Kalkarindji through the geophysical lens

Structural characteristics of the Kalkarindji basalt from non-seismic geophysical data

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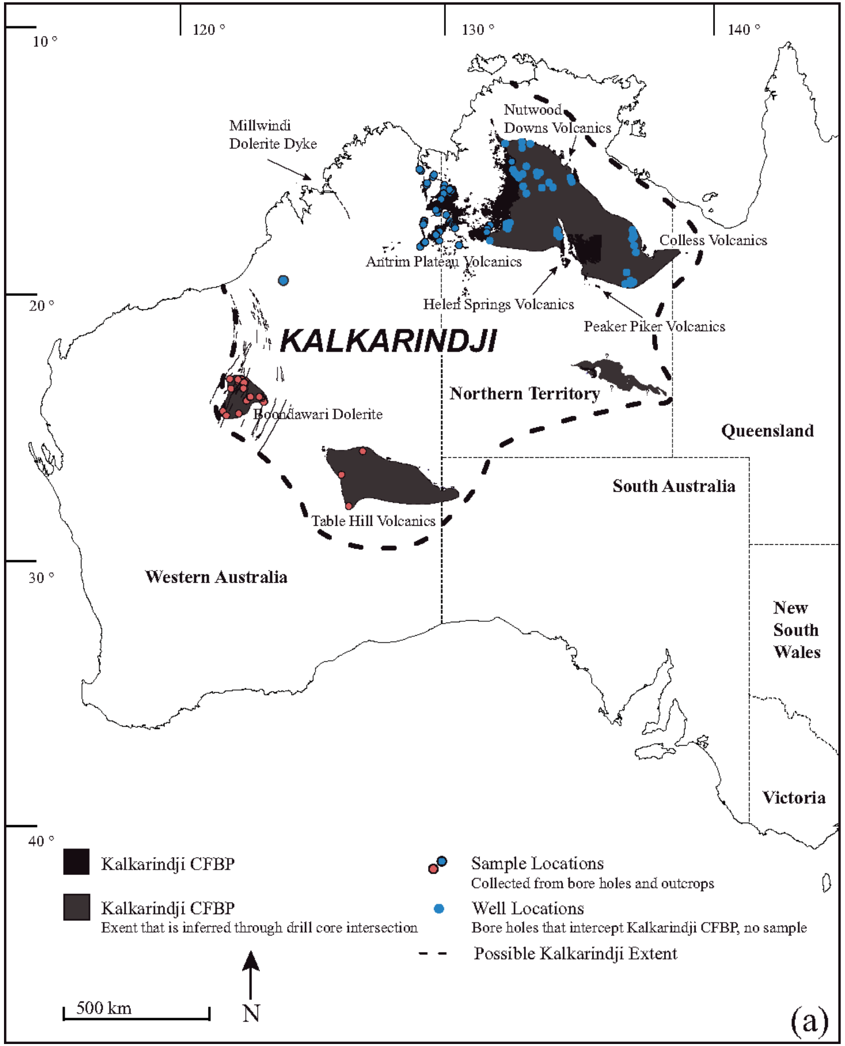
Australia's National Science Agency

Acknowledgment

Collaboration with **Ernest Swierczek** (formerly CSIRO, now BHP) and **Clive Foss** (CSIRO) with scientific contributions from **Claudio Delle Piane** (CSIRO) and **Mohinudeen Faiz** (CSIRO)

Talk outline

- Data, processing and interpretation:
  - Tempest – GALEI inversion
  - Bell Geospace FTG – curvature analysis
  - Aeromagnetic – edge enhancement, 3D modelling
- Spatial propagation, thickness of the KV, thickness of the overlaying sediments
- Modelling of low magnetisation zones in the KV



c.511 Ma Early – Middle Cambrian

Fig. 1. (a) Sketch map showing the distribution and constituent suites of the Kalkarindji continental flood basalt province

Bryant D Ware, Fred Jourdan, Renaud Merle, Massimo Chiaradia, Kyle Hodges, The Kalkarindji Large Igneous Province, Australia: Petrogenesis of the Oldest and Most Compositionally Homogenous Province of the Phanerozoic, *Journal of Petrology*, Volume 59, Issue 4, April 2018, Pages 635–665, https://doi.org/10.1093/petrology/egy040

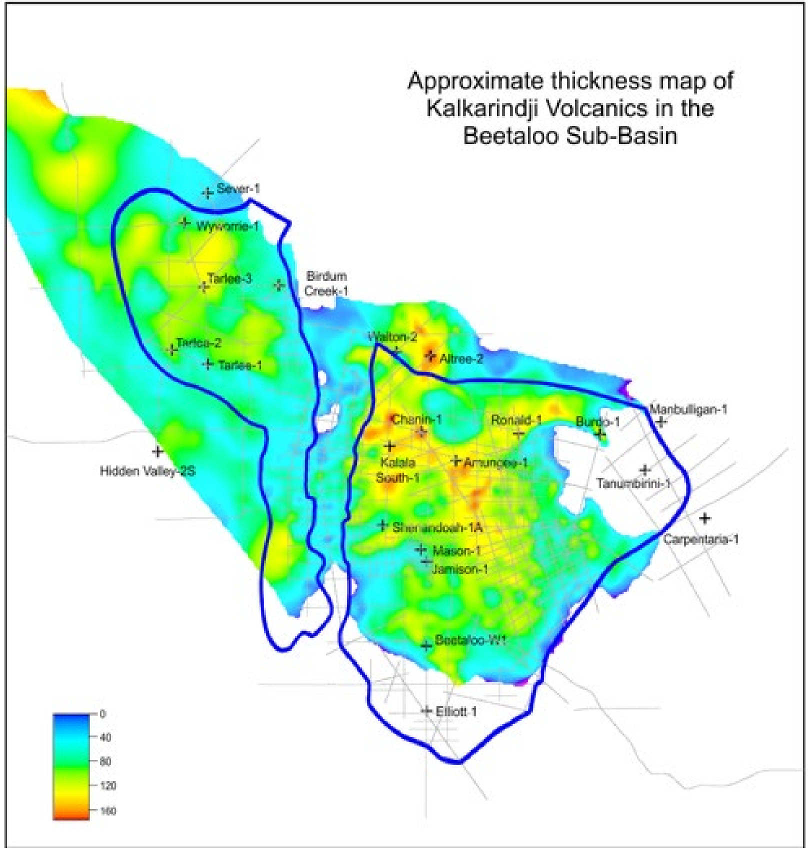
Available data and resolution limitations

Available data	Line spacing (m)	Sensor height (m)	Line direction
Aeromagnetic	400*	80-100 m	Various*
Ground gravity	N/A	Ground level	N/A
FTG	500 - 2000	80 (draped survey)	EW
Tempest	20000	120	NS (in NT)

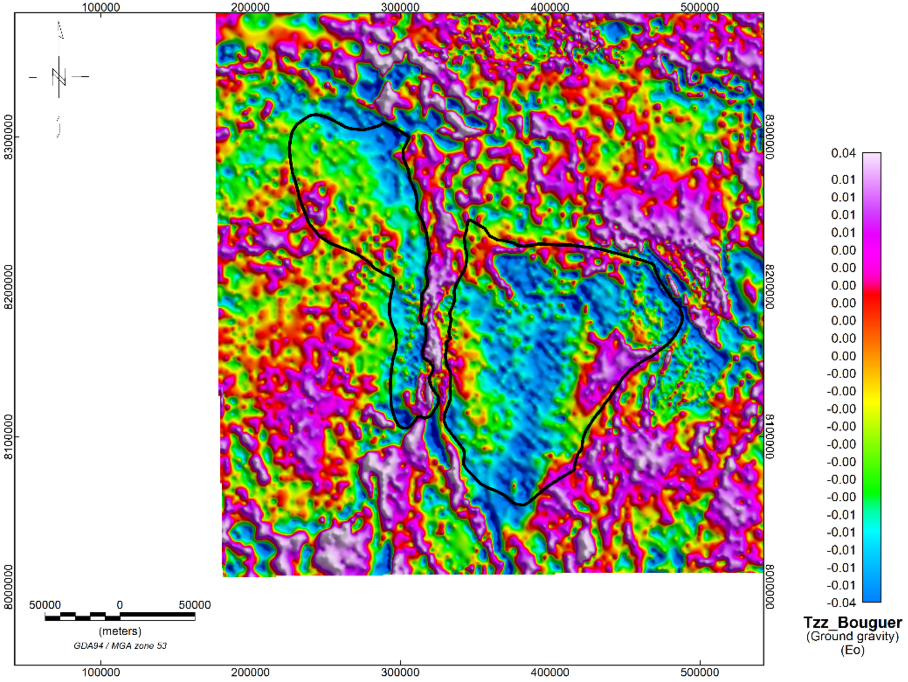
Available data	Resolution along the lines	Resolution across the lines (grid)	Depth limit
Aeromagnetic	~20 m	400 m	Geology dependent/survey design
Ground gravity	N/A	N/A	Geology dependent/survey design
FTG	~20 m	1000 - 4000 m	Geology dependent/survey design
Tempest	~20 m	40 000*	~ few hundreds of meters

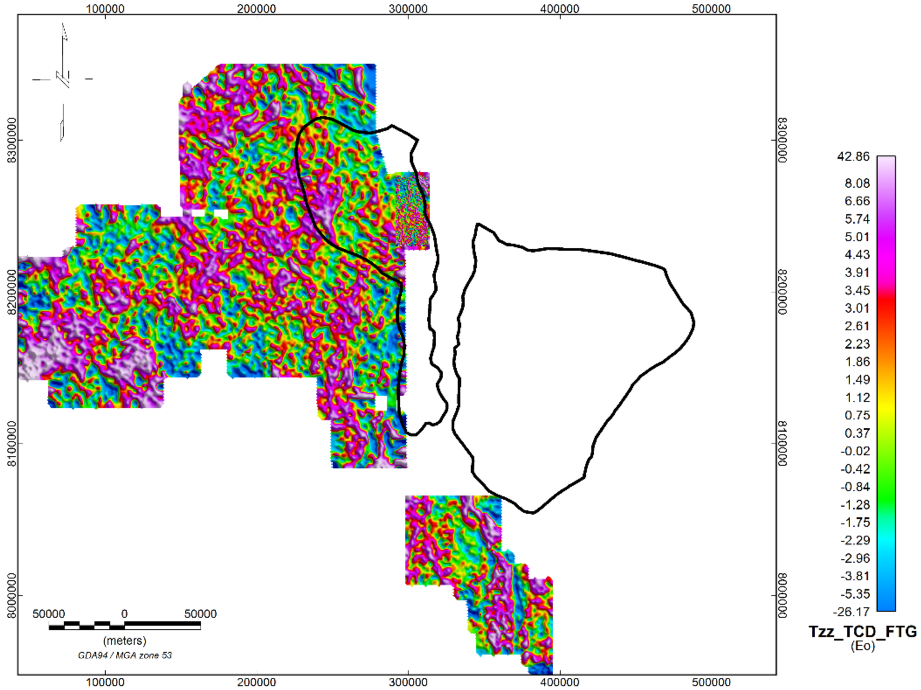
2D Seismic lines* (> 9000 km), ~ 25 wells with geophysical logs

Basalts of the Kalkarindji Suite

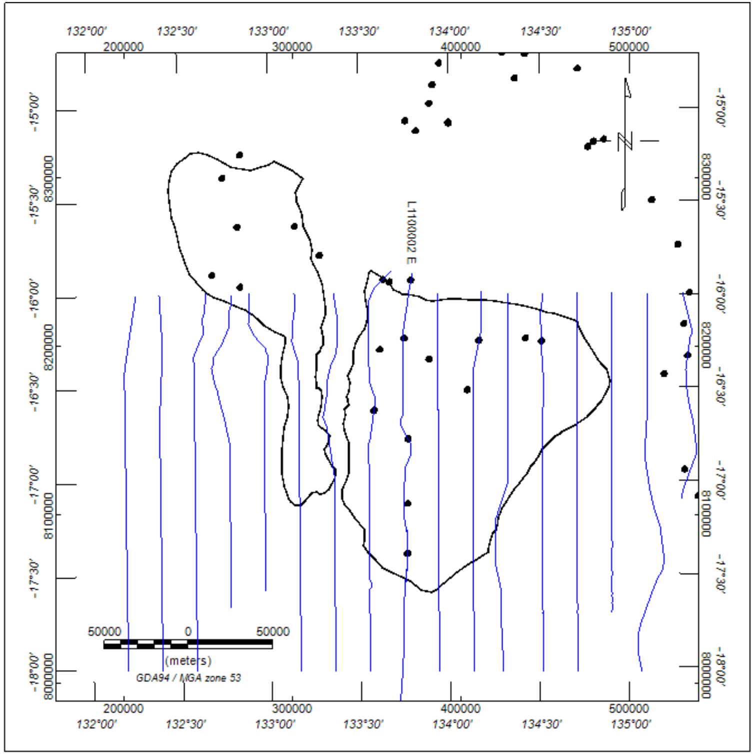


Ground gravity and full tensor gravity (FTG) gradiometry data

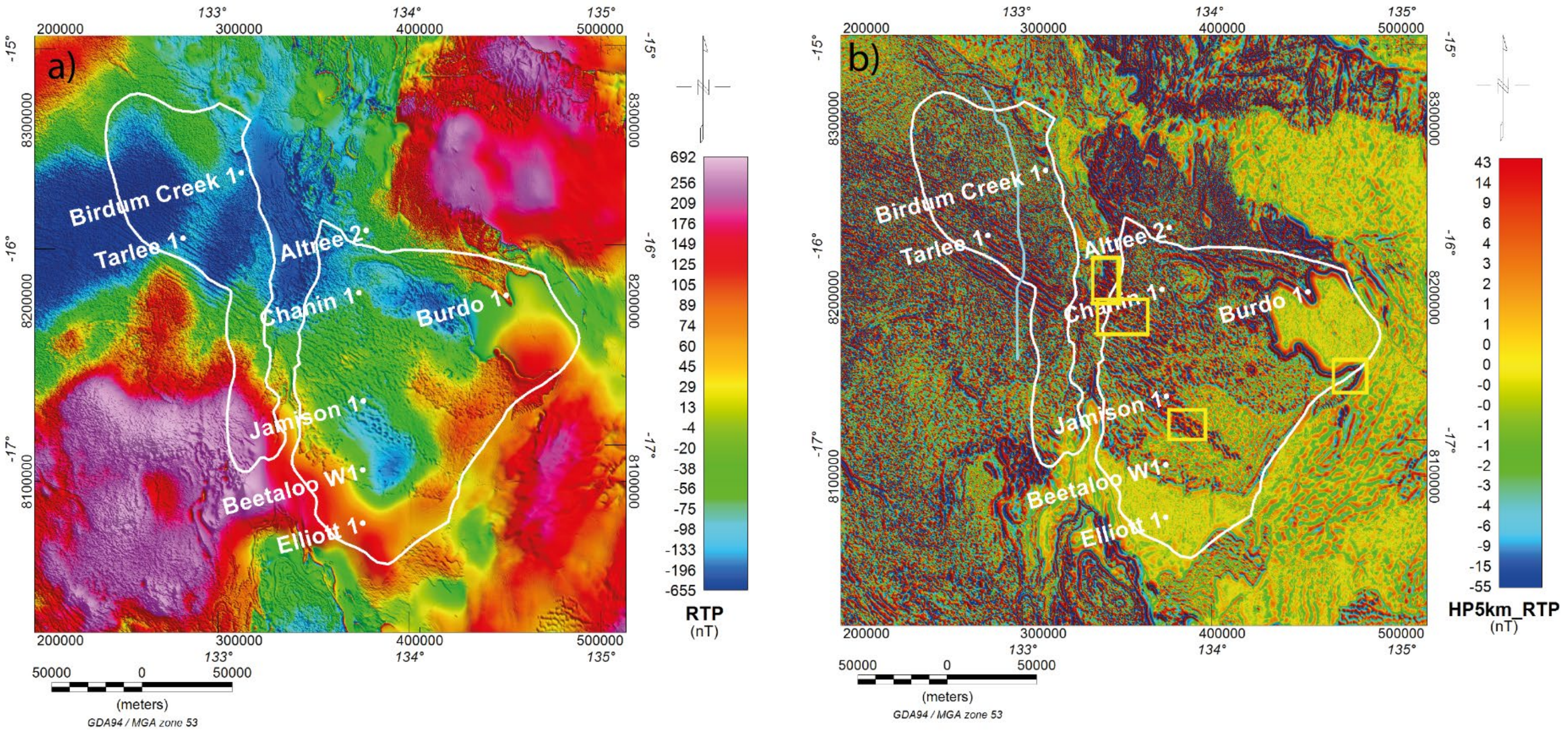




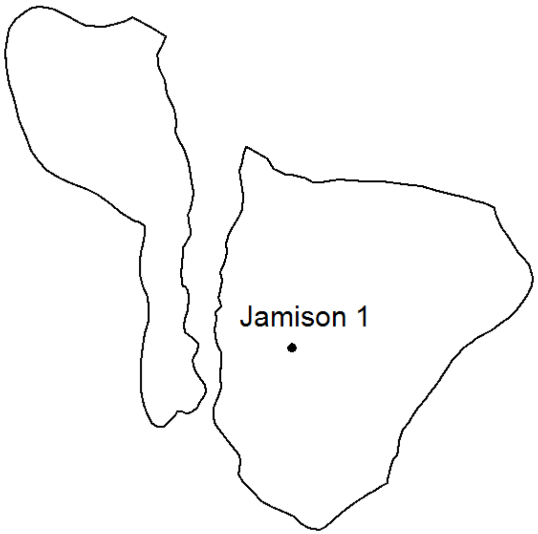
Tempest data – availability

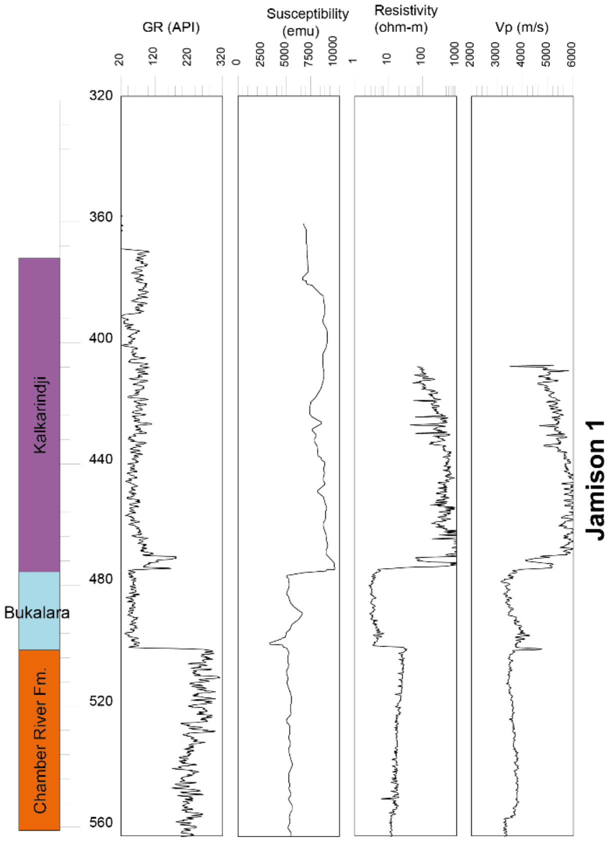


Aeromagnetic data availability

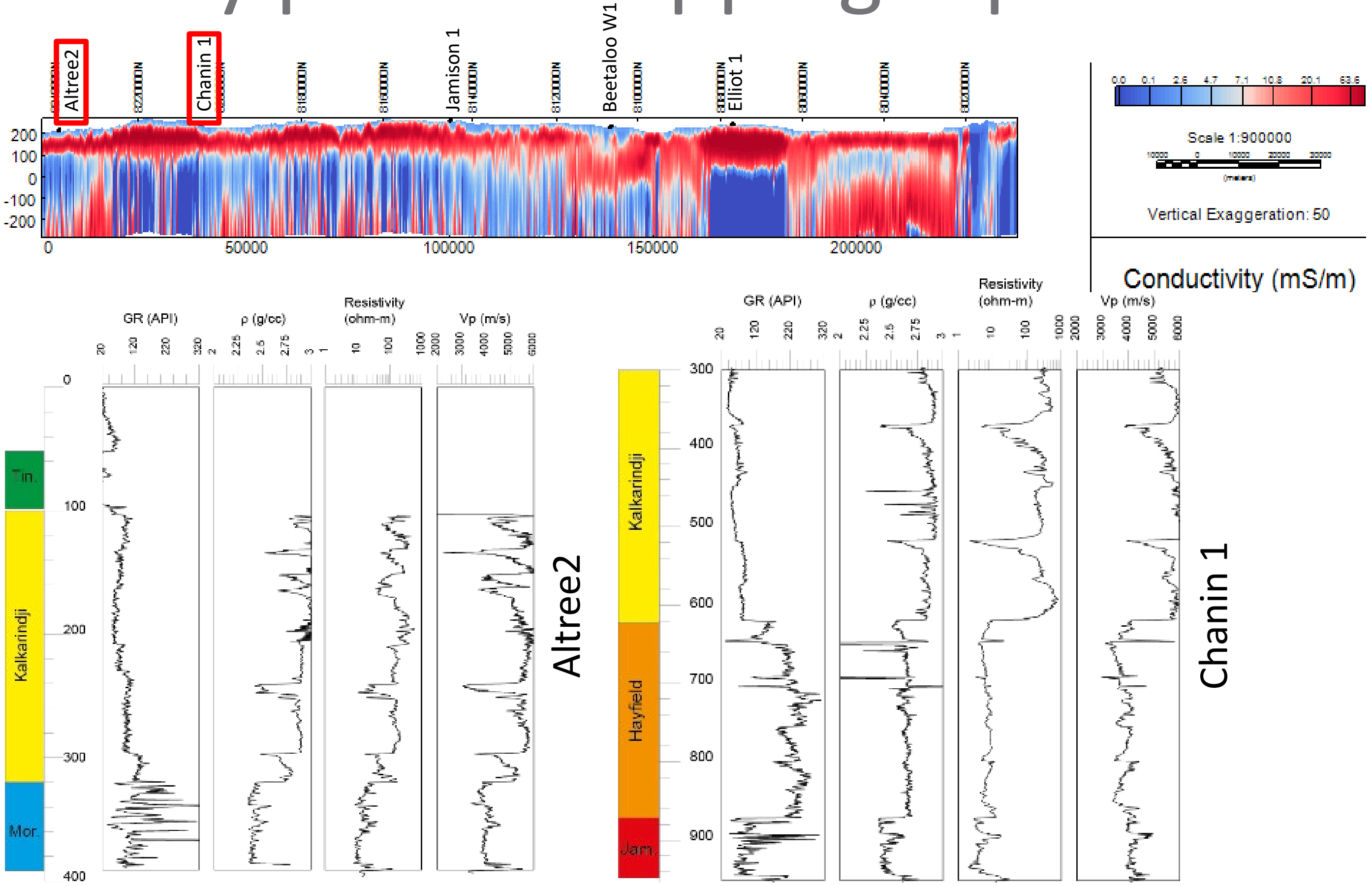


Enhancement of aeromagnetic data





Conductivity profile mapping top of the KV



Curvature Analysis

- Synthetic model – 1km cube, +1 g/cc (left) and -1 g/cc contrast compared to 2.67 g/cc background. Cubes are separated by 1 km and depth to top is 100 m

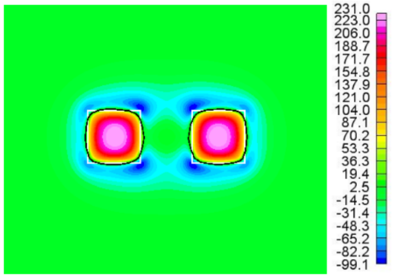


Figure 5. Gaussian curvature and its zero contour (black) over the synthetic model cubes shown by the white outlines (denser body on left). Values range from -9.9×10^{-9} m^{-2} (blue) to 23.2×10^{-9} m^{-2} (pink).

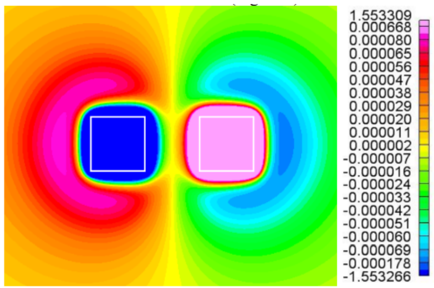


Figure 2. . Mean curvature over the synthetic model cubes shown by the white outlines (denser body on left). Values range from -1.6×10^{-7} m^{-1} (blue) to 1.6×10^{-7} m^{-1} (pink).

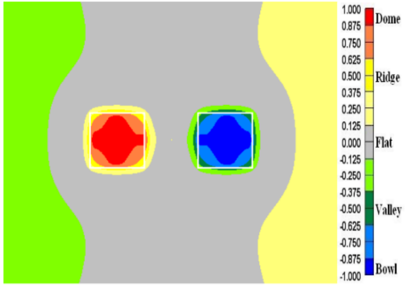


Figure 6. AGG Geometry Map over the synthetic model cubes shown by the white outlines (denser body on left). Values range from −1.0 (blue) to 1.0 (red).

$$K_g = \frac{T_{xx}T_{yy} - T_{xy}^2}{g^2}$$

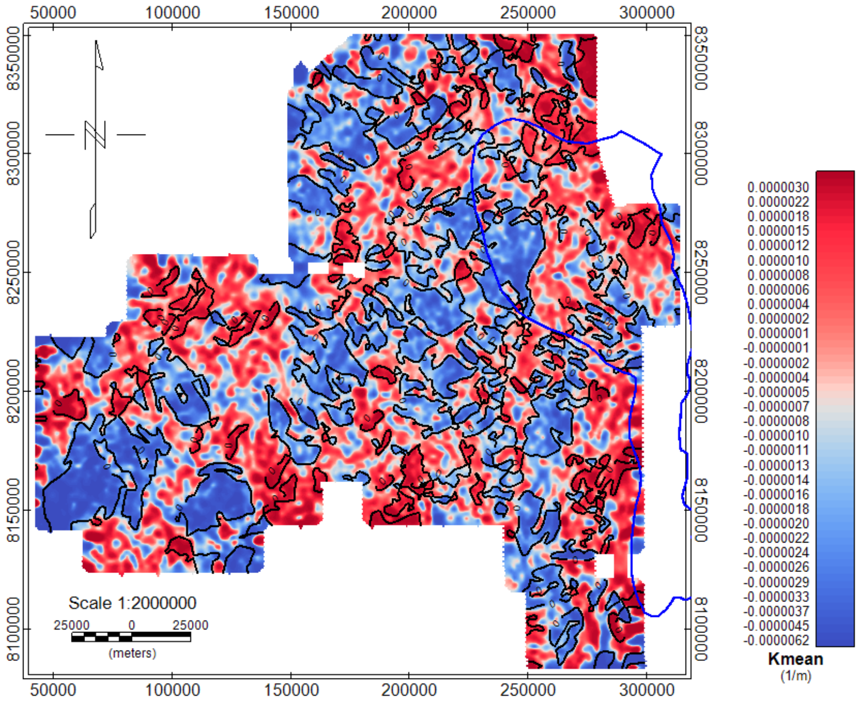
$$K_m = -\frac{T_{xx} + T_{yy}}{2g} = -\frac{T_{zz}}{2g}$$

$$SI = \frac{2}{\pi} tan^{-1} \frac{-T_{xx} - T_{yy}}{2\sqrt{T_{xy}^2 + T_{uv}^2}}$$

Figures from Cevallos Carlos , Kovac Peter, Lowe Sharon (2013) Application of curvatures and Poisson's relation to airborne gravity gradient data in oil exploration. *ASEG Extended Abstracts* **2013**, 1-4.

Formulas from Li Xiong (2015) Curvature of geometric surface and curvature of gravity and magnetic anomalies. Geophysics, vol.80, no.1, G15-G26.

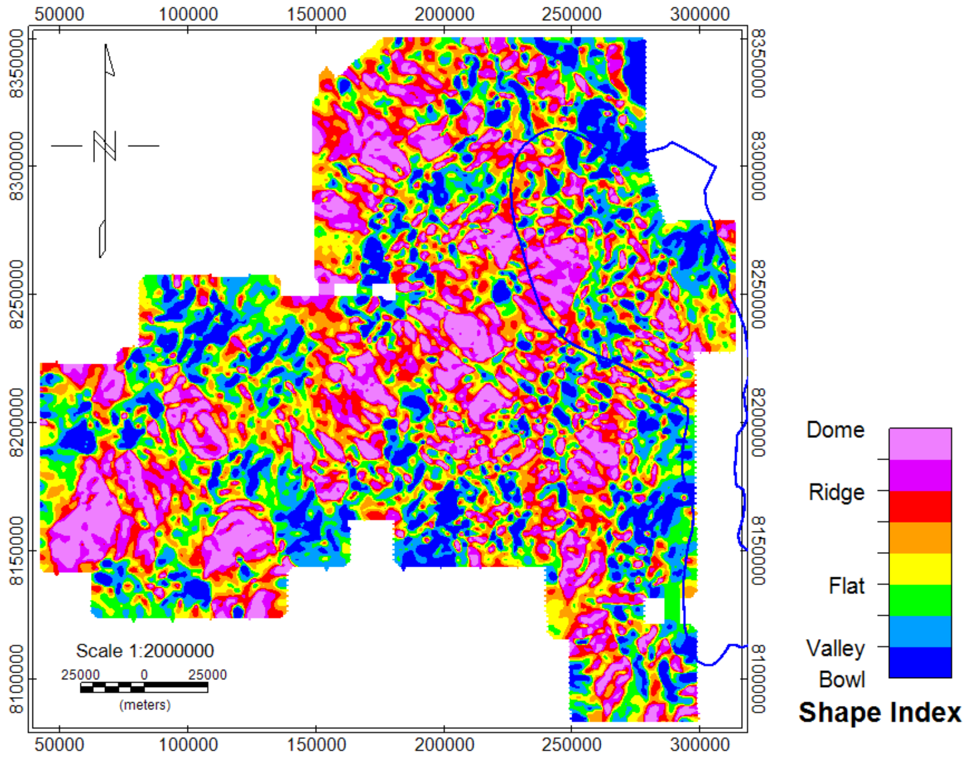
FTG Data – Mean and Gaussian Curvatures



Km – location of mass distribution, negative *Km* positive density contrast

Kg – zero contour of the Gaussian curvature lithological boundaries

FTG Data – Shape Index Analysis



Magnetic Anomalies over Holes in a Volcanic Sheet

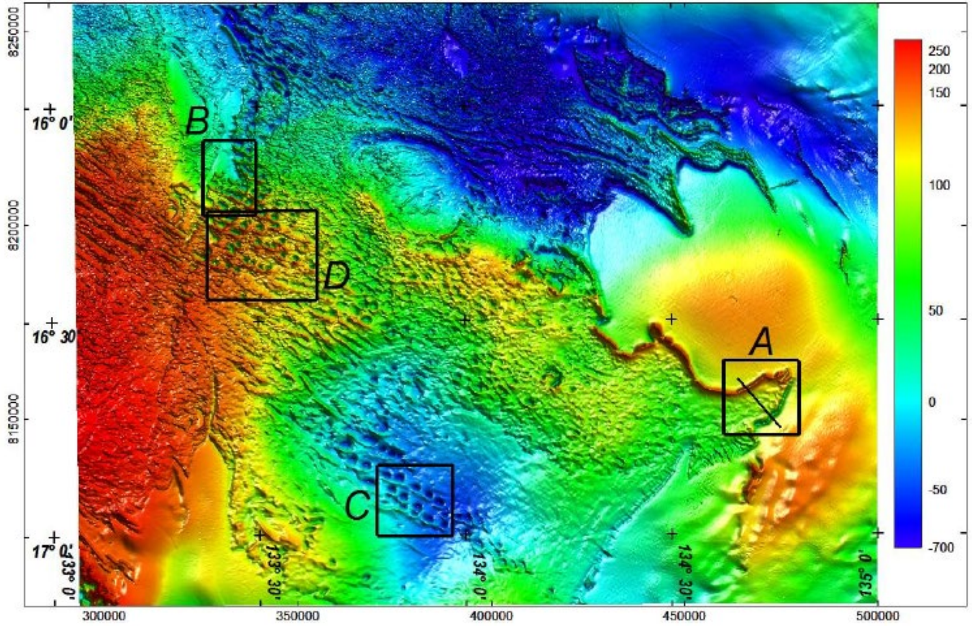


Figure 1 Total magnetic intensity (TMI) image over an interpreted shallow volcanic sheet in the Beetaloo Sub-basin.

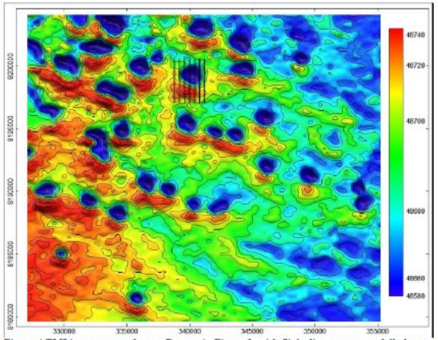


Figure 4 TMI image over sub-area D sown in Figure 1, with flight-lines over a modelled anomaly

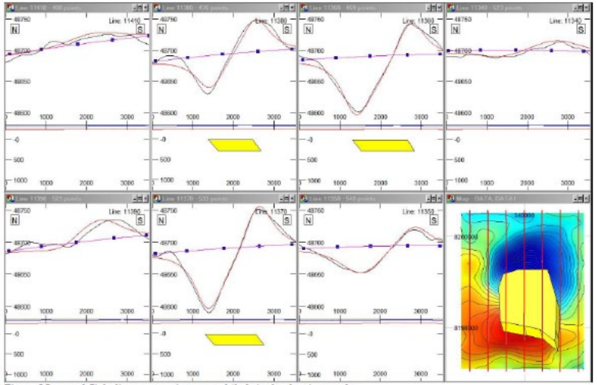
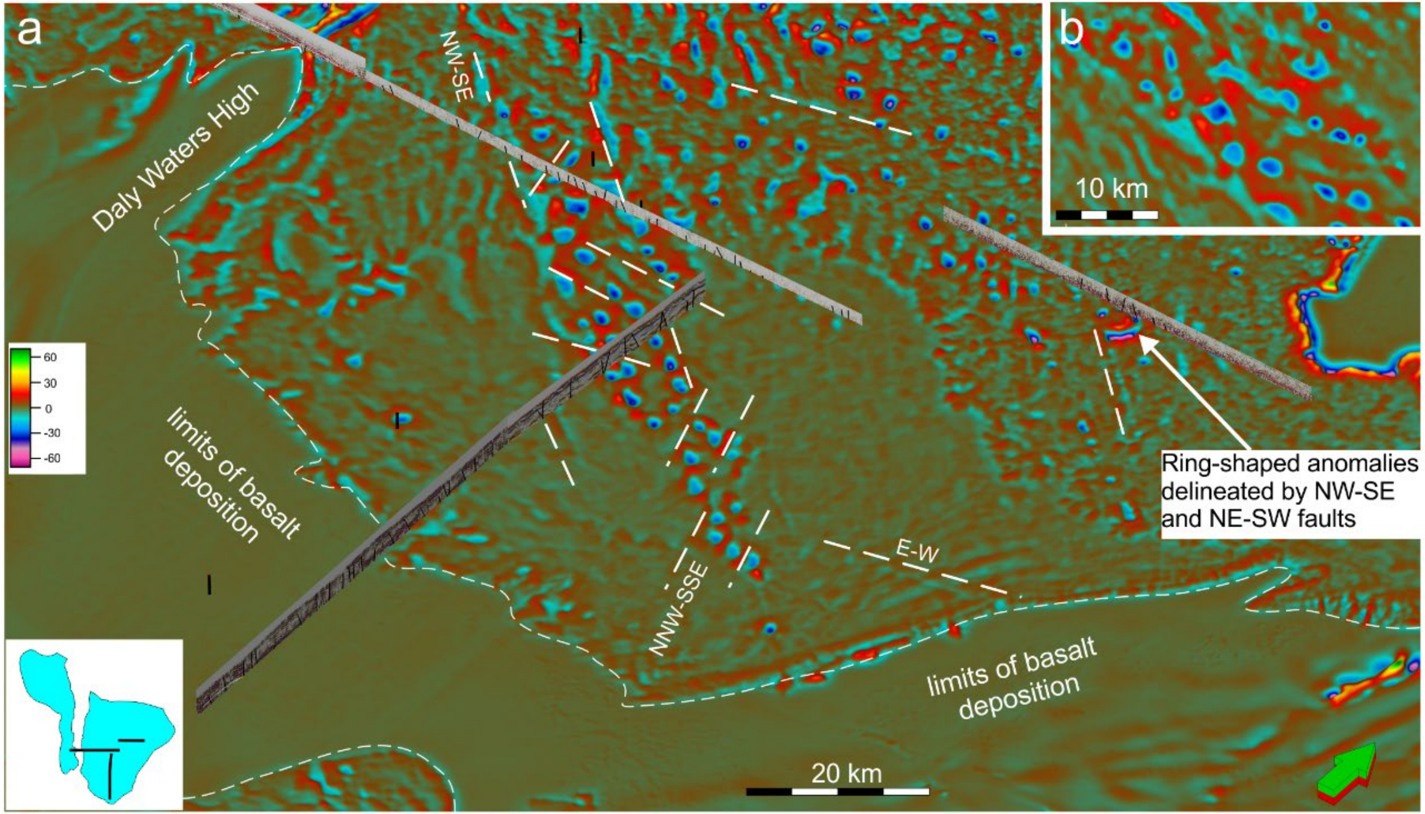


Figure 5 Inverted flight lines over an interpreted 'hole in the sheet' anomaly

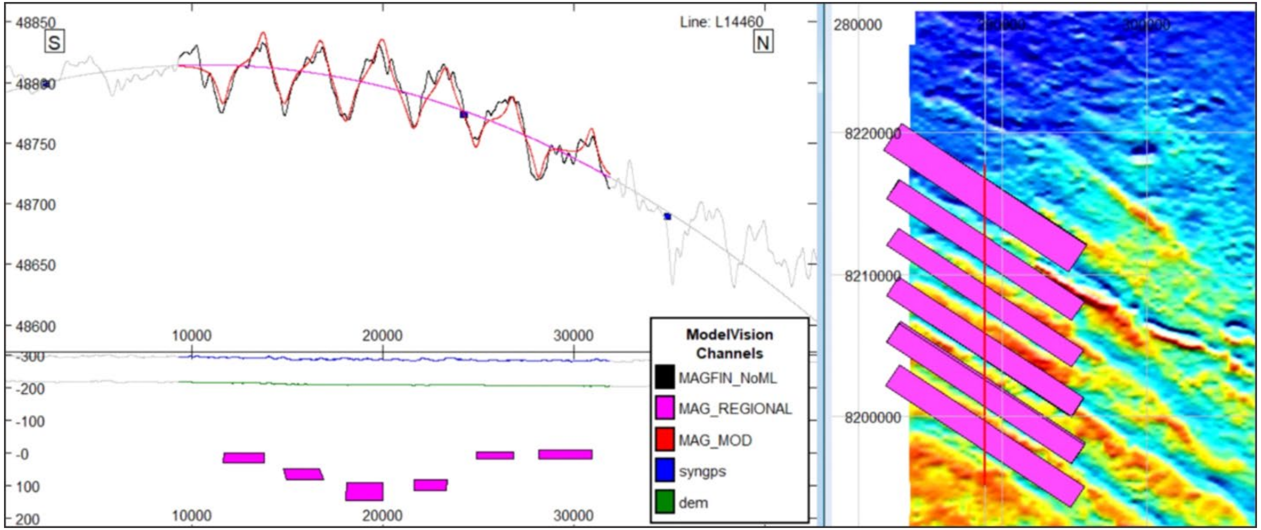
"…the holes may be due to local destruction of the sheet at fracture intersections, which have acted as conduits for fluid flow." (Foss and Dhu, 2016)

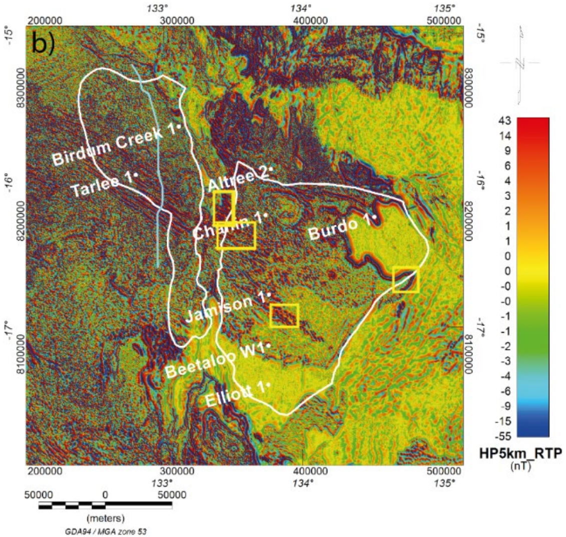
Clive Foss & Tania Dhu (2016) The Bark without a Dog - Magnetic Anomalies over Holes in a Volcanic Sheet in the greater McArthur Basin, NT, ASEG Extended Abstracts, 2016:1, 1-5, DOI:10.1071/ASEG2016ab276

Integrated Interpretation



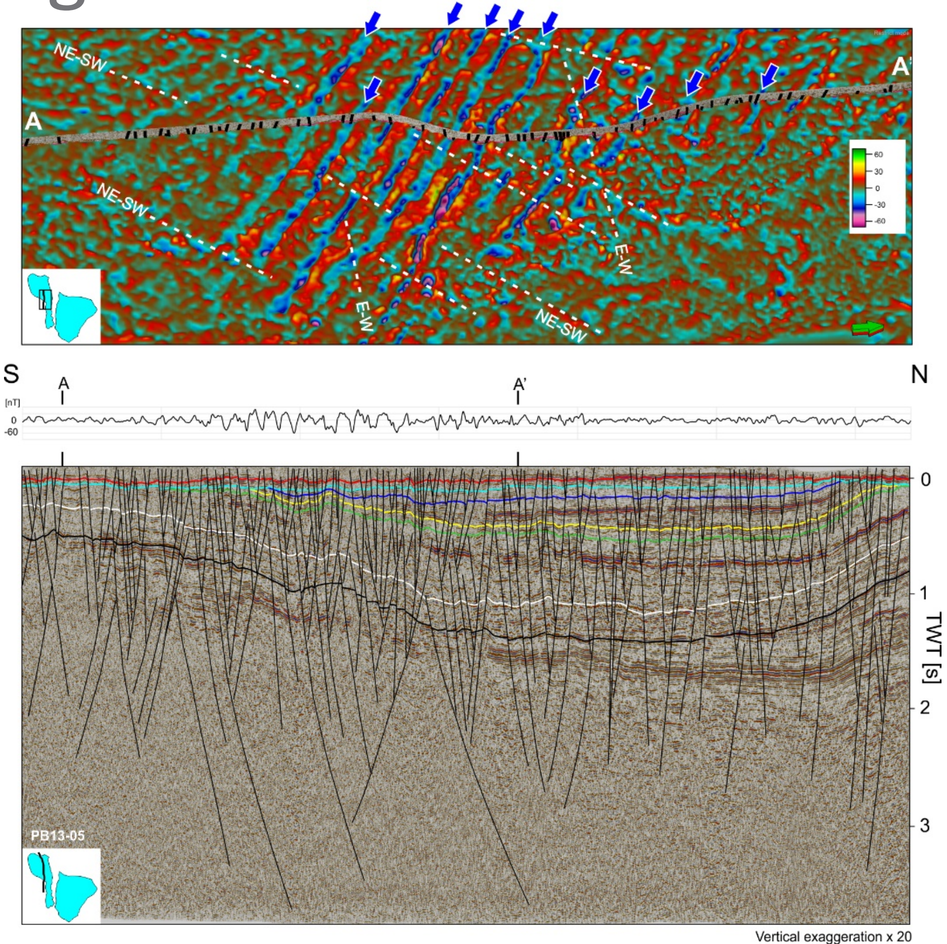
Low magnetisation zones in the western Beetaloo

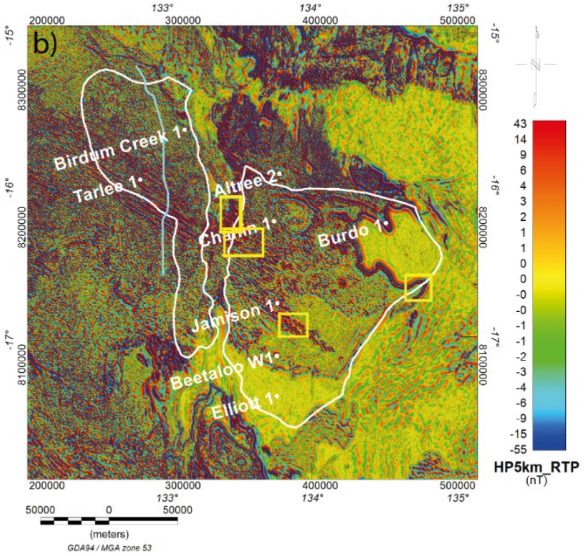




Susceptibility = 0.05 SI
Depth to top ~ 200 m to 300 m
Thickness ~ 50 - 75 m

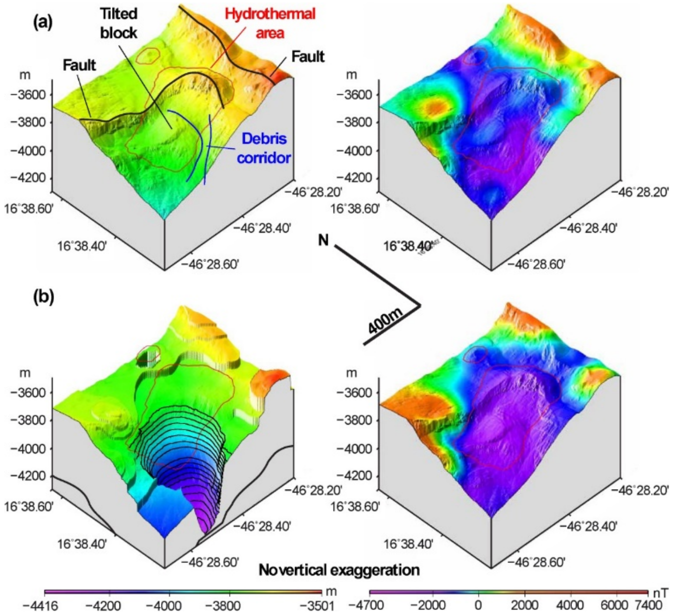
Low magnetisation zones correlation with faults





Low magnetisation zones in oceanic basalts

- Hydrothermal fluid circulation?
- Szitkar, F., Dyment, J., Choi, Y., and Fouquet, Y. (2014), What causes low magnetization at basalt-hosted hydrothermal sites? Insights from inactive site Krasnov (MAR 16°38'N), *Geochem. Geophys. Geosyst.*, 15, 1441– 1451, doi:10.1002/2014GC005284.



(a, left) Perspective view of the high-resolution multibeam bathymetry and (right) reduced-to-the-pole magnetic anomaly in the Krasnov hydrothermal area. (b) Perspective view of the base of the overlying nonmagnetic layer (left; thick lines on the block sides mark the base of the magnetic layer) and (right) the corresponding magnetic anomaly.

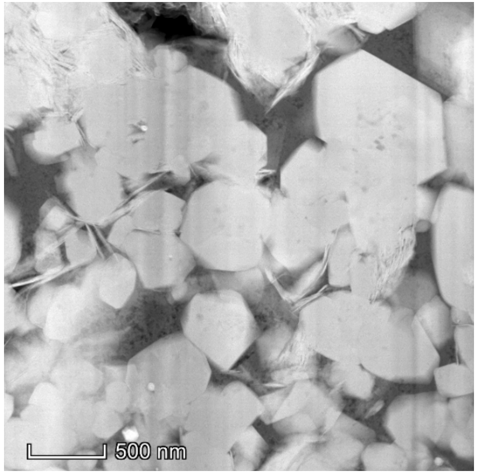
- Doubrovine, P. V., and J. A. Tarduno (2006), Alteration and self-reversal in oceanic basalts, J. Geophys. Res., 111, B12S30, doi:10.1029/2006JB004468.

Conclusion

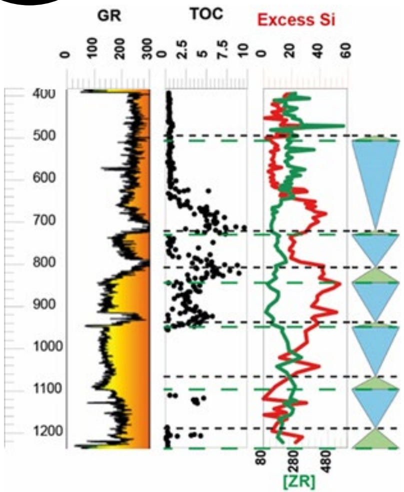
- Aeromagnetic data provides insight into faulting occurring in the KV and maps the edges of the unit
- We highlighted a potential damage zones in the basalt sheet which might be result of faulting or hydrothermal activity(?)
- FTG provided information on the subsurface density variation, most likely under the KV
- Conductivity profiles can provide information on the top of the KV, where the KV is shallower then ~400 m (NW in the Eastern Beetaloo)

A snapshot of our activities

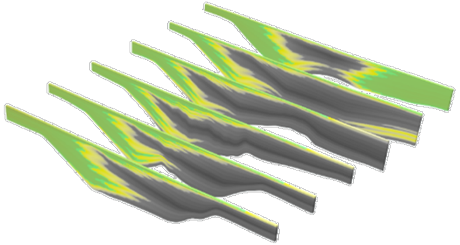
Nano-micro scale imaging and quantitative characterization

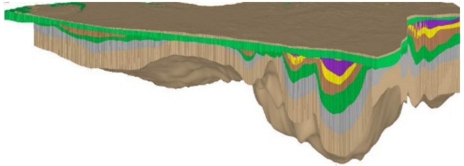


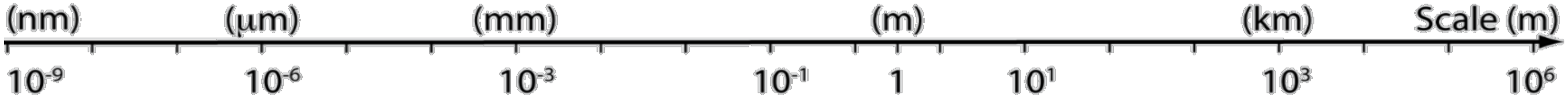
Well scale analytics, rock physics, machine learning



Basin scale analysis and modelling







Linking properties and processes across scales through integration of microstructural/geochemical investigations with geophysical measurements to reveal patterns between depositional, diagenetic, deformational processes and rock properties distribution in sedimentary basins.

CSIRO

Thank you!

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