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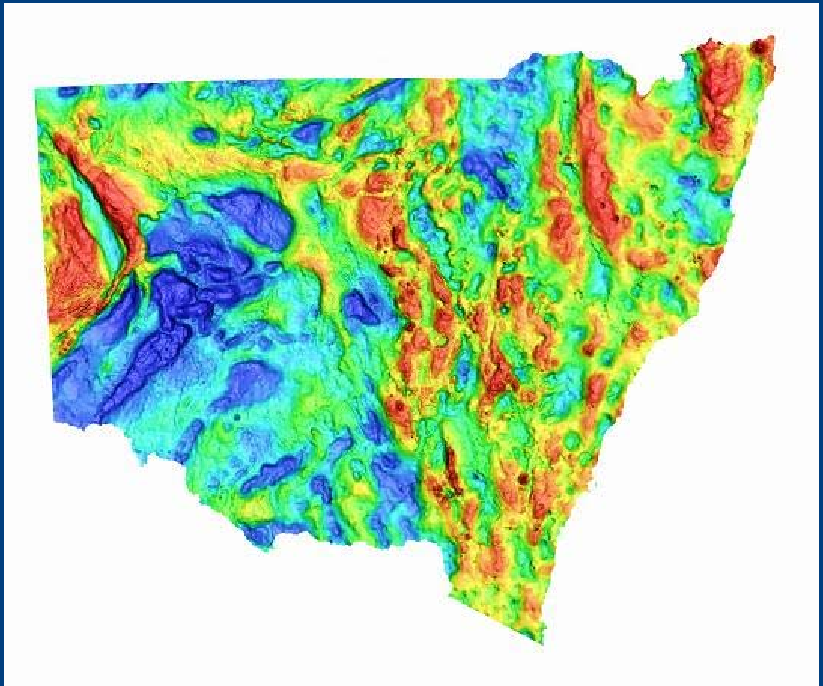
How deep do you want to look?

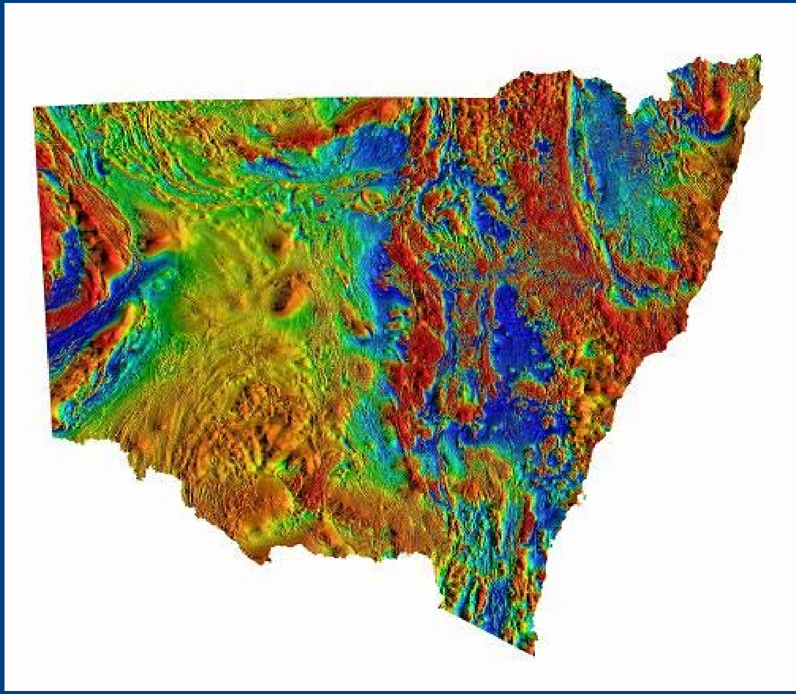
Tilt filters, layer filters, and other new ways of extracting depth structure from geophysical data

Robert Musgrave

Geological Survey of NSW

Current state of NSWGS grid data





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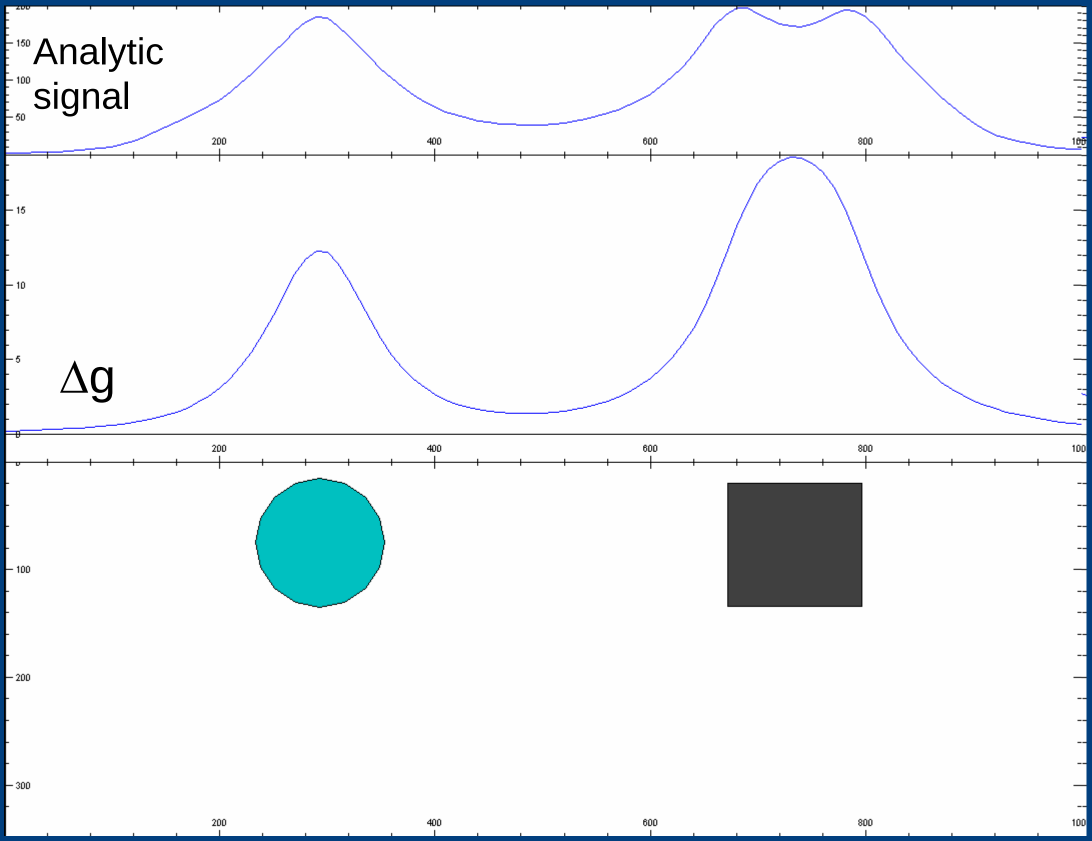
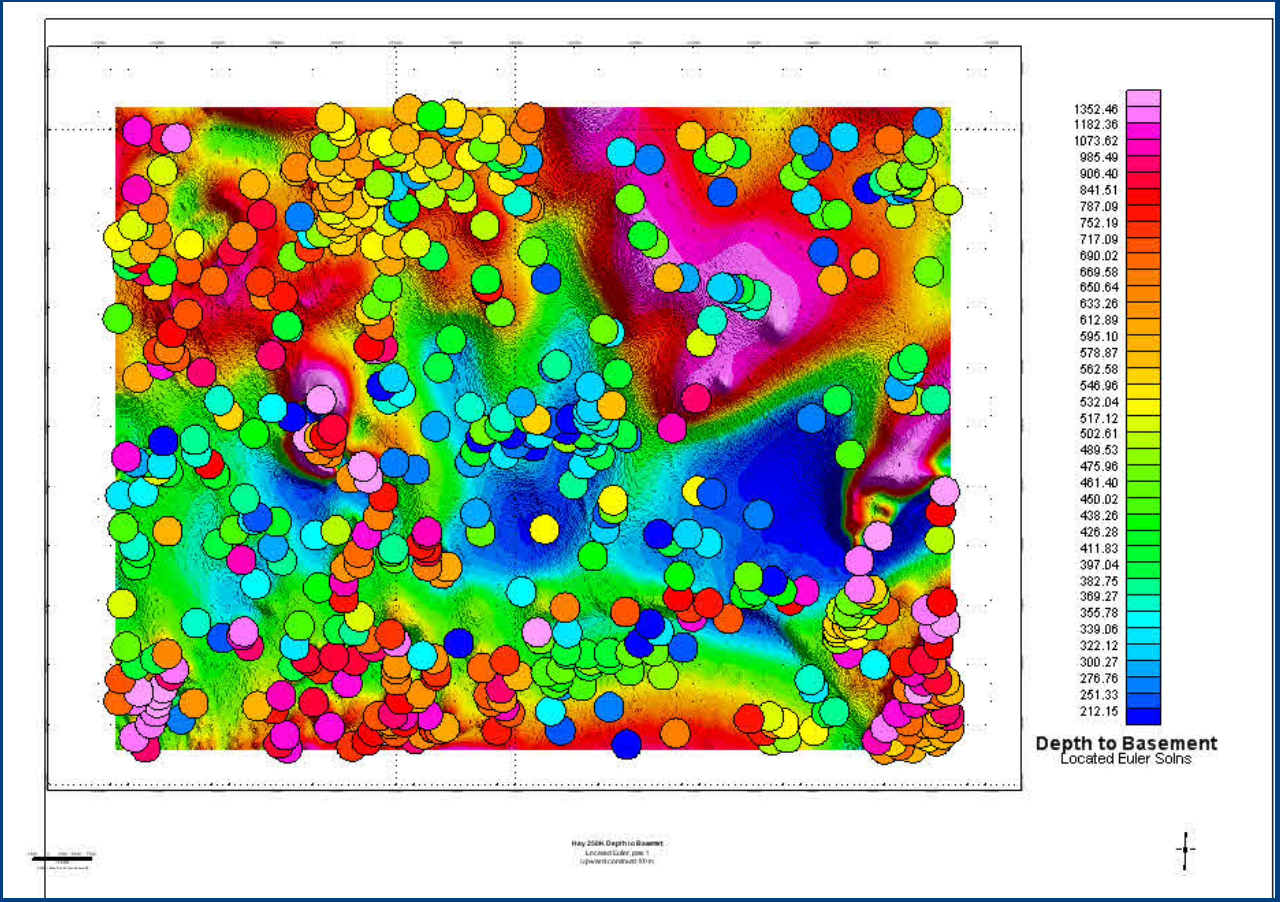
Wavelength, depth, and shape



$$|A(x,y)| = \sqrt{\left(\frac{dT}{dx}\right)^2 + \left(\frac{dT}{dy}\right)^2 + \left(\frac{dT}{dZ}\right)^2}$$

Classical inversion:
Euler deconvolution



But what do geologists want?

- "How deep does this image see?"
- Qualitative, geological-style interpretation of geophysical datasets
  - Some indication of the depth of the structures resolved
  - Discrimination of competing shallow and deep structural trends
- Visualisation method that:
  - extracts the anomaly wavelength information related to source depth
  - in a form that preserves its map position and trends.

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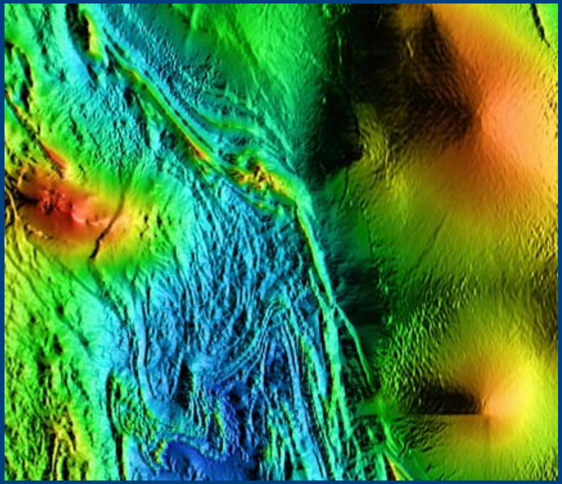
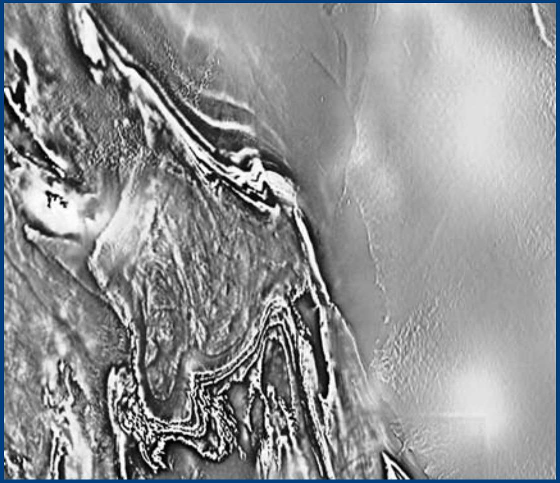
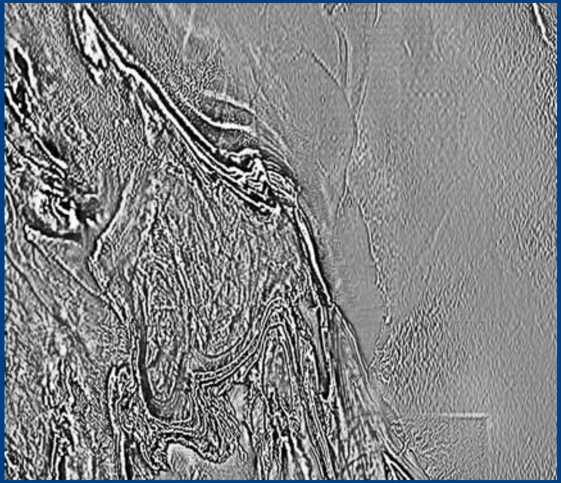
Vertical derivatives



TMI RTP



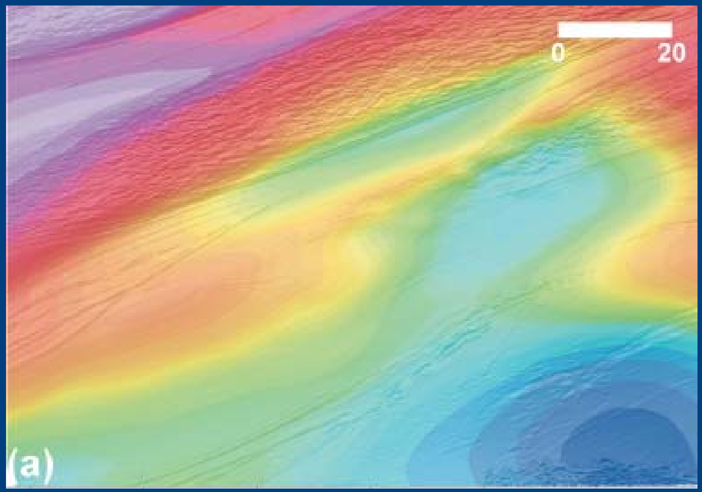
1VD



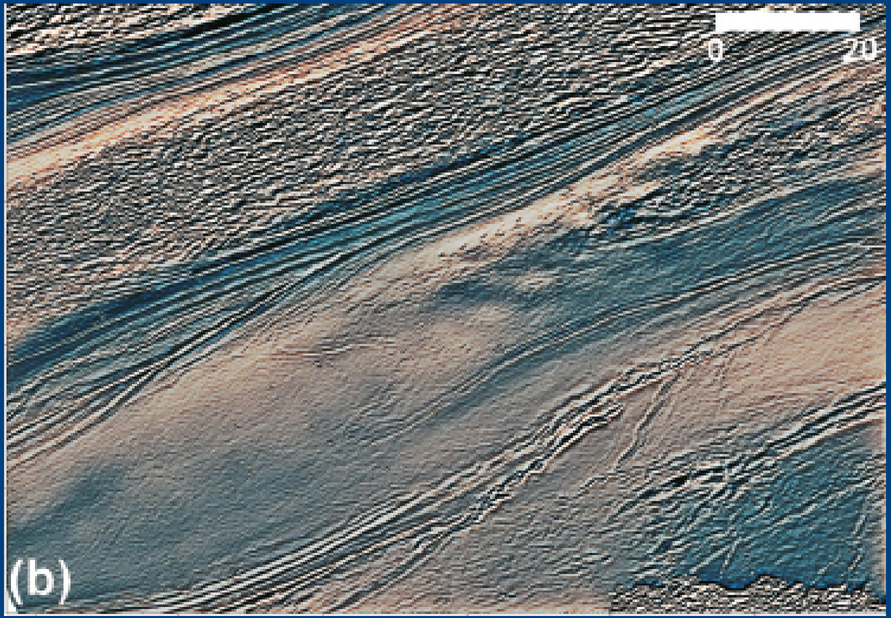
2VD

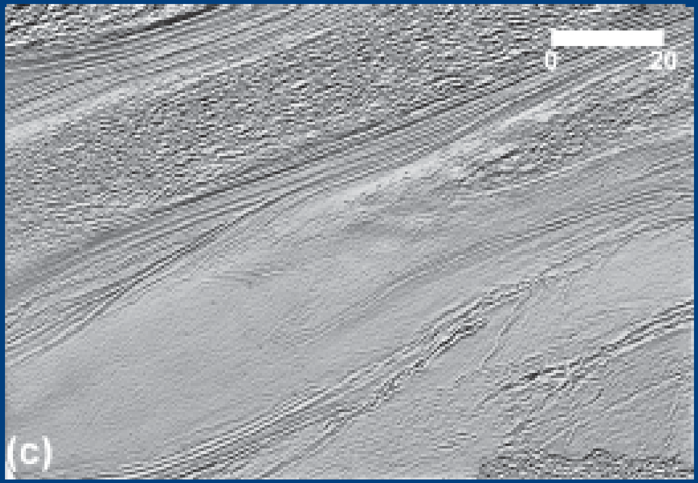
Farnell Group, Curnamona Block

Fractional derivatives



TMI

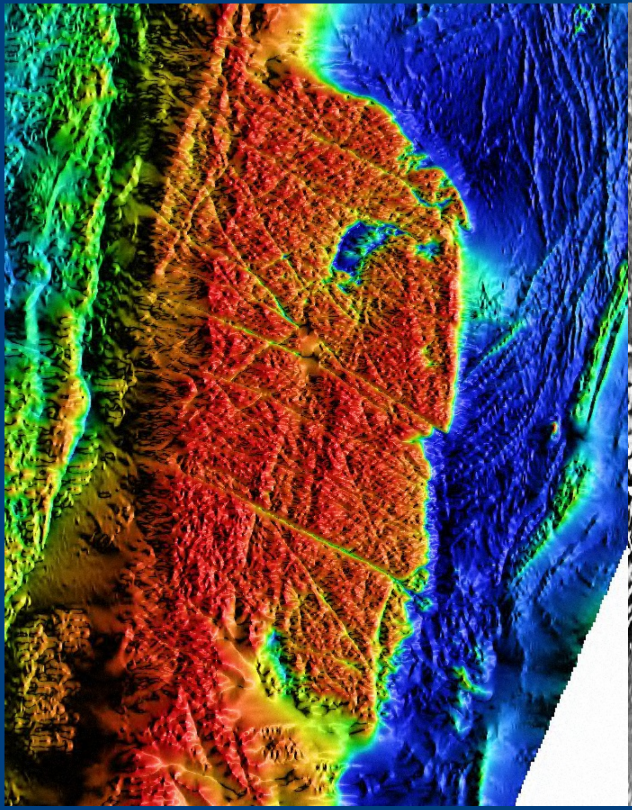




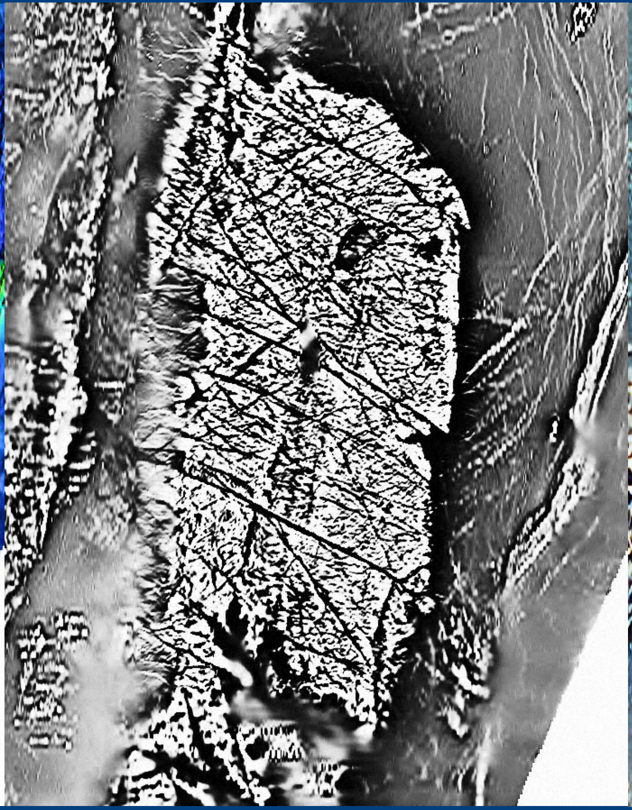
1.5 VD

Cowan & Cooper 2005

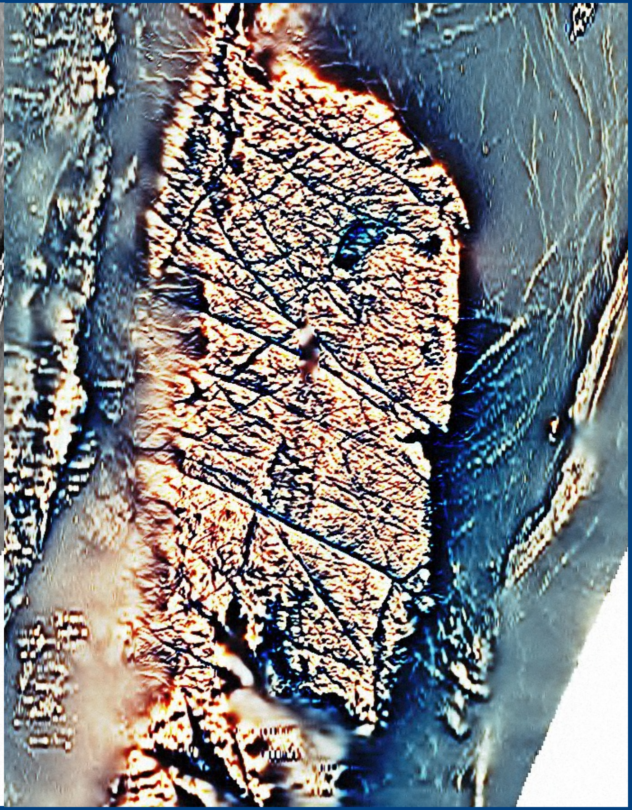
Braidwood fractional derivatives



TMI

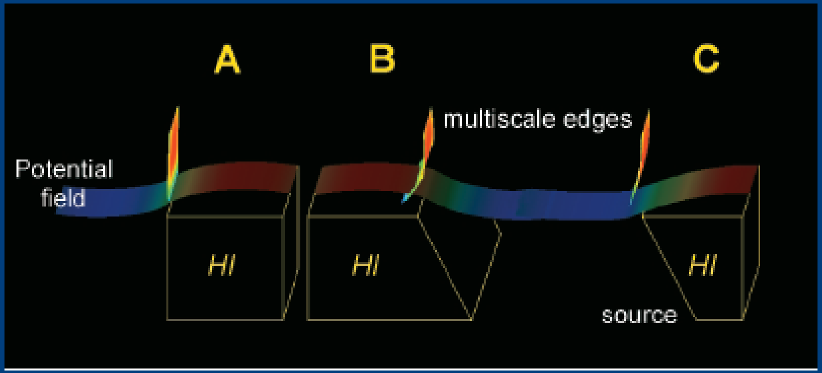


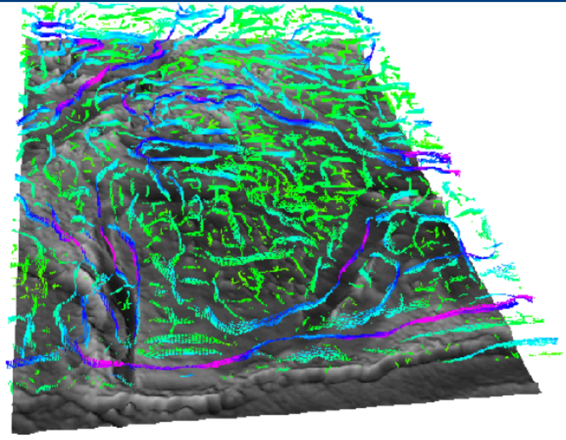
1VD



0.7 + 1.0 + 1.3 VD

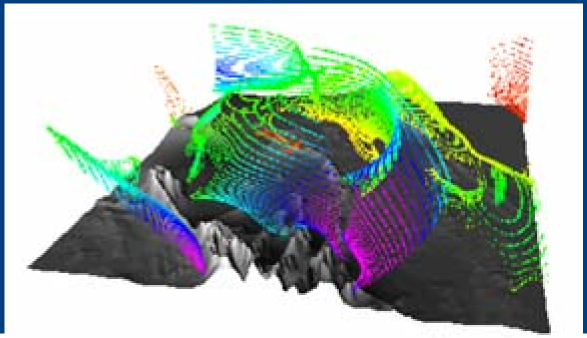
Multiscale edges ("worms") and geological structure





Holden et al., 2000, *Exploration Geophysics*, **31**, 617-621

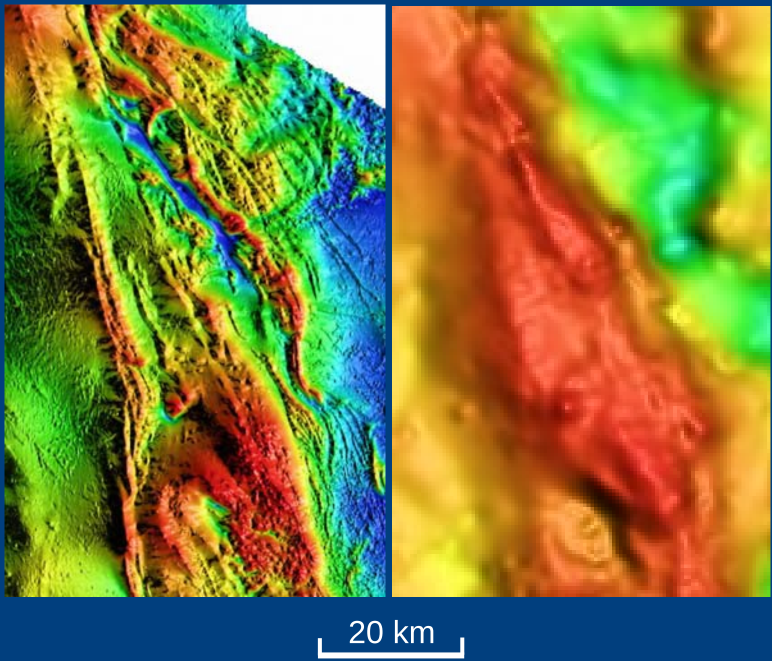
WA Gravity



Kambalda dome

Magnetics vs gravity

- Gravity images more influenced by deep (middle/lower crust) sources than (unfiltered) TMI
  - Partly due to lower sampling density
    - ~2–4 km spacing for gravity, ≤400 m interline spacing for magnetics
  - But also inherent
- Gravity monopoles, magnetic dipoles (if finite z)
- Magnetic anomalies decline more rapidly with z
- Shows up in structural index (Euler)
  - Effectively exponent of rate of decline with distance from source
- $S_{gravity} = S_{magnetic} - 1$ *(ceteris parabis)*



North Parkes *pars*

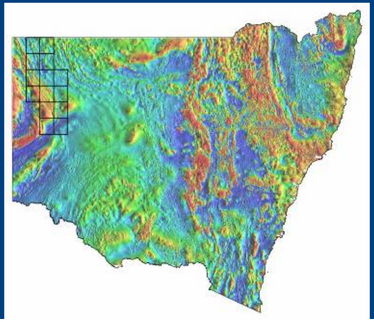
$$\Delta g \propto {}^{1}\!/_{z^{2}}$$

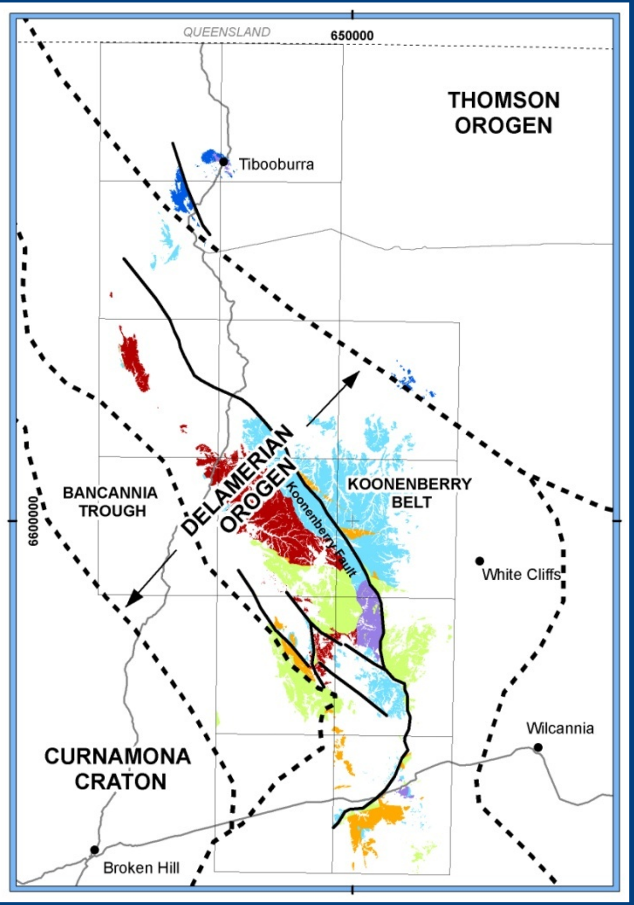
$$\Delta B \propto {}^{1}\!/_{z^{3}}$$

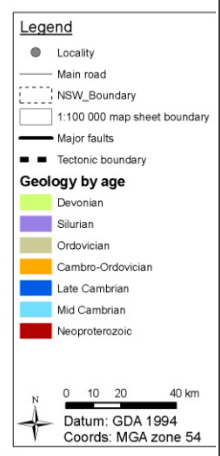
Magnetics vs gravity: structure

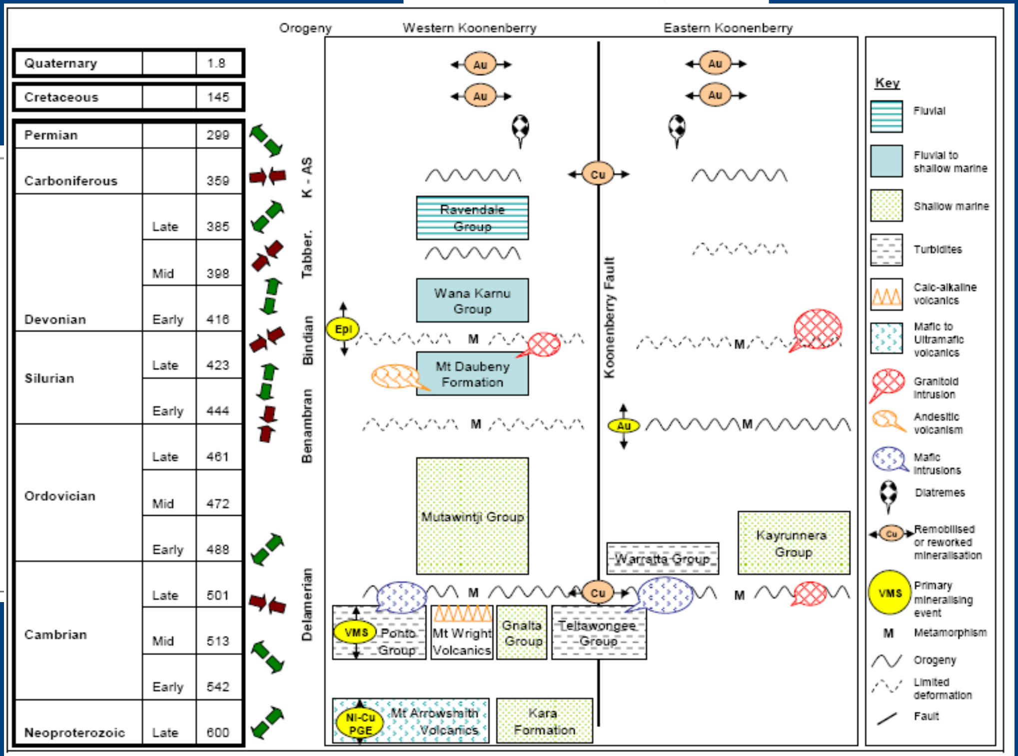
- So gravity map more influenced by deeper structure than is magnetic map
- Cross-cutting magnetic and gravity trends may reveal structural discontinuity between shallow and deep geology
  - Thin-skinned tectonics
- Proves useful in comparing magnetic and gravity edges

Koonenberry Belt: examples of edge analysis

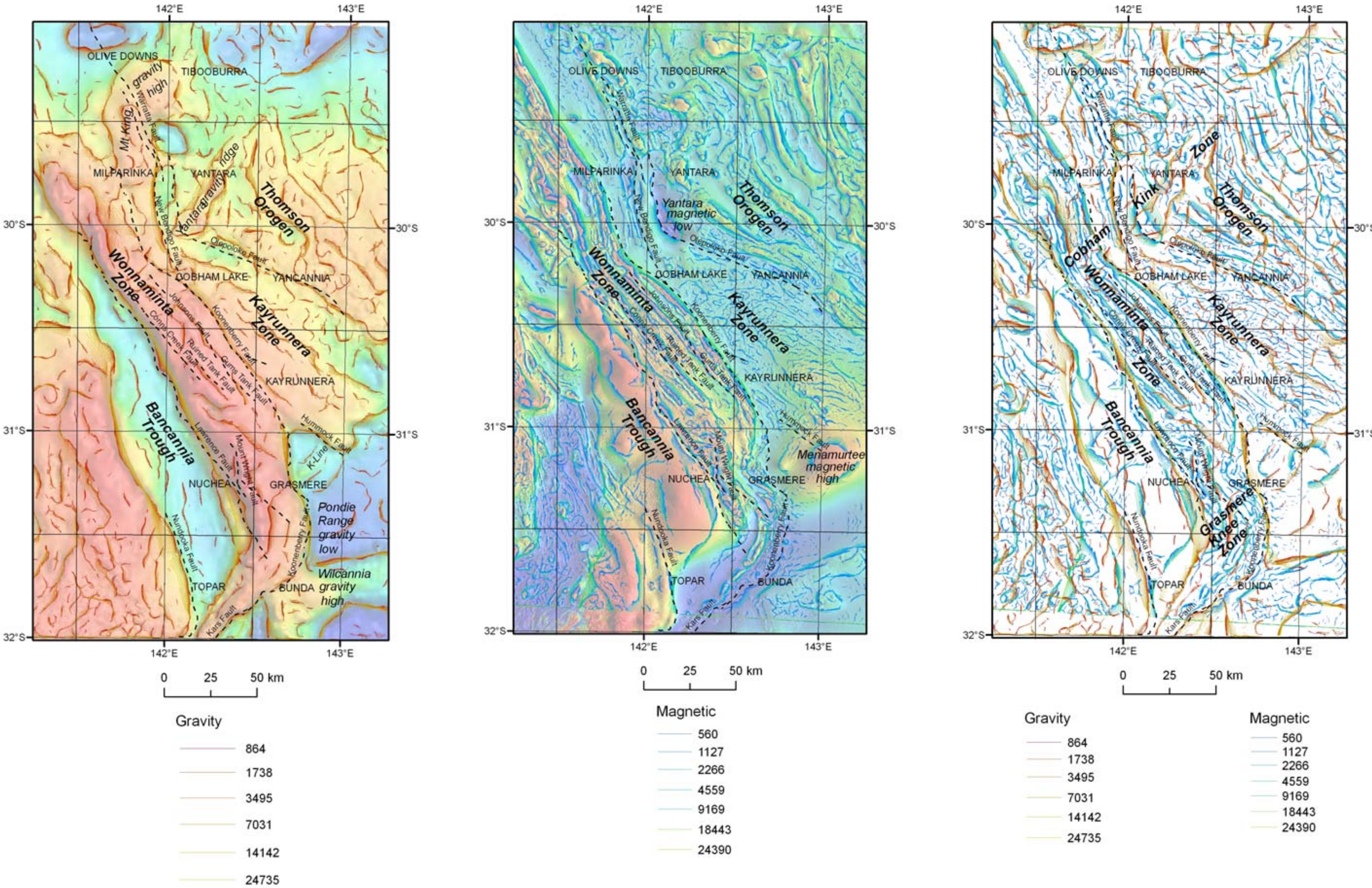




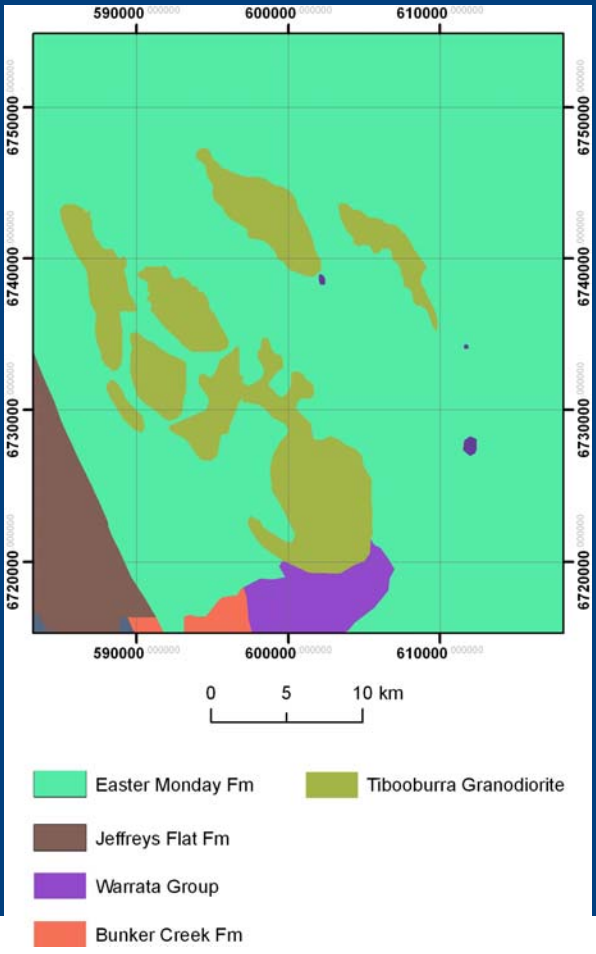


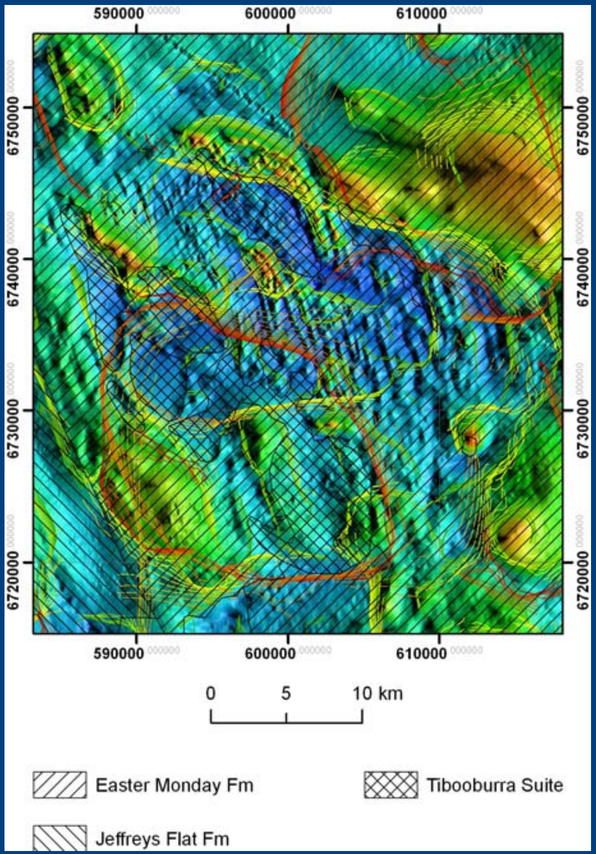


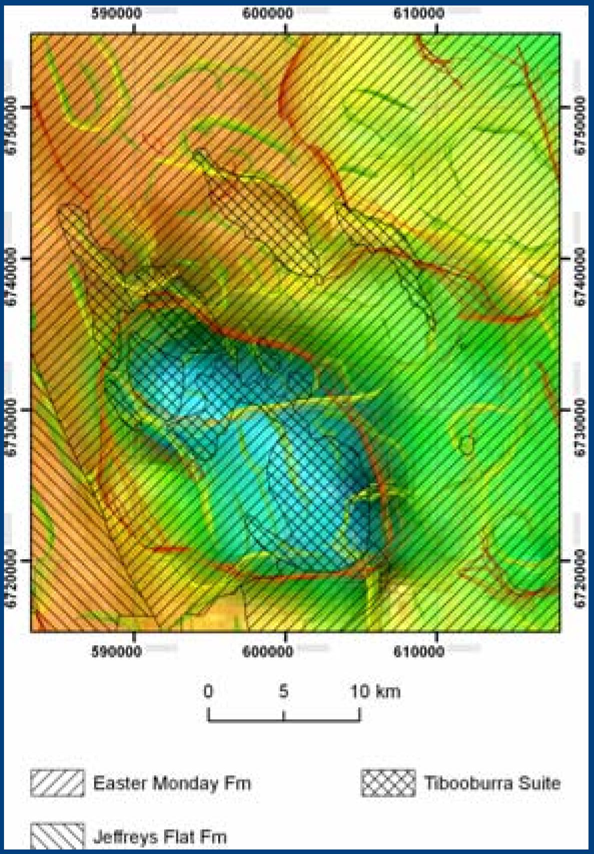
Koonenberry edge analysis



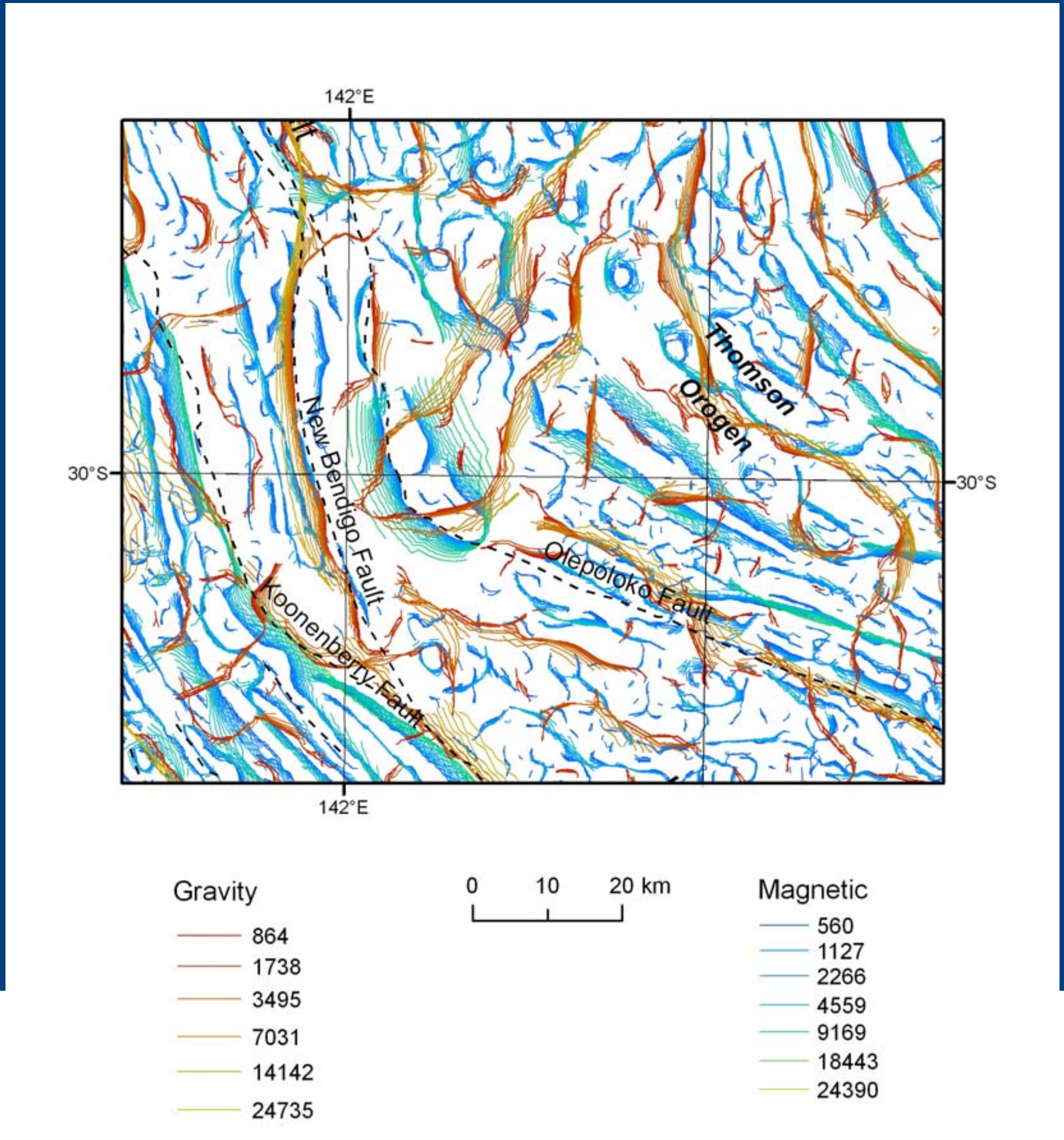
Tibooburra Granodiorite: deep structure from edge comparison







Edge comparisons: thin-skinned tectonics



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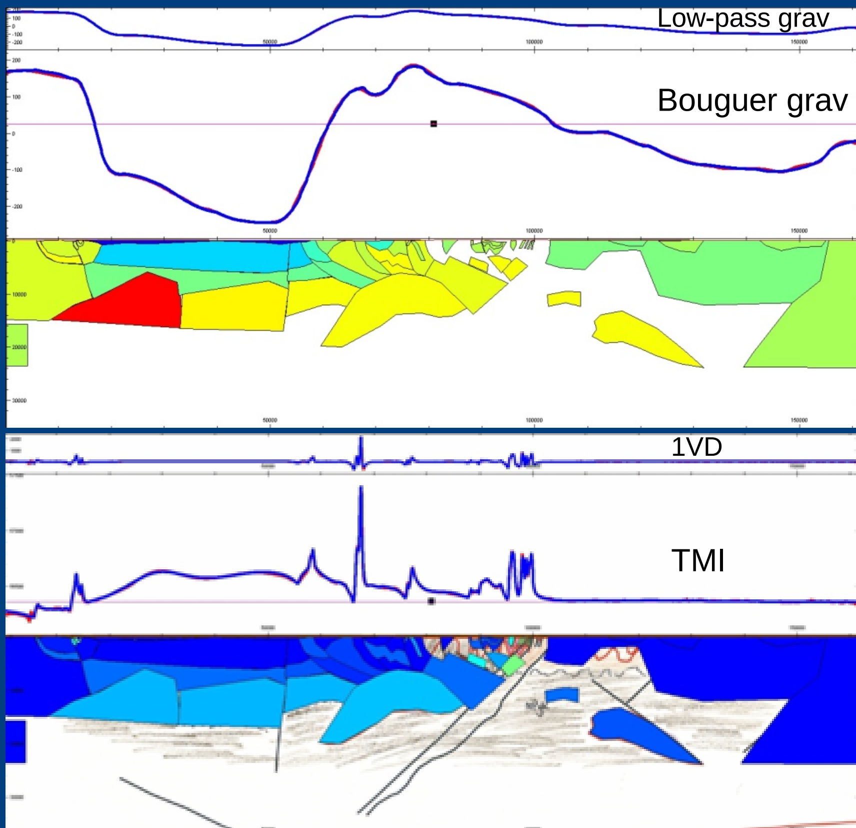
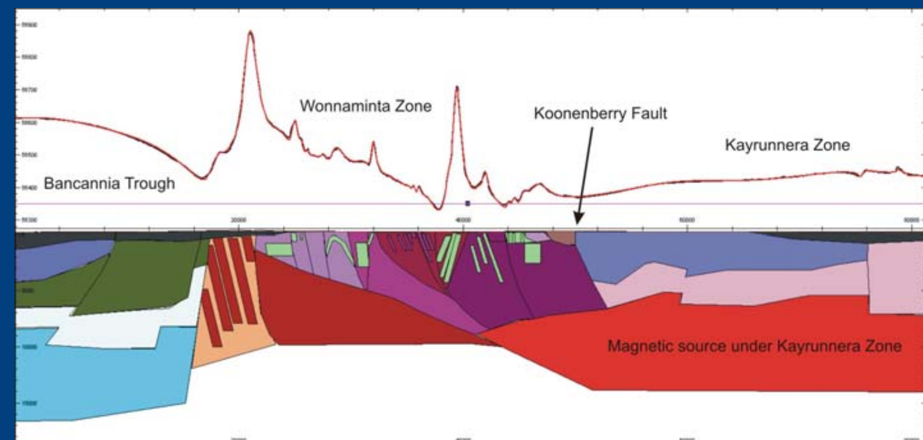
Potential field modelling





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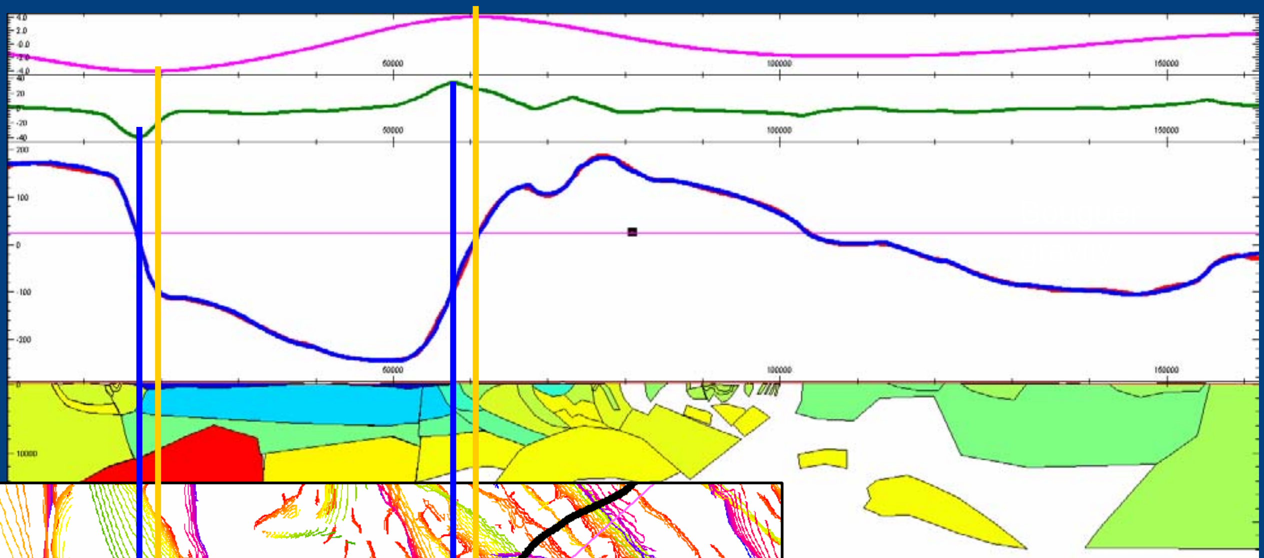
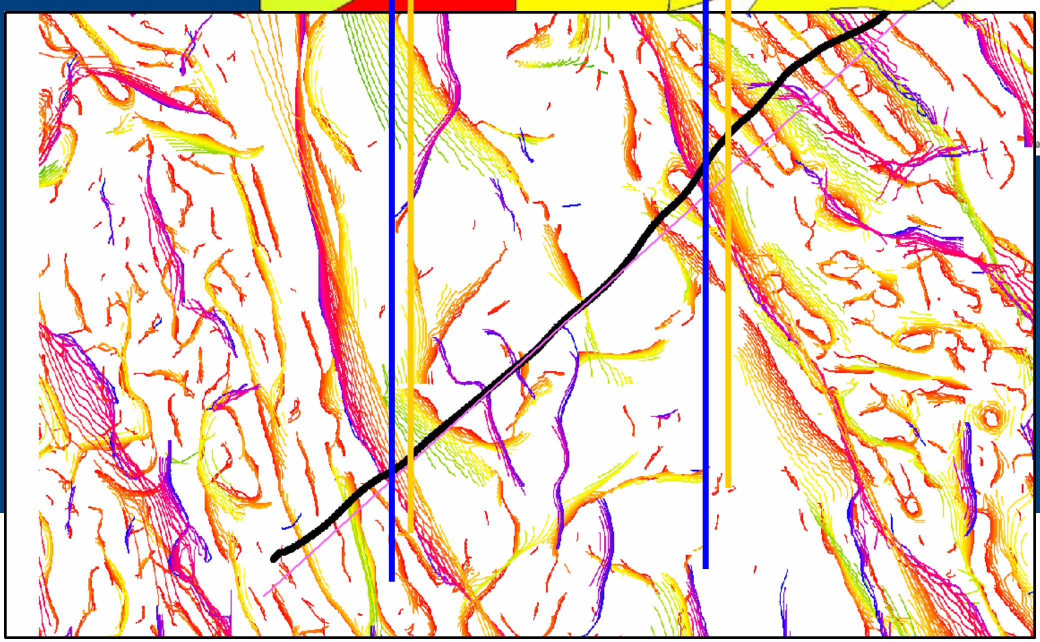
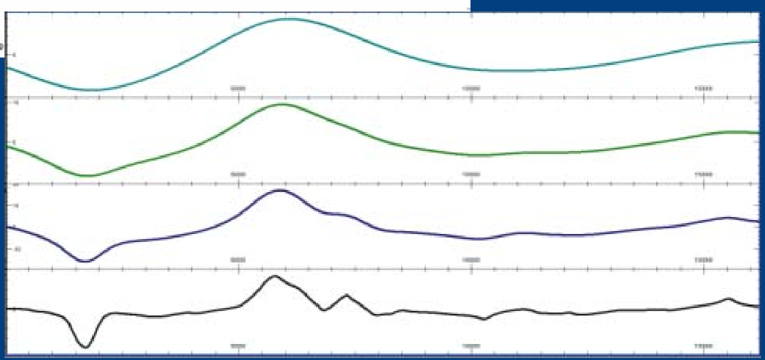
Edges & modelling







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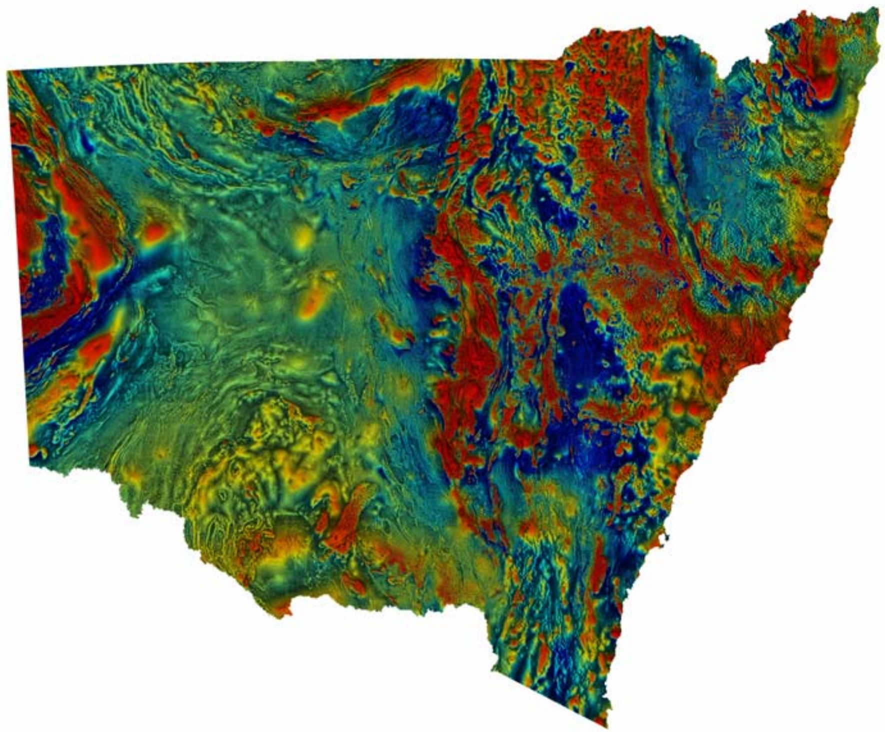
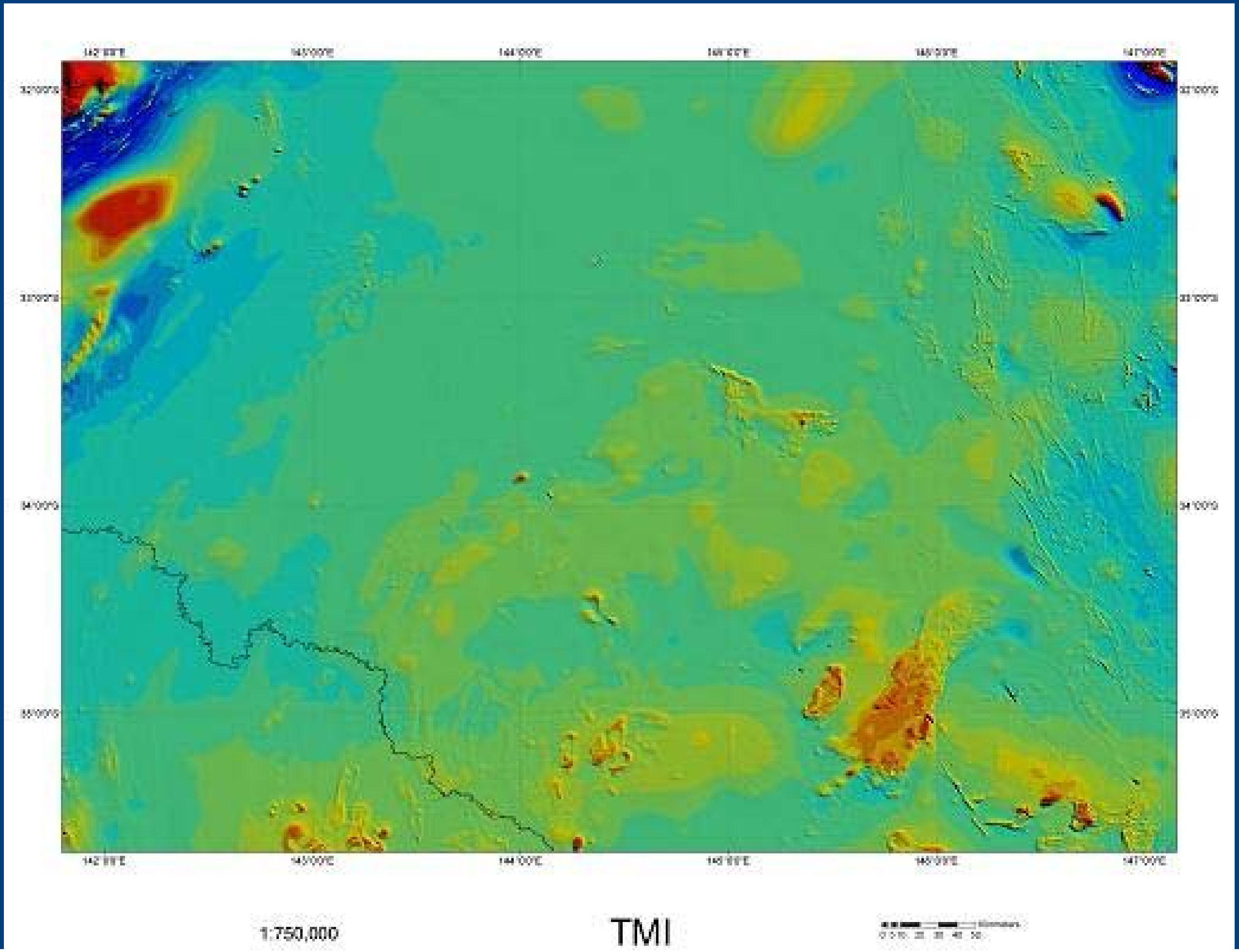
Tilt filter

- Positive over body, zero near edges
- Still traces bodies, like 1VD – so looks "map-like"
- But normalisation acts as gain control
- So does not suppress deeper sources as much as 1VD does
- Large dynamic range for amplitude
- Good compromise for mapping structure below variable cover depth, and for integrating structural elements at different depths

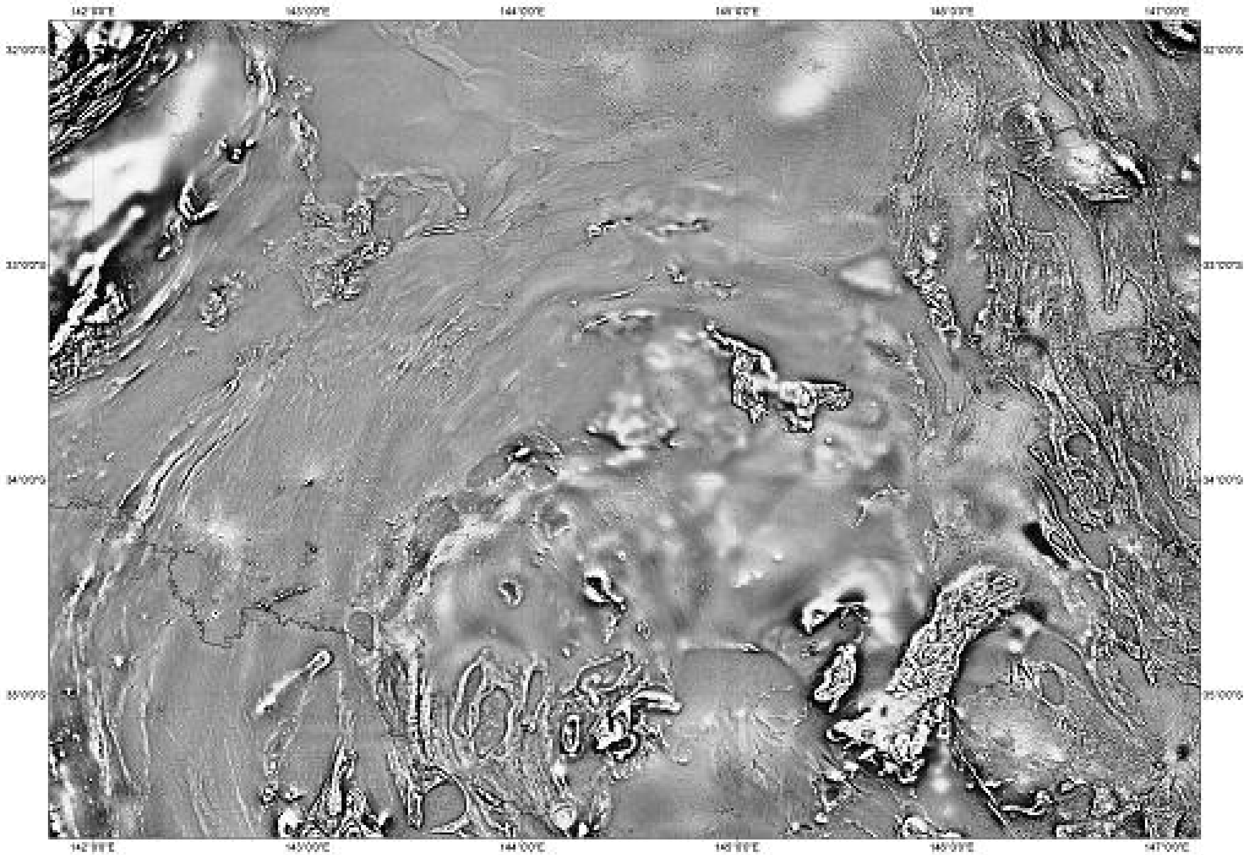
$$T = \tan^{-1}\left(\frac{\partial f / \partial z}{\sqrt{((\partial f / \partial x)^2 + (\partial f / \partial y)^2)}}\right)$$



Hay-Booligal and Stawell Zones



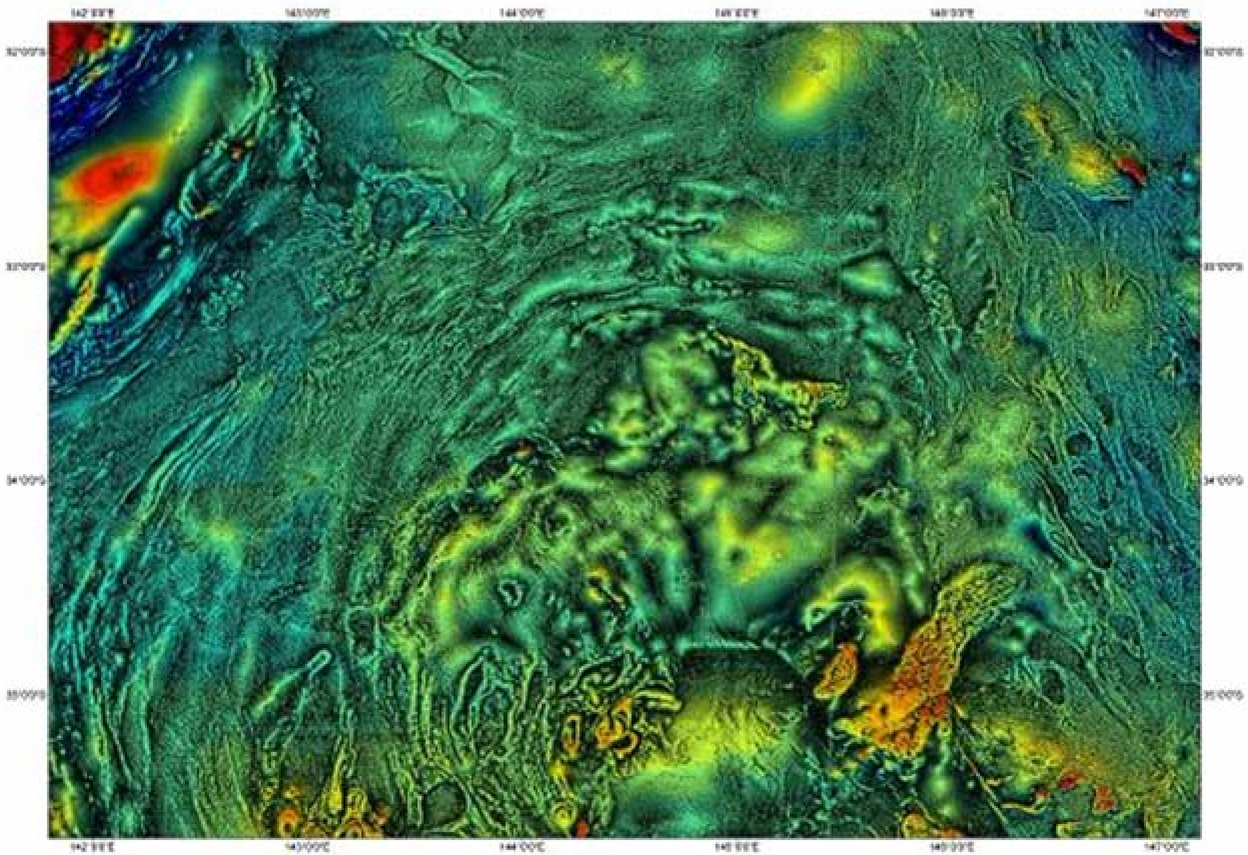
Hay-Booligal and Stawell Zones



1:750,000

1VD of TMI

Hay-Booligal and Stawell Zones



1:750,000

TMI over Tilt filter

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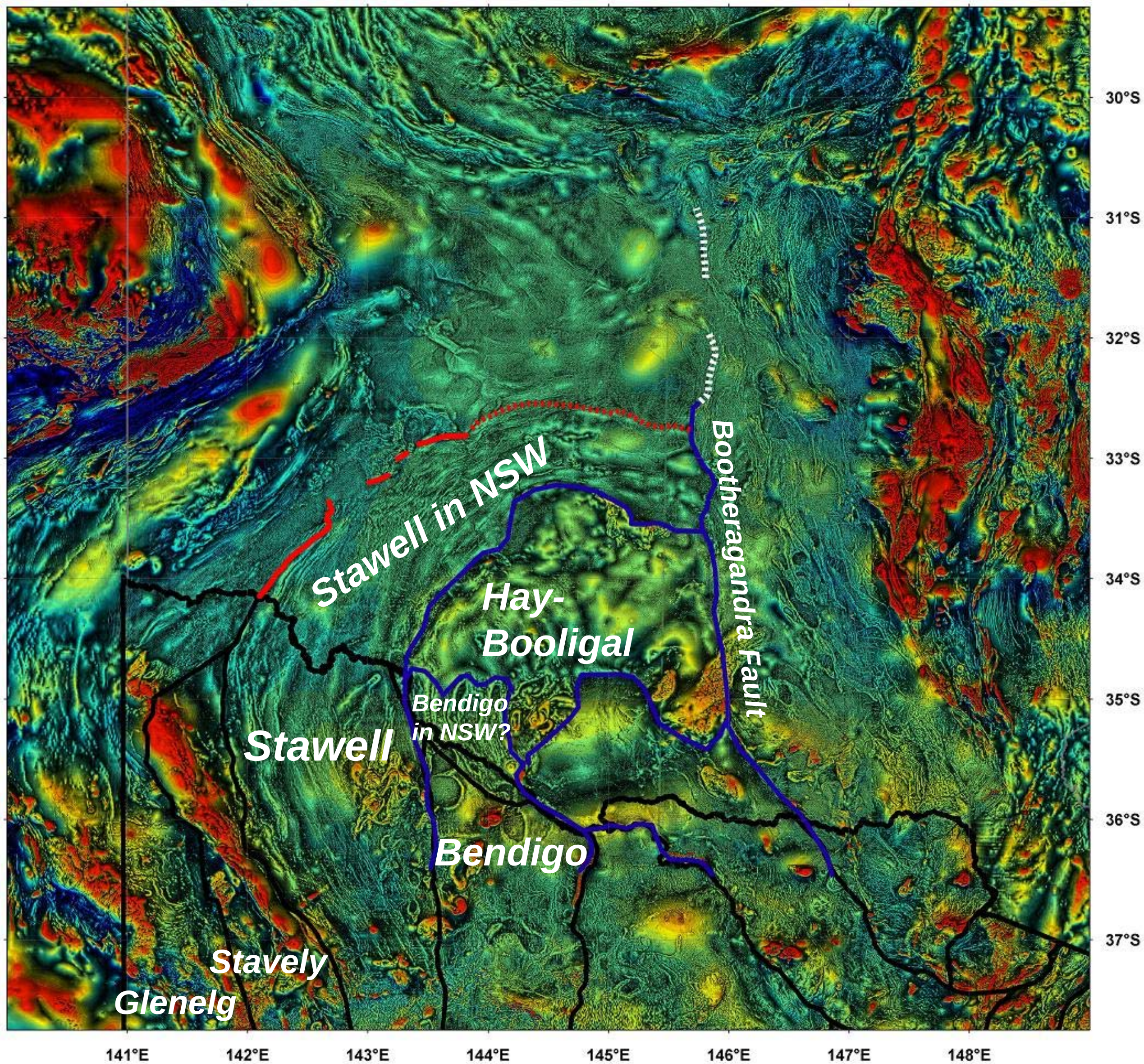
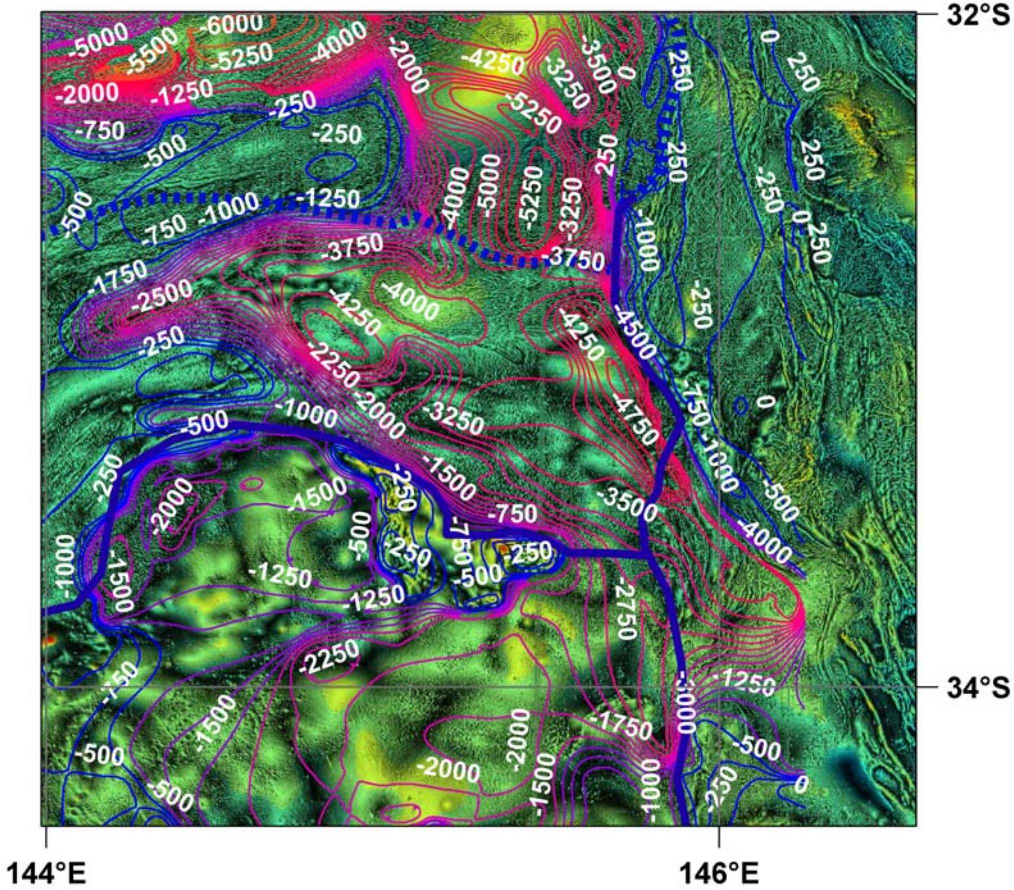
Geological terranes – tilt filter



Tilt filter TMI – depth of response



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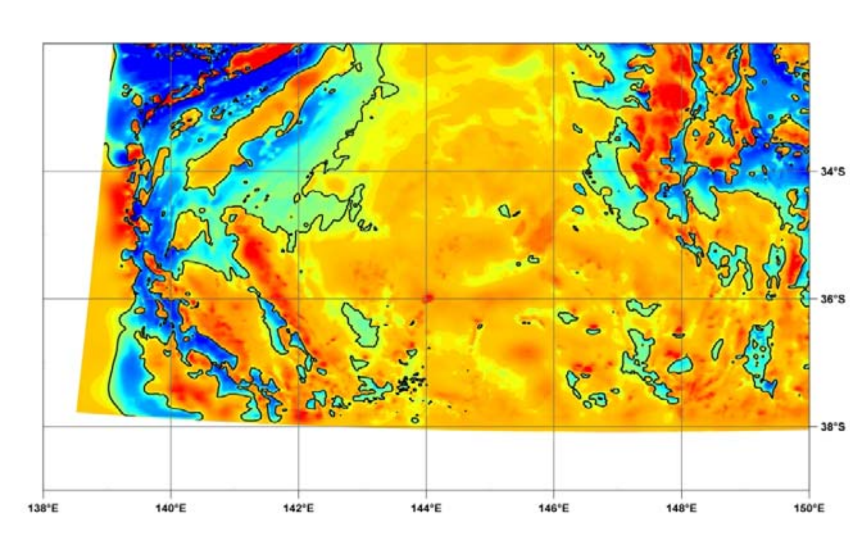
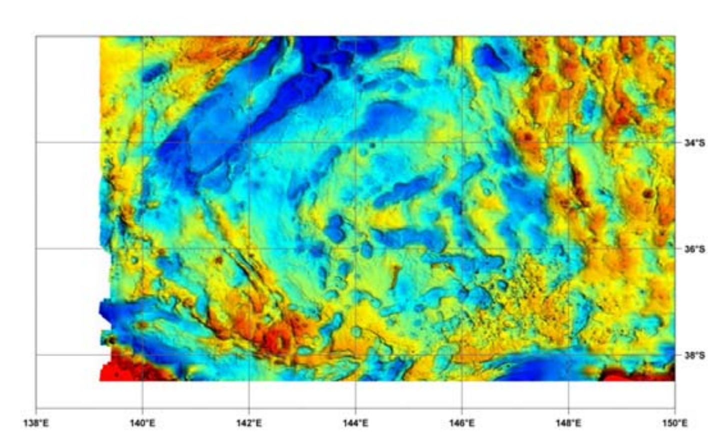
Low pass filter of TMI

- Imaging deeper structure is more problematic
- Layer filters
  - Attenuation of wavenumbers for sources above or below depth range of interest
- Gridding of TMI involves subtraction of IGRF/AGRF
  - So removes sub-crustal contribution
- So layer filter for middle/lower crust reduced to low-pass filter
- We use 20 km

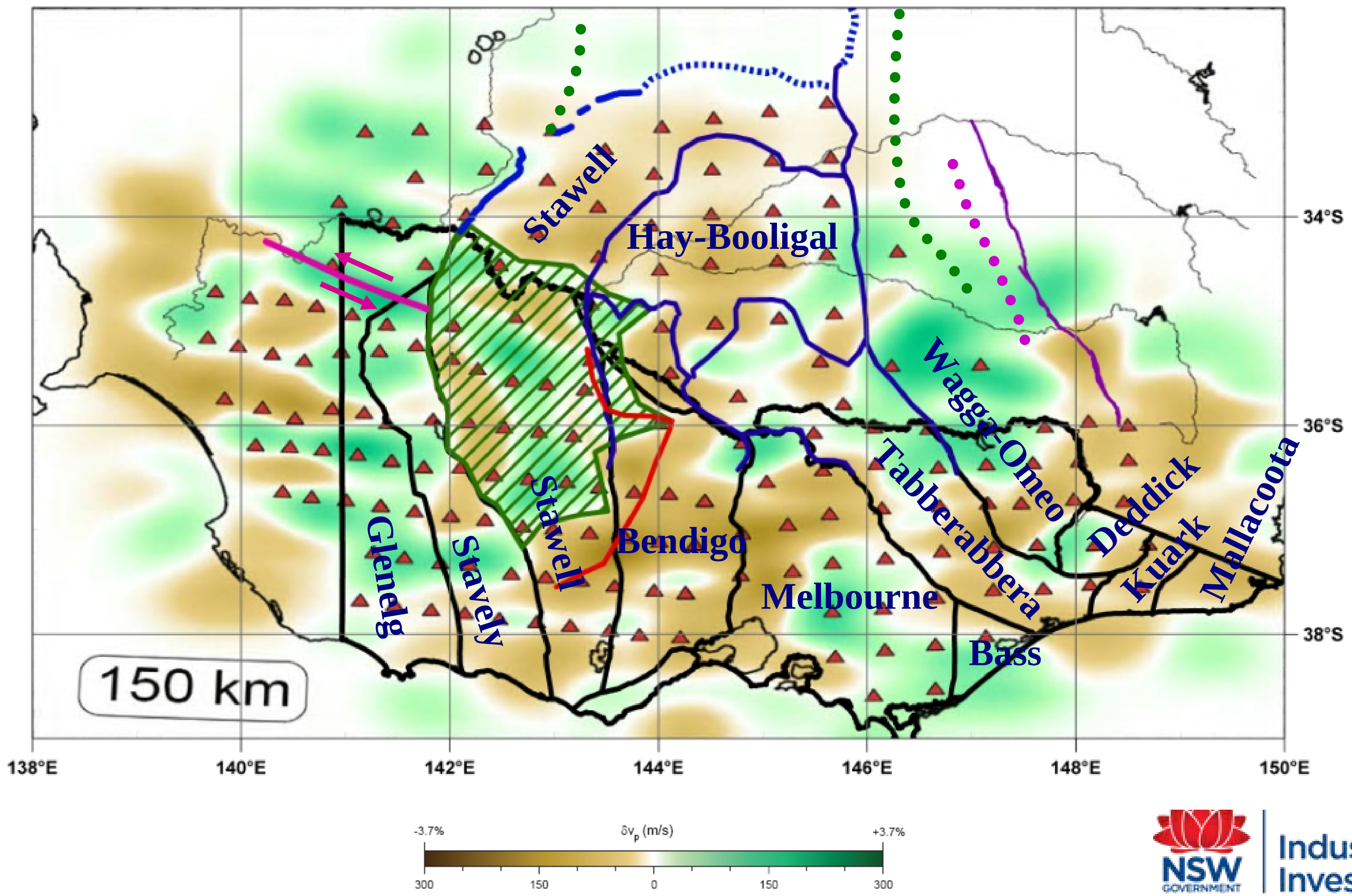


Low pass filter of gravity

- Isostatically reduced Bouguer gravity, with ellipsoidal datum, removes much for the long wavelength, upper mantle contribution.
- So again, effectively a layer filter for middle to lower crust.
- *BUT* shallow granites may obscure deep signal in gravity.



Journey through the lithosphere



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