole TMI and component surveys
- CSIRO DETCRC tensor down-hole probe



## 2) Resolution

# Source diameter 2t<sub>im</sub>, depth 3t<sub>im</sub>

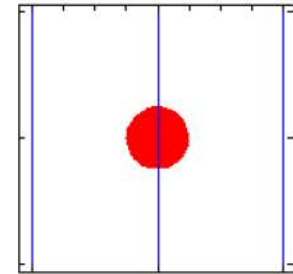
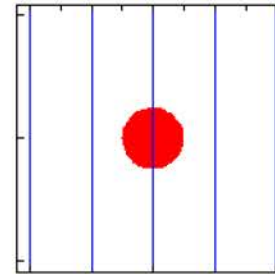
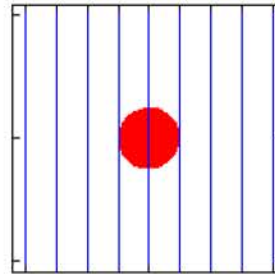
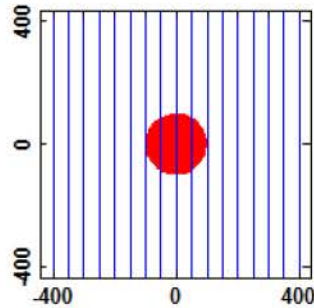
Line Spacing:

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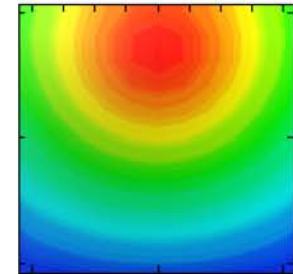
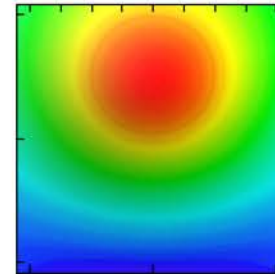
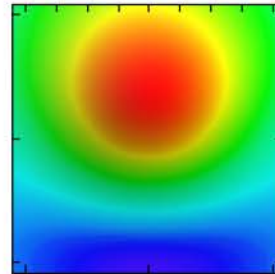
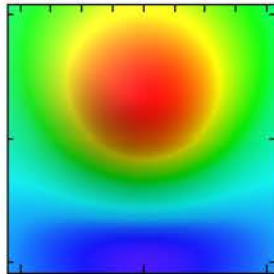
100m

200m

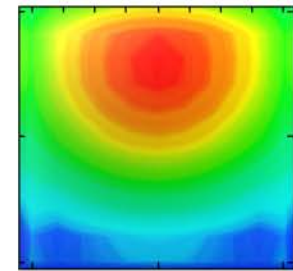
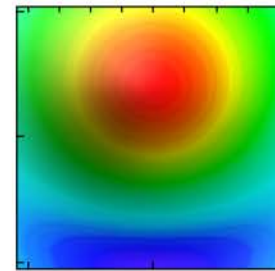
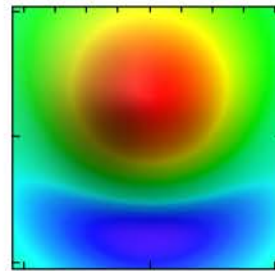
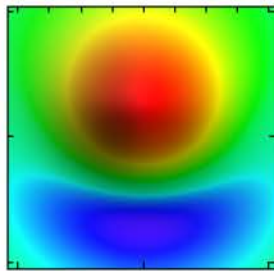
400m



TMI



FVD



# Source diameter 2titim, depth 2titim

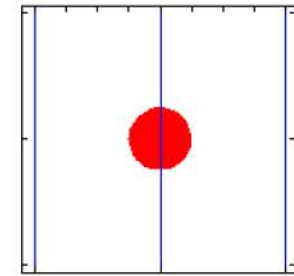
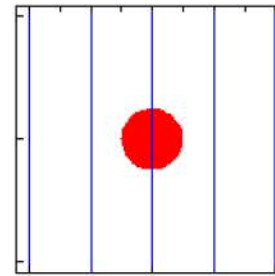
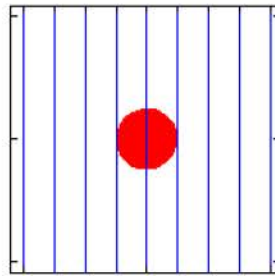
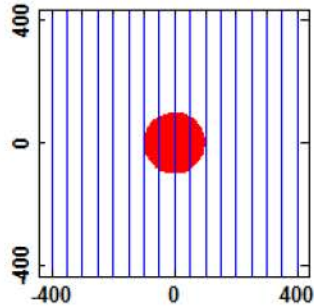
Line Spacing:

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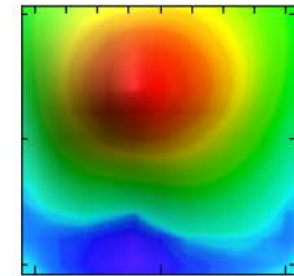
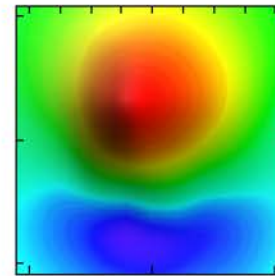
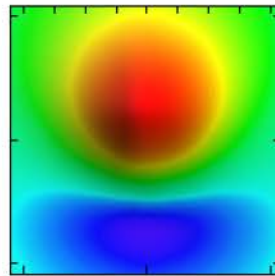
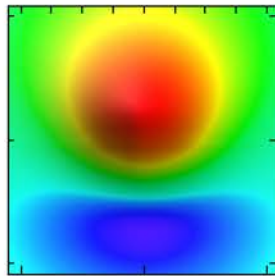
100m

200m

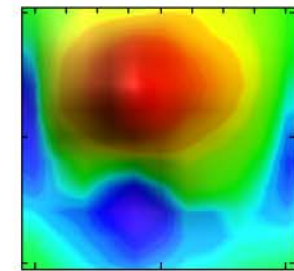
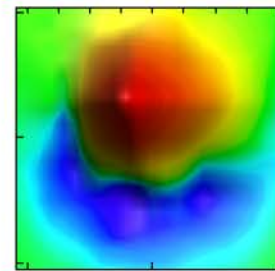
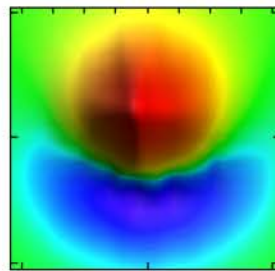
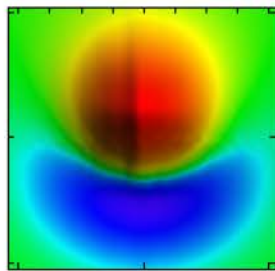
400m



TMI



FVD





# Source diameter 2t<sub>im</sub>, depth 1t<sub>im</sub>

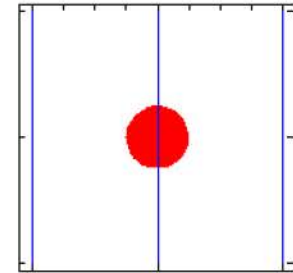
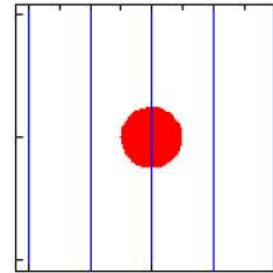
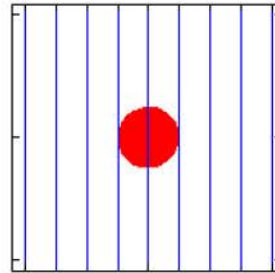
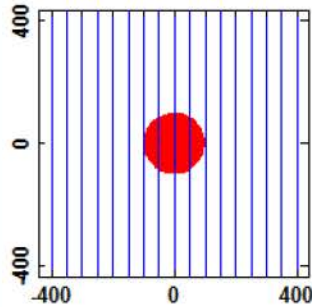
Line Spacing:

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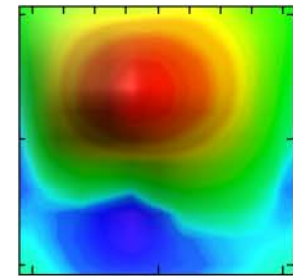
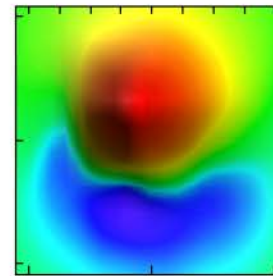
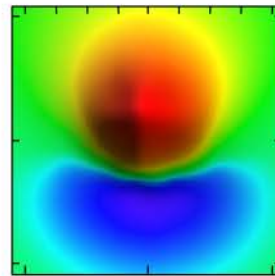
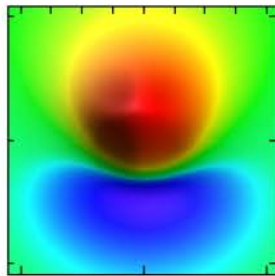
100m

200m

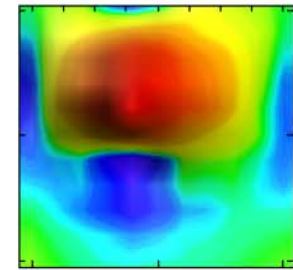
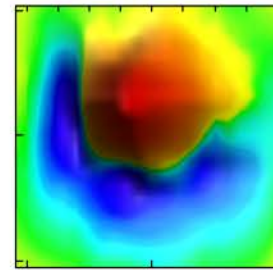
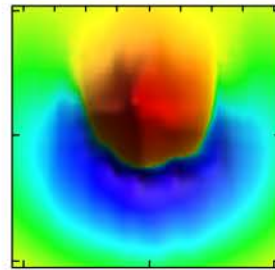
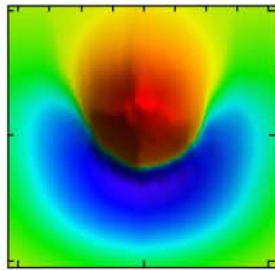
400m



TMI



FVD



# Source diameter 2tim, depth 5tim

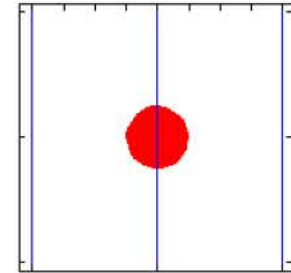
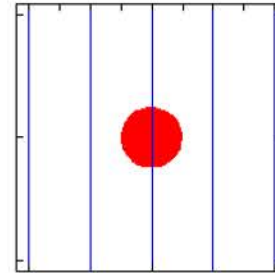
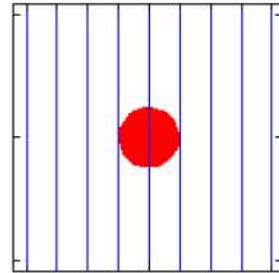
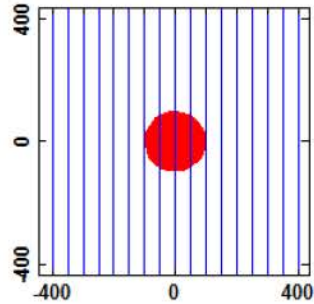
Line Spacing:

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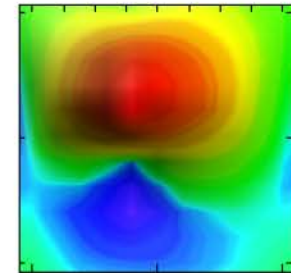
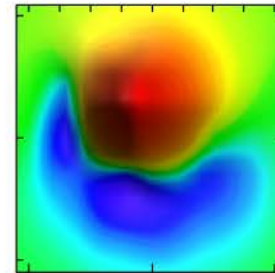
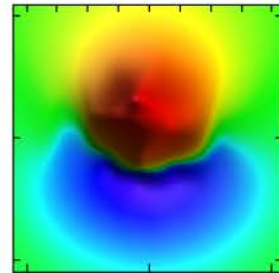
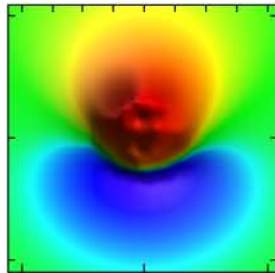
100m

200m

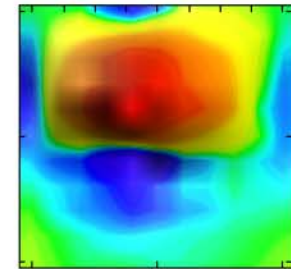
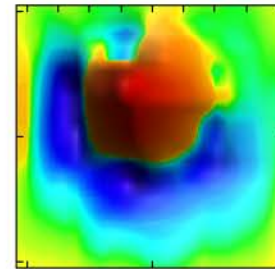
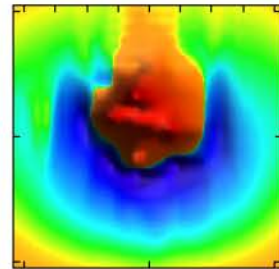
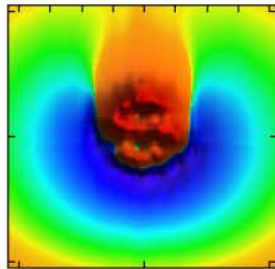
400m



TMI



FVD



# Source diameter 8t<sub>lim</sub>, depth 3t<sub>lim</sub>

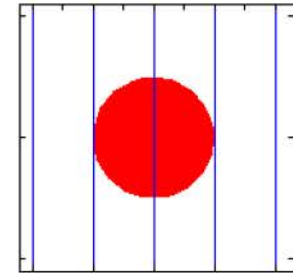
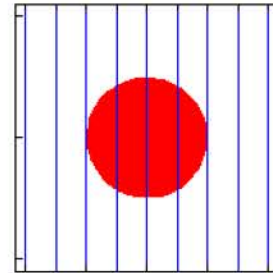
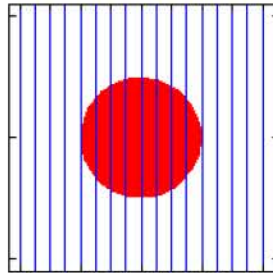
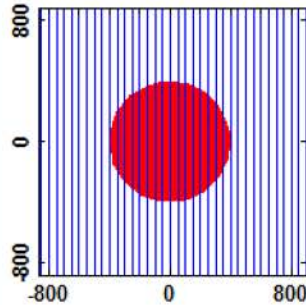
Line Spacing:

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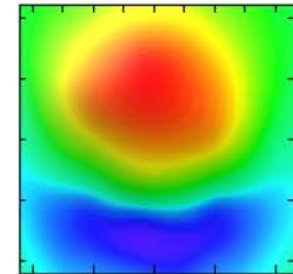
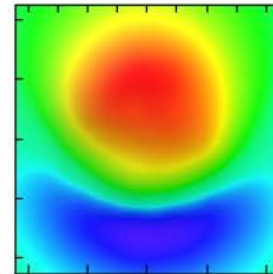
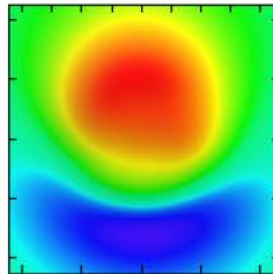
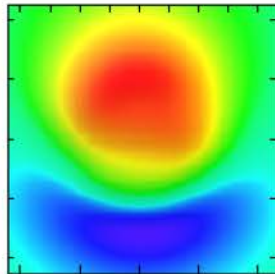
100m

200m

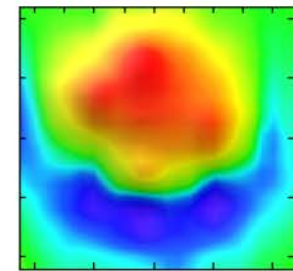
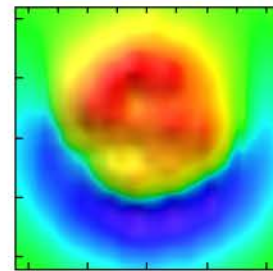
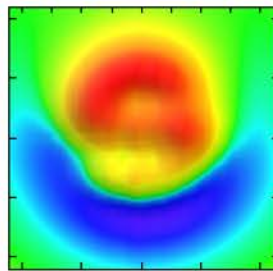
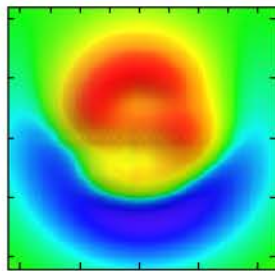
400m



TMI



FVD



# Source diameter 8t<sub>lim</sub>, depth 2t<sub>lim</sub>

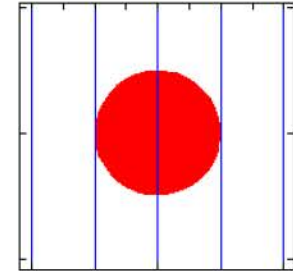
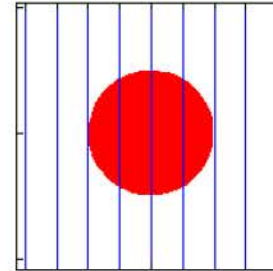
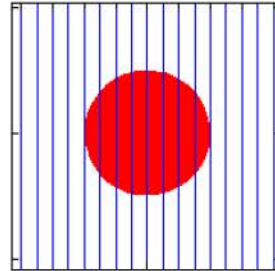
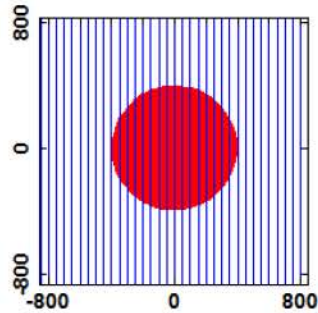
Line Spacing:

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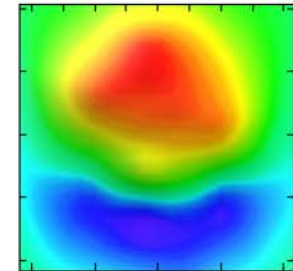
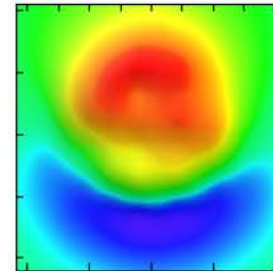
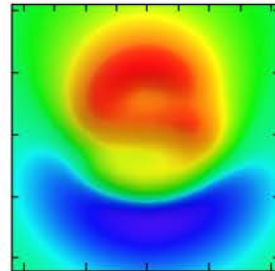
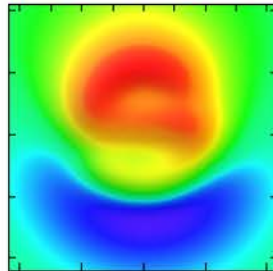
100m

200m

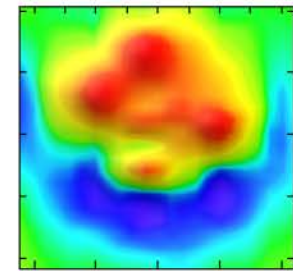
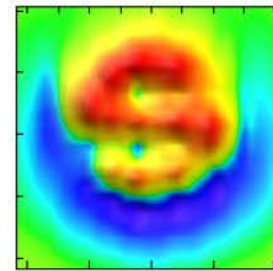
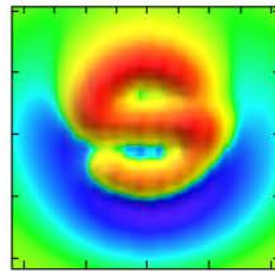
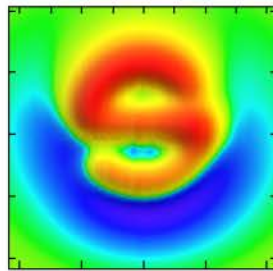
400m



TMI



FVD



# Source diameter 8t<sub>lim</sub>, depth 1t<sub>lim</sub>

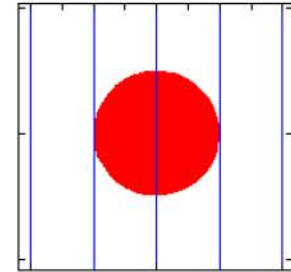
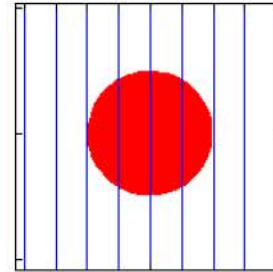
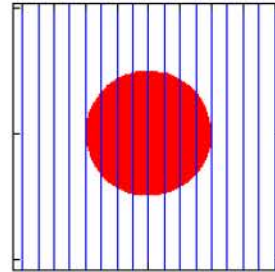
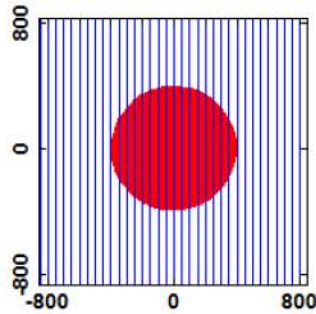
Line Spacing:

50m

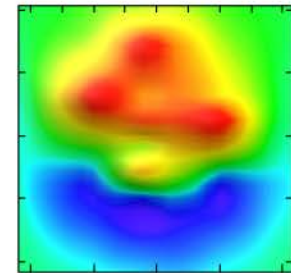
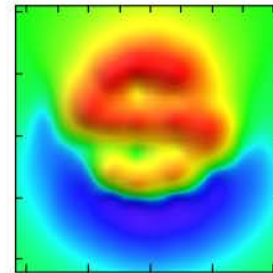
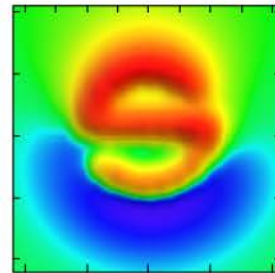
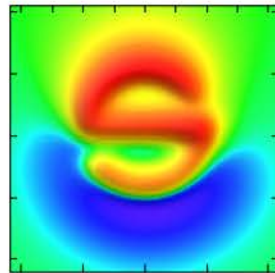
100m

200m

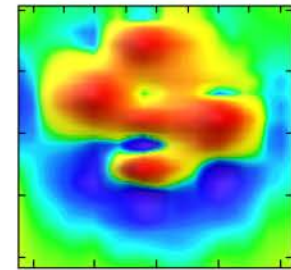
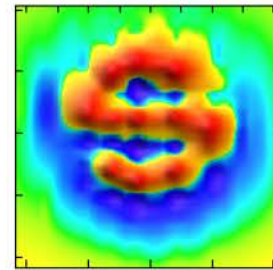
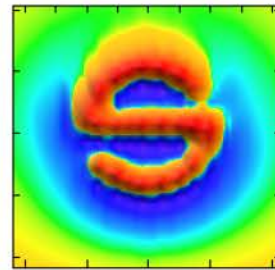
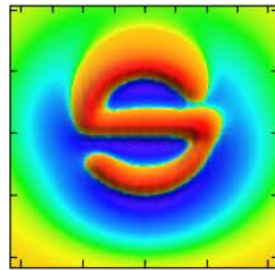
400m



TMI



FVD



# Source diameter $8t_{im}$ , depth $5t_{im}$

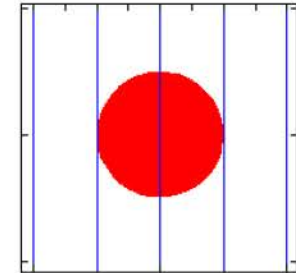
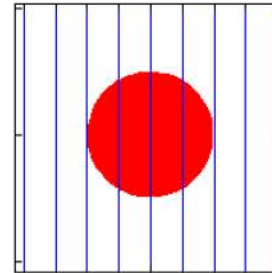
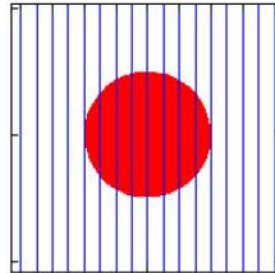
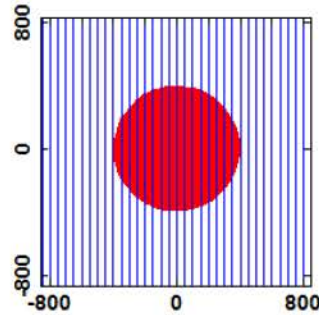
Line Spacing:

50m

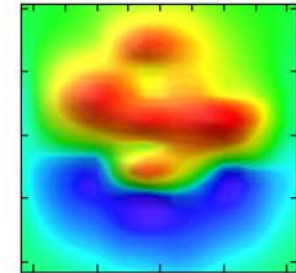
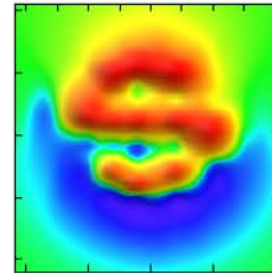
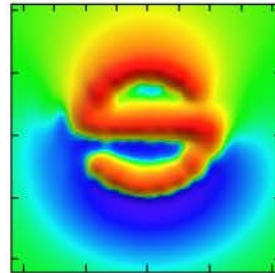
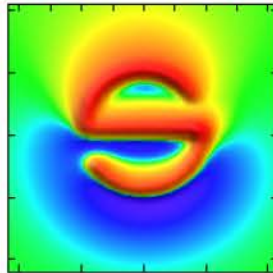
100m

200m

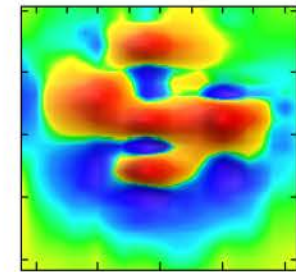
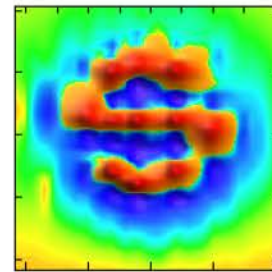
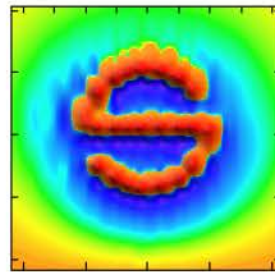
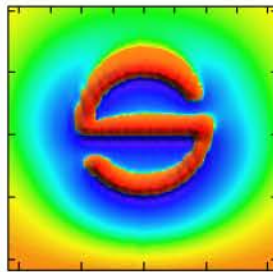
400m



TMI



FVD



# Will we acquire closer line-spaced data?

- This decision is made on budget considerations
- Depends on the relevance of the magnetic bodies to mineralisation

## Will closer line-spaced data provide significant new information?

- Depends on depth to the magnetic sources
- Depends on the scale of the geological structures

As a general rule, if an area is worth exploring, has regional magnetic coverage at 400 metre line spacing and sources <200 below surface, it should be worthwhile infilling to 100 or 50 metre spacing.

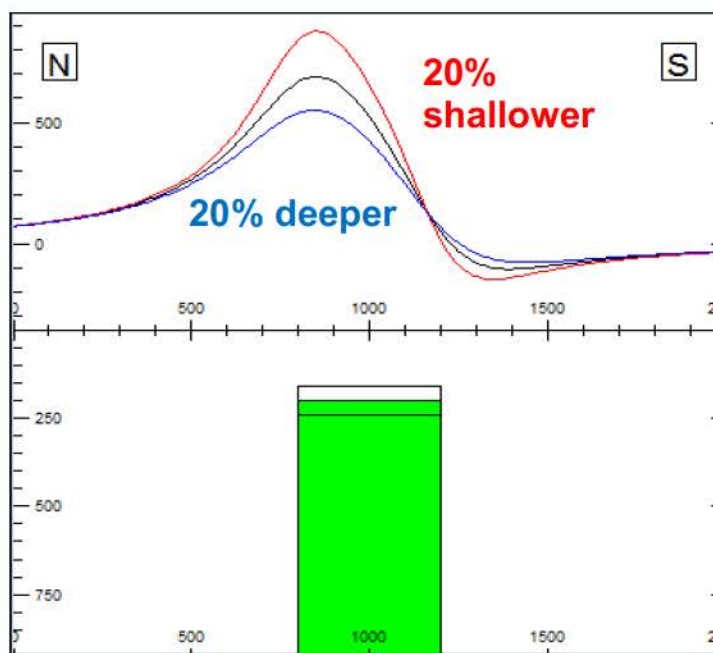
# 3) How is Uncertainty Assessed?



**This Slide Intentionally Blank**

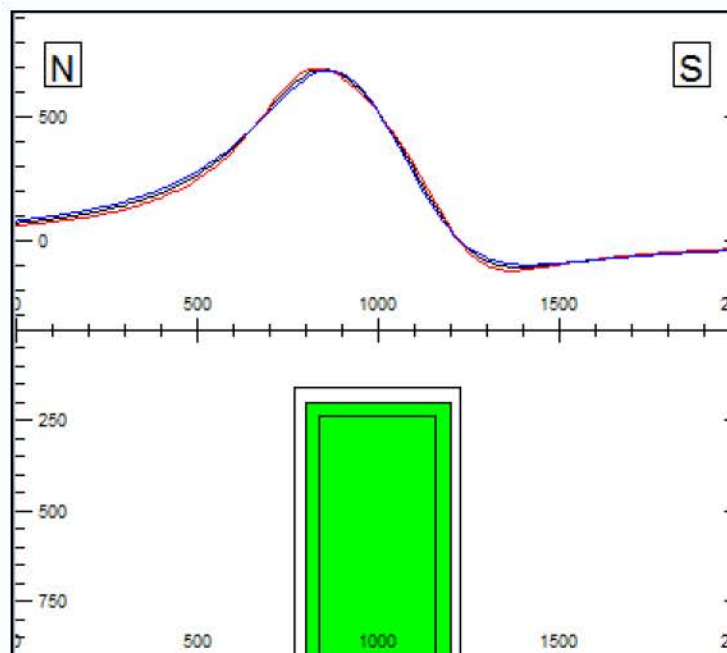
# Sensitivity to source depth

Depth offset for identical sources  
(appropriate to looking for a known source)



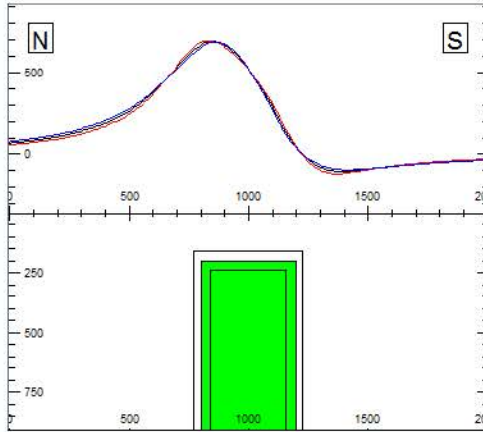
# Sensitivity to source depth

Depth offset inversion-matched sources  
(appropriate to looking for an unknown source)



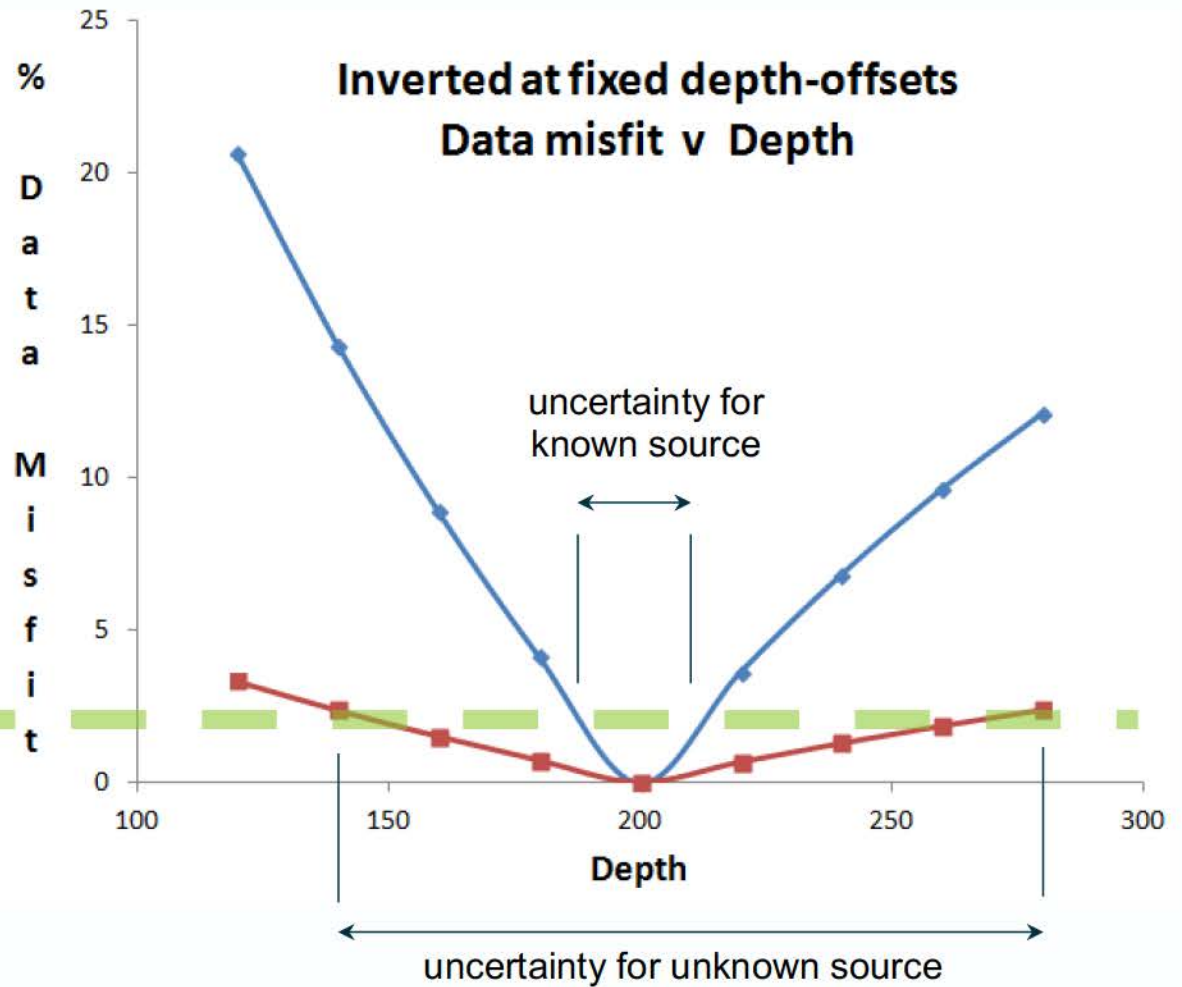
Anomaly changes due to depth variation can be mostly compensated by changes in other parameters – especially susceptibility and thickness

# Evaluating sensitivity to depth



Depth offset of an unknown source model

Level at which the misfit is proposed to be significant (interpretational)

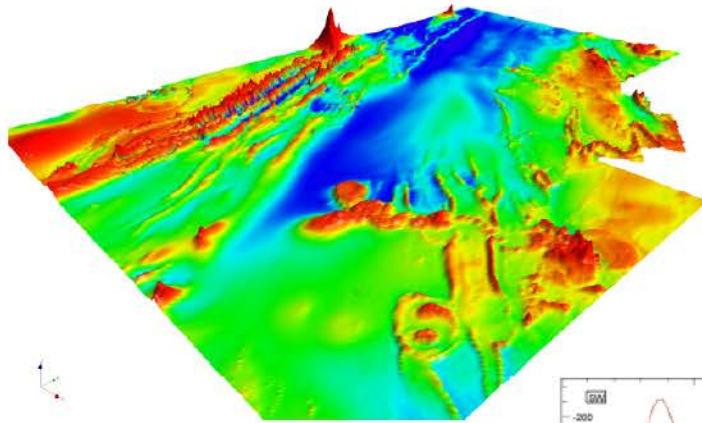


# An Australian Magnetic Source Database ?

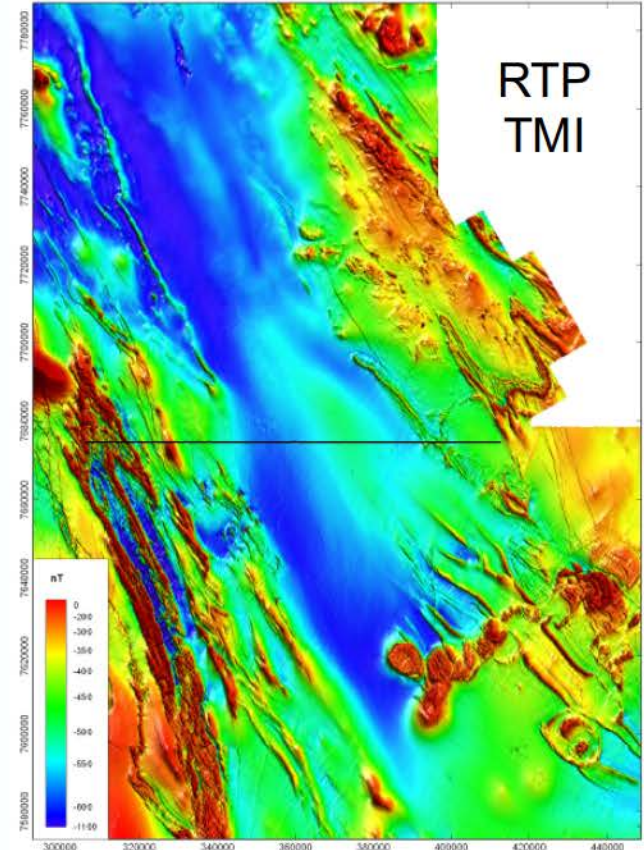
- Magnetic source depth estimation doesn't cut it
  - we need dedicated inversion of isolated anomalies
- CSIRO and Geoscience Australia have investigated suitable work-flows and have the necessary skills to generate a national database of inverted source solutions with associated parameter attributes and sensitivity estimates

# 4) Examples Illustrating Strengths and Weaknesses

# Case Study (strength) Waukarlyarly Basin, WA

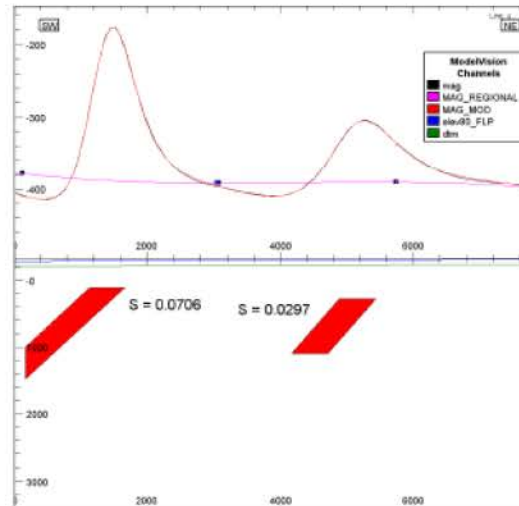


RTP  
TMI

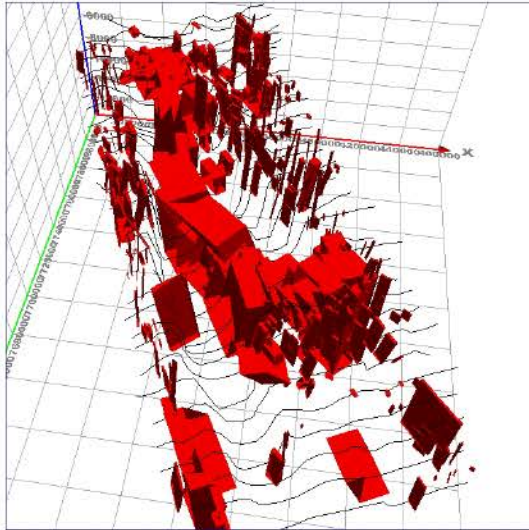


RTP  
TMI

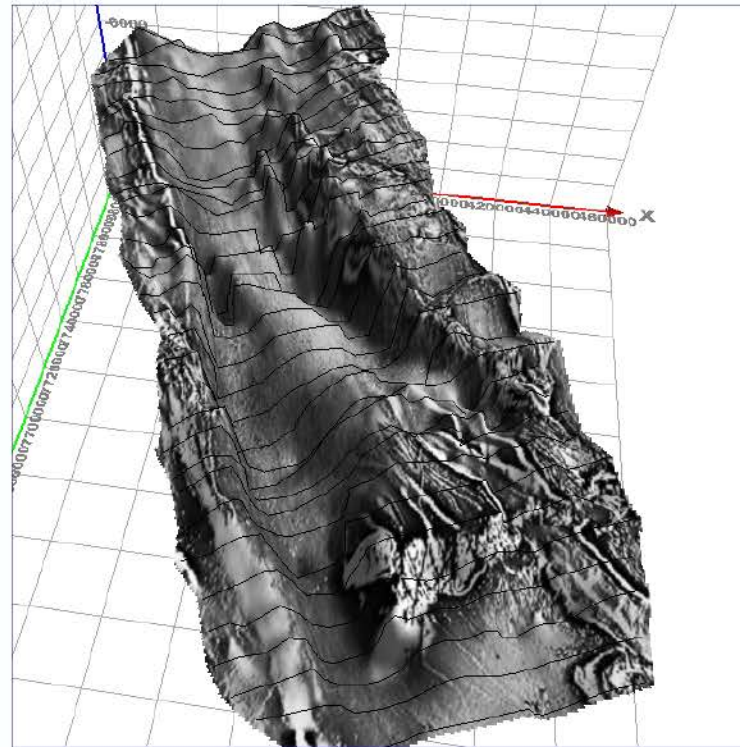
Selected profile  
inversions



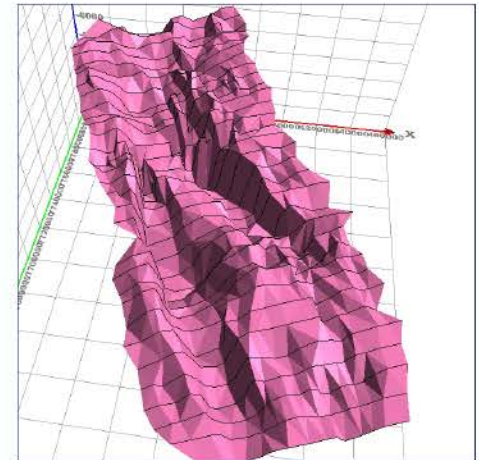
# Waukarlycarly Basin, WA



Solutions

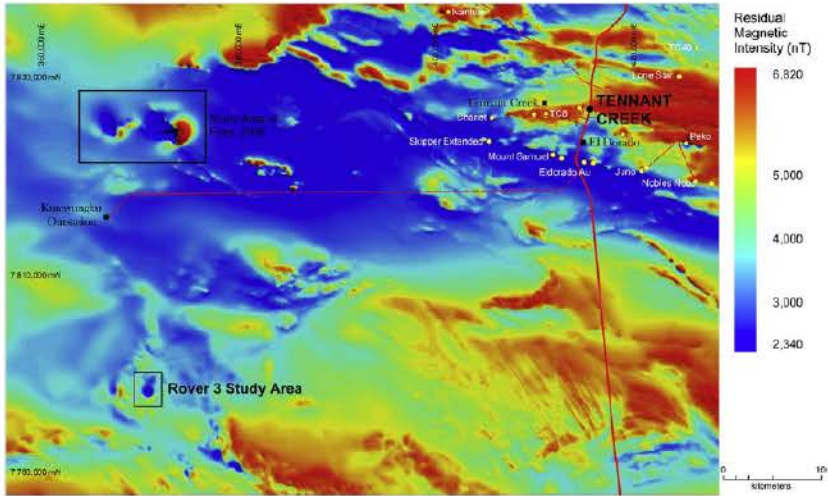


Depth surface

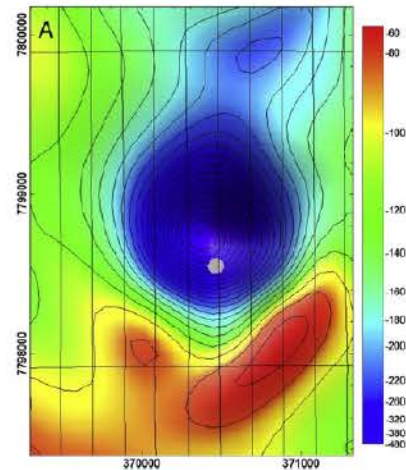




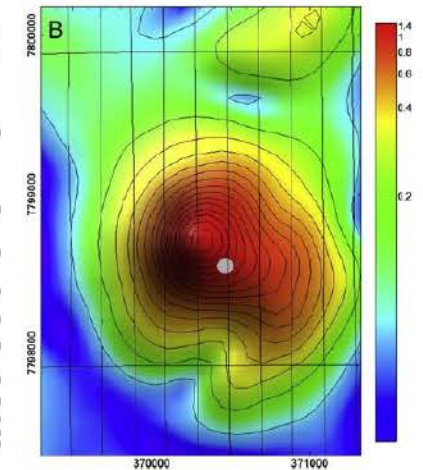
# Case Study (weakness) Rover 3 Tennant Creek



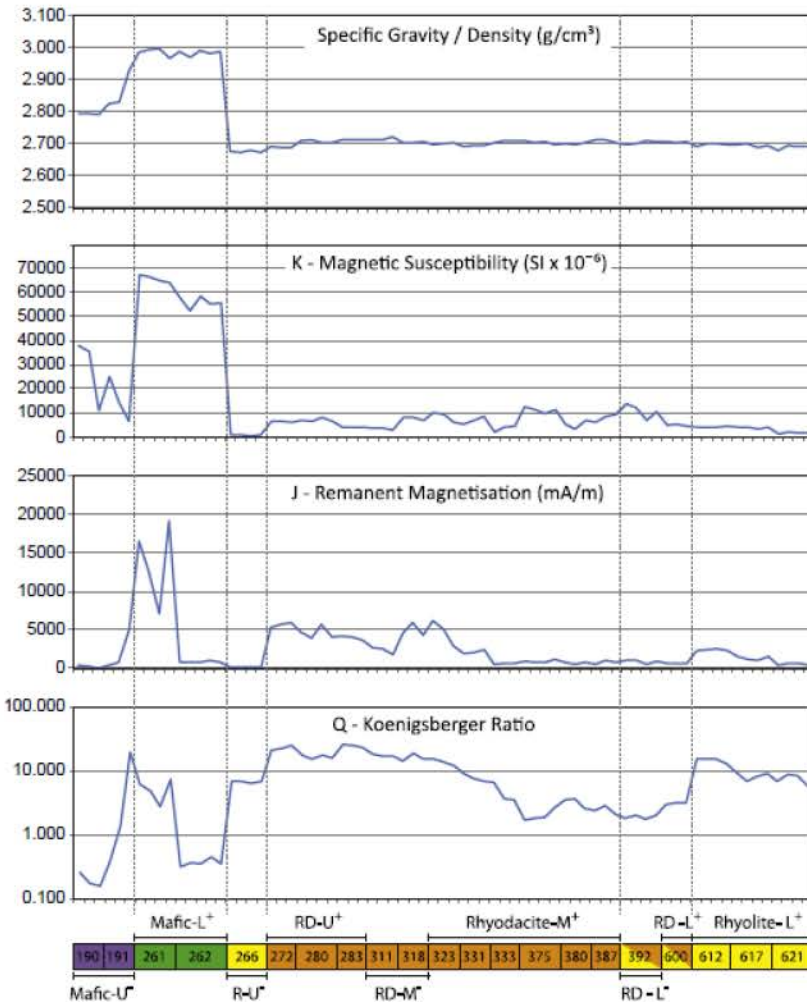
TMI anomaly



Total Gradient anomaly



# Rover 3 Tennant Creek



- Estimated depth 250 metres (a good estimate)
- Magnetization was only tested with a susceptibility meter
- Q factor of the most significant shallow magnetization is up to 10
- Drilling continued to a depth of 738 metres

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journal homepage: [www.elsevier.com/locate/jappgeo](http://www.elsevier.com/locate/jappgeo)



The Paradox of Scale: Reconciling magnetic anomalies with rock magnetic properties for cost-effective mineral exploration

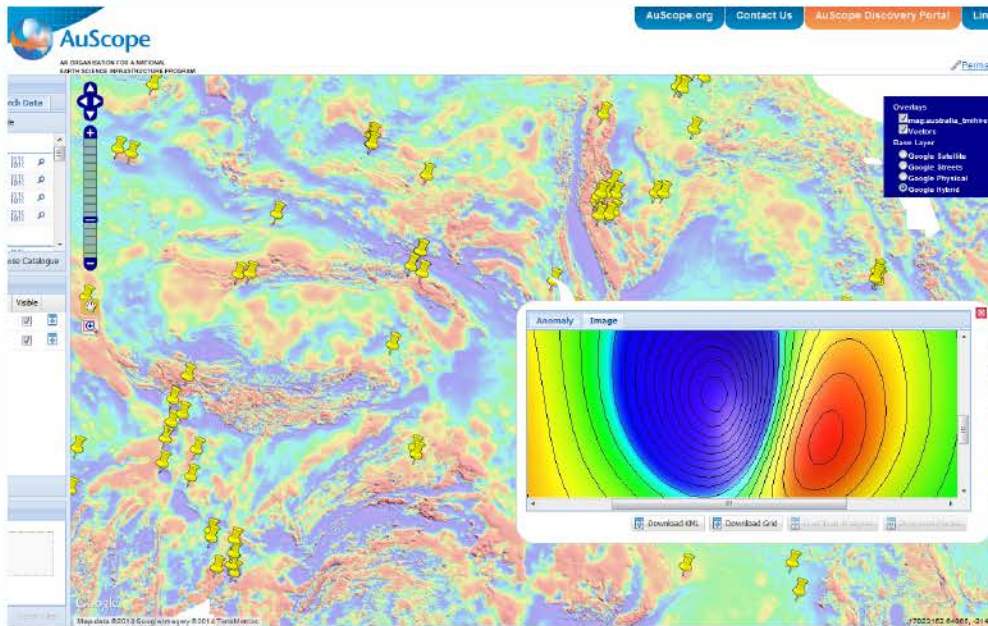
James R. Austin<sup>1,\*</sup>, Clive A. Foss

CSIRO Earth Science and Resource Engineering, PO Box 136, North Ryde, NSW 1570, Australia

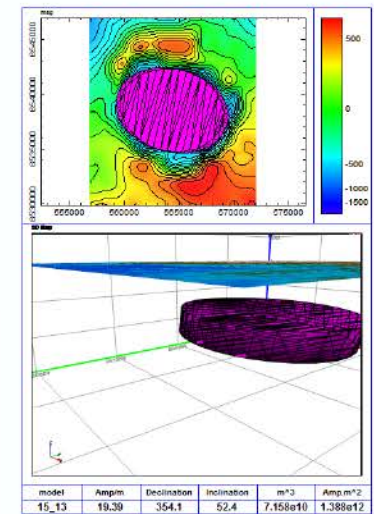
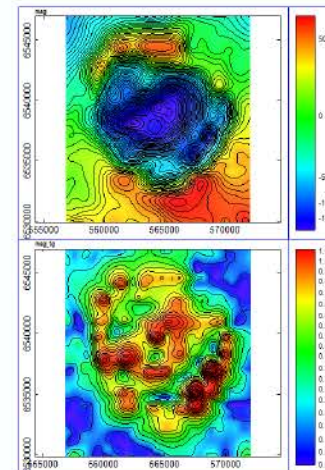


# The Australian Remanent Anomalies Database

- A joint CSIRO – Geoscience Australia initiative available through the AuScope Portal (link at: [www.magresearch.org](http://www.magresearch.org))



Example grid download



Example model download

# Conclusions

- Magnetic Field Studies are crucial for exploration beneath cover
- We need tenement-scale high-resolution magnetic surveys
- We need to value-add to the existing regional datasets
  - The National Remanent Anomalies Database  
(available through the AuScope portal)
  - A suggested national magnetic source database  
(this will require funding)

[www.magresearch.org](http://www.magresearch.org)

# Thank you

CSIRO Earth Science and Resource Engineering  
Minerals Down Under Flagship

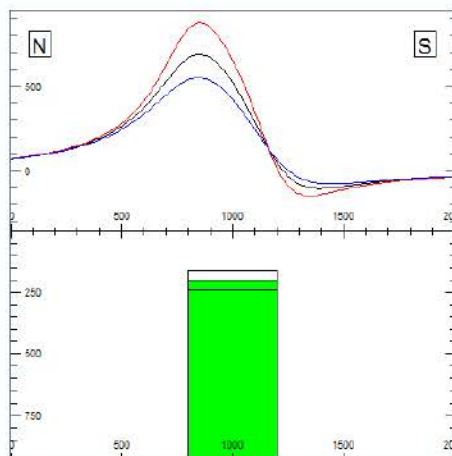
Clive Foss

t +61 2 949ti 8713  
e [clive.foss@csiro.au](mailto:clive.foss@csiro.au)

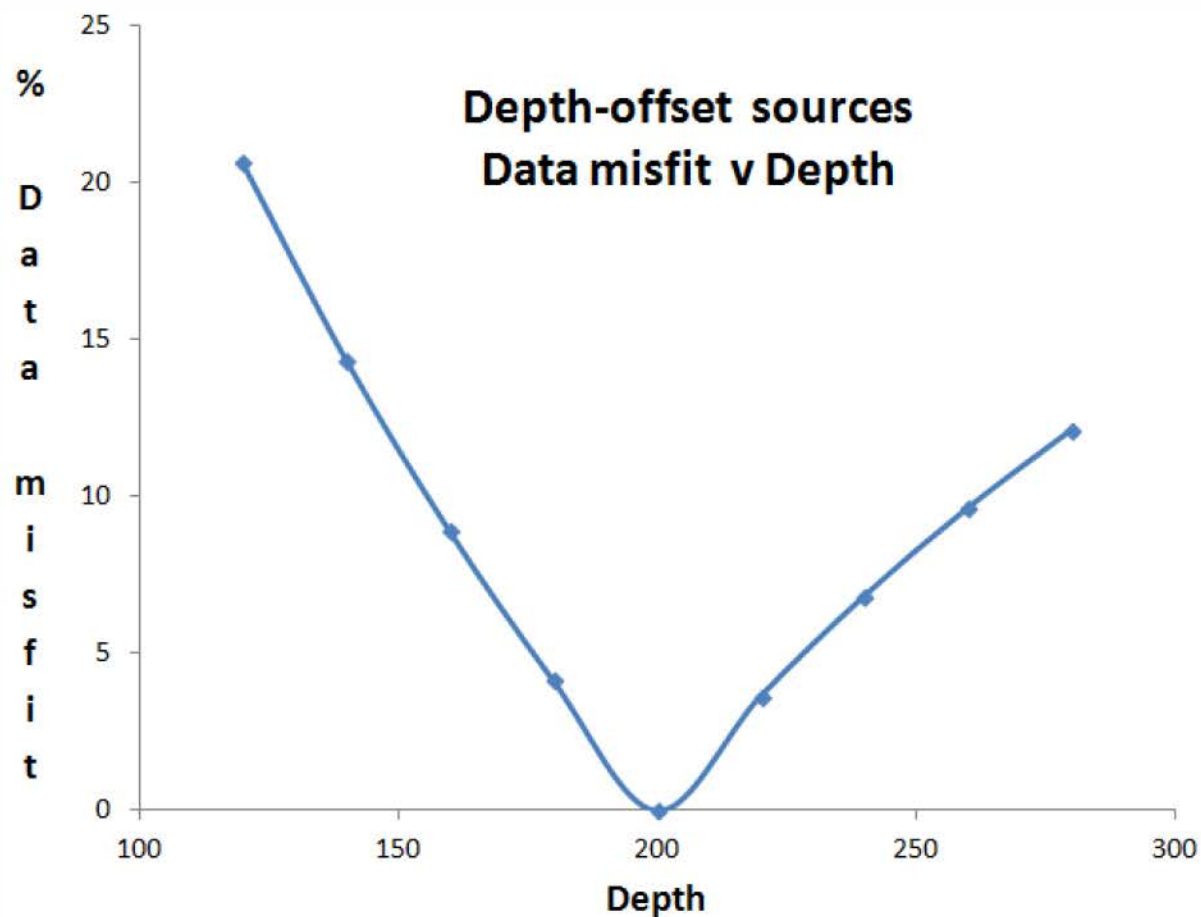
MINERALS DOWN UNDER FLAGSHIP  
[www.csiro.au](http://www.csiro.au)



# Evaluating sensitivity to depth



Depth offset of a known source model



Data misfit = % rms difference between curves, normalised to the measured curve