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# Australia's lithospheric architecture: imaging for under cover mineral discovery

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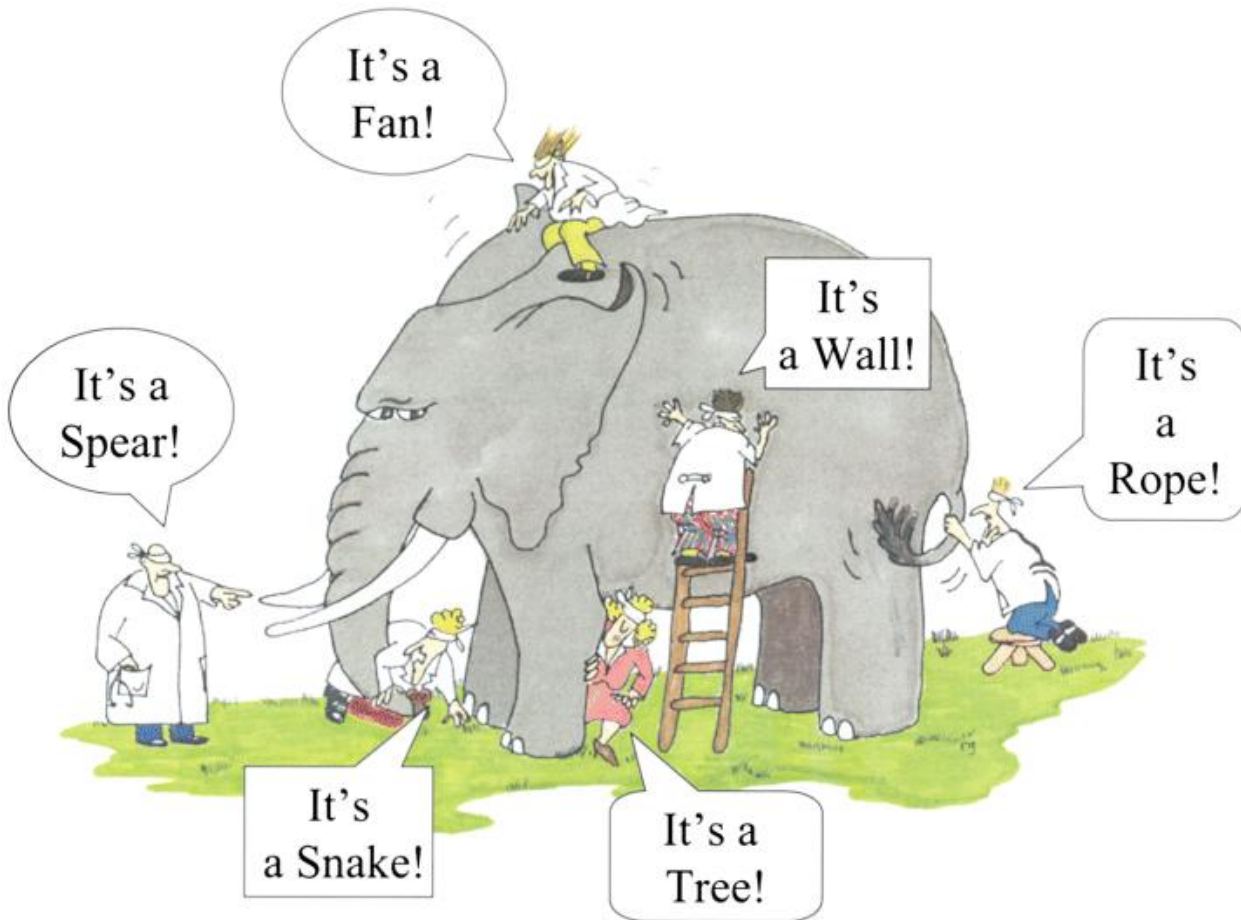
Group Leader: Mineral Systems Group



## Acknowledgements:

Roger Skirrow, Dave Champion, Brian Kennett, Dave Huston, George Gibson, Karol Czarnota, Richard Chopping, Helen Dulfer, Terry Brennan, Russell Korsch, Michael Doublier, Peter Milligan, Patrice de Caritat, Jon Cloaue-Long, John Wilford, Tristan Kemp

# The 6 blind men and the elephant



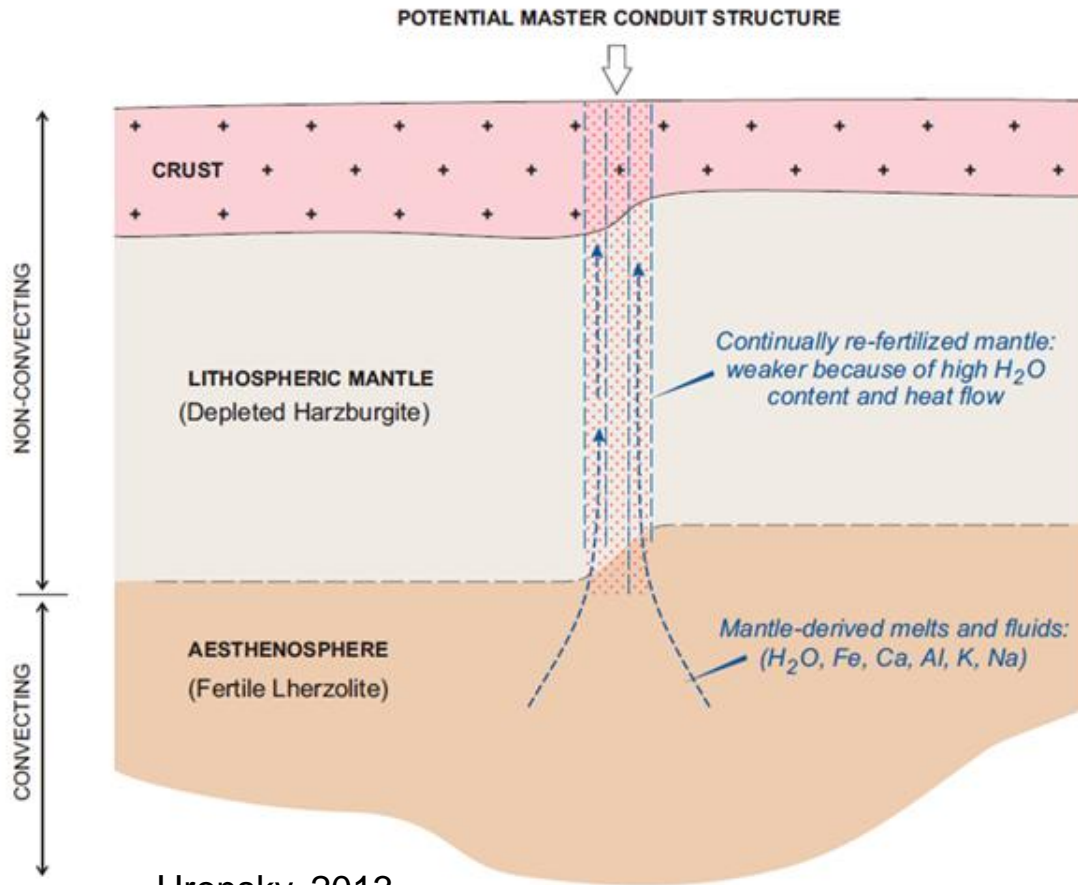
- Multiple views via geophysics (mag, grav, velocity, resistivity), geochem and geology
- Each method, like the 6 blind men, sees the earth differently
- We are imaging one earth
- How to make sense of these different views?
- The key is integration

Poem by John Godfrey Saxe, cartoon by G. Renee Guzlas

# Point of view

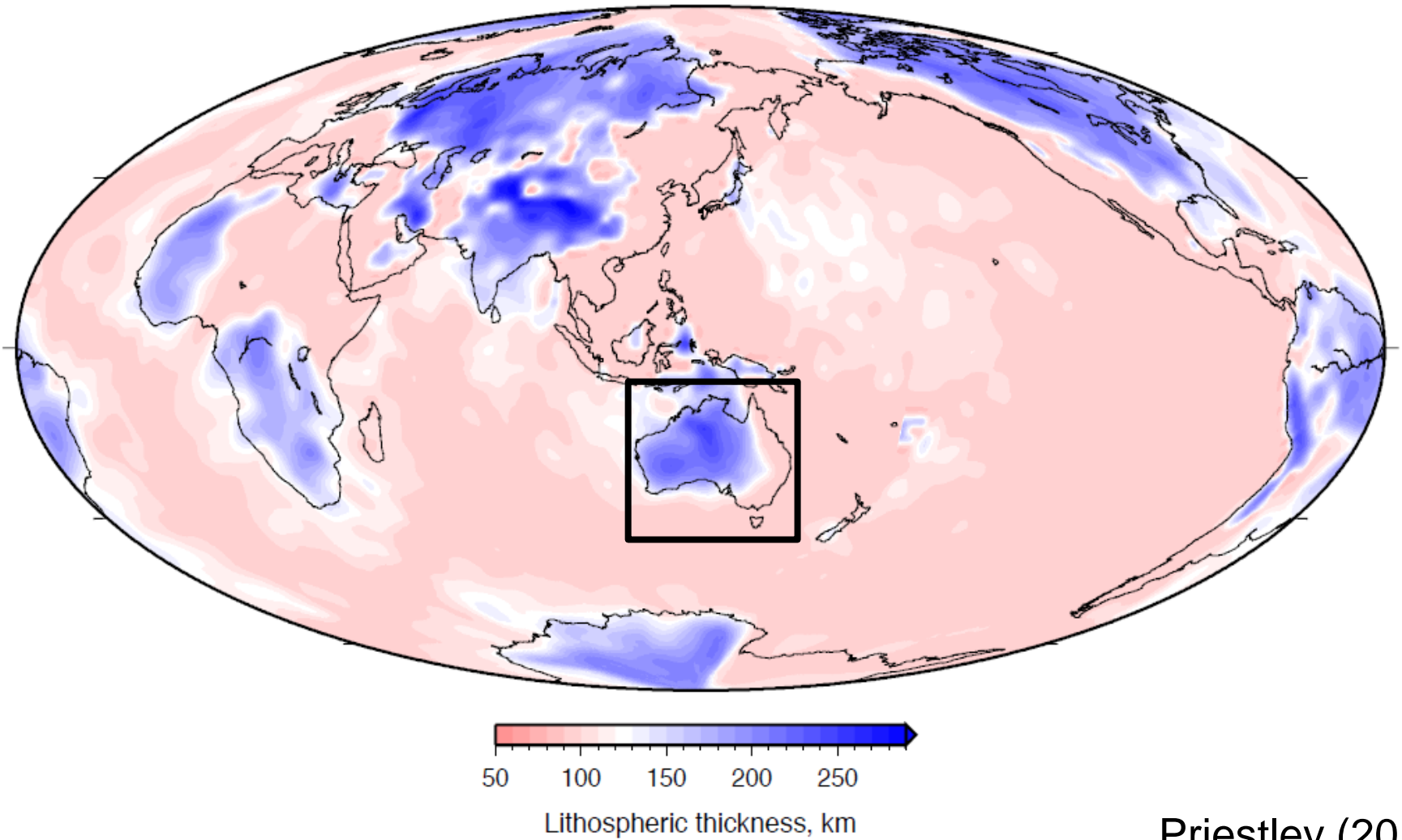
- Architecture (structure) is a key ingredient of mineral systems thinking
- Can map (or infer) architecture from integration of geology, geophysics, geochemistry, geochronology,
- From architecture we can infer something about:
  - Geodynamic processes
  - Source (metals-fluids)
  - Pathways and depositional sites
- Australia enriched in world-class data
- Fantastic opportunity to use mineral system thinking to make informed predictions about under cover resources in Australia

# Why are deep/big structures important?



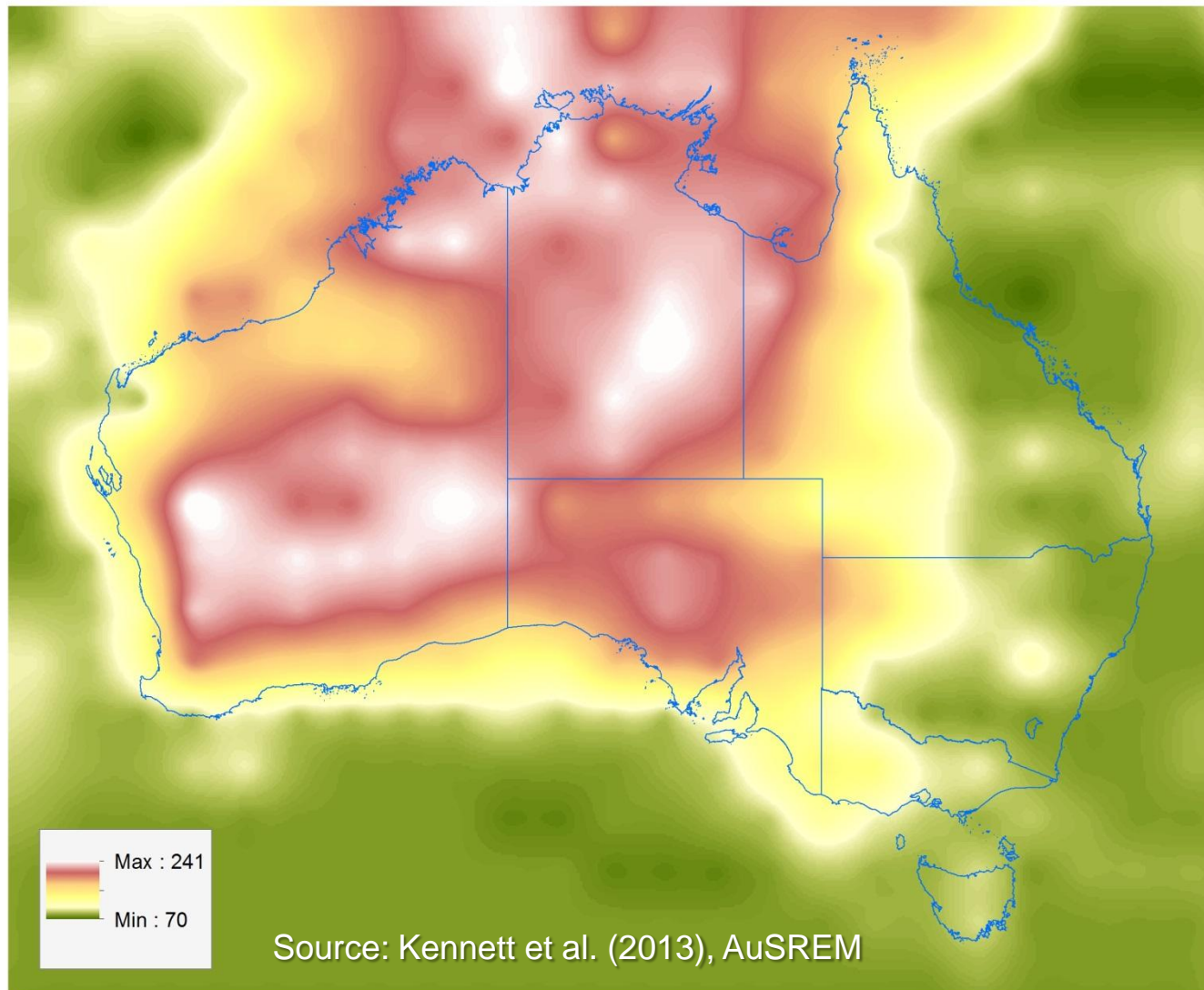
- Pathways for enormous energy and mass fluxes needed to form a giant?
- Proximity to deep structures considered by many as favourable for area selection
- How can we map them?
- What is their preservation potential?
- Nature of connectedness of crust and mantle?
- Does this matter anyway?

# Lithosphere: what is it?



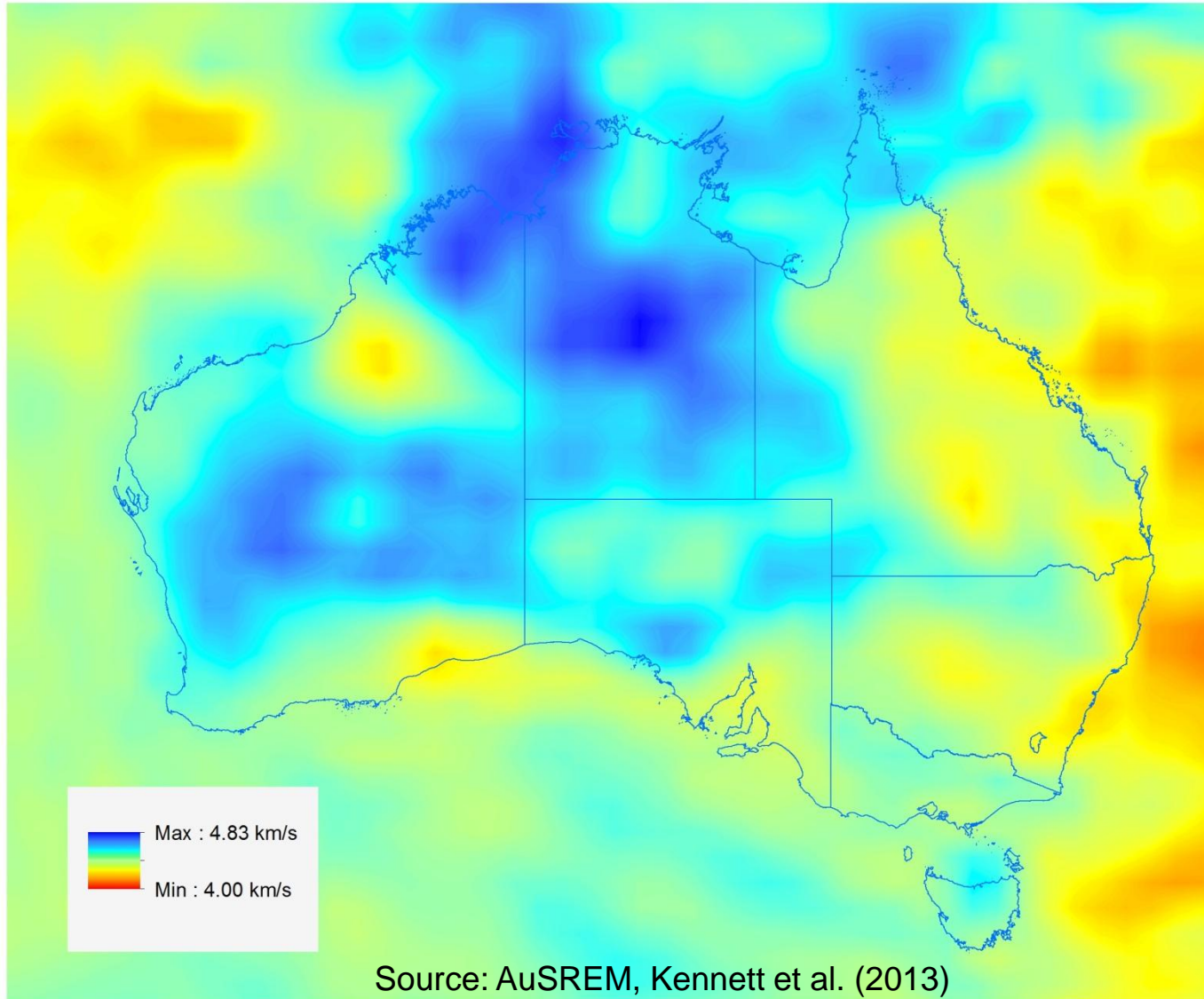
Priestley (2013)

# Lithosphere-asthenosphere – LAB – depth in km



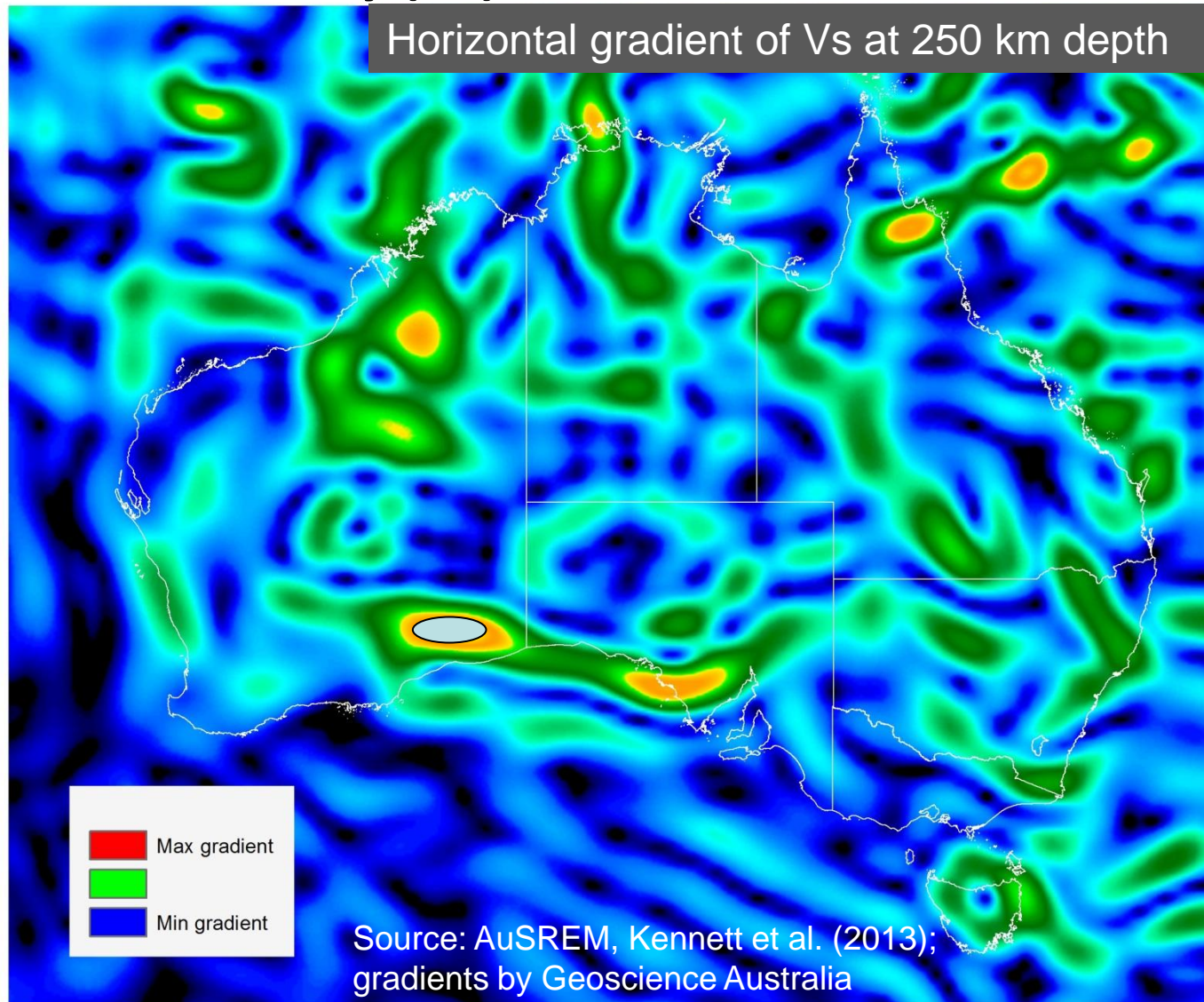
Milligan

# Shear wave velocity ( $V_s$ ) slice at 250 km



Milligan

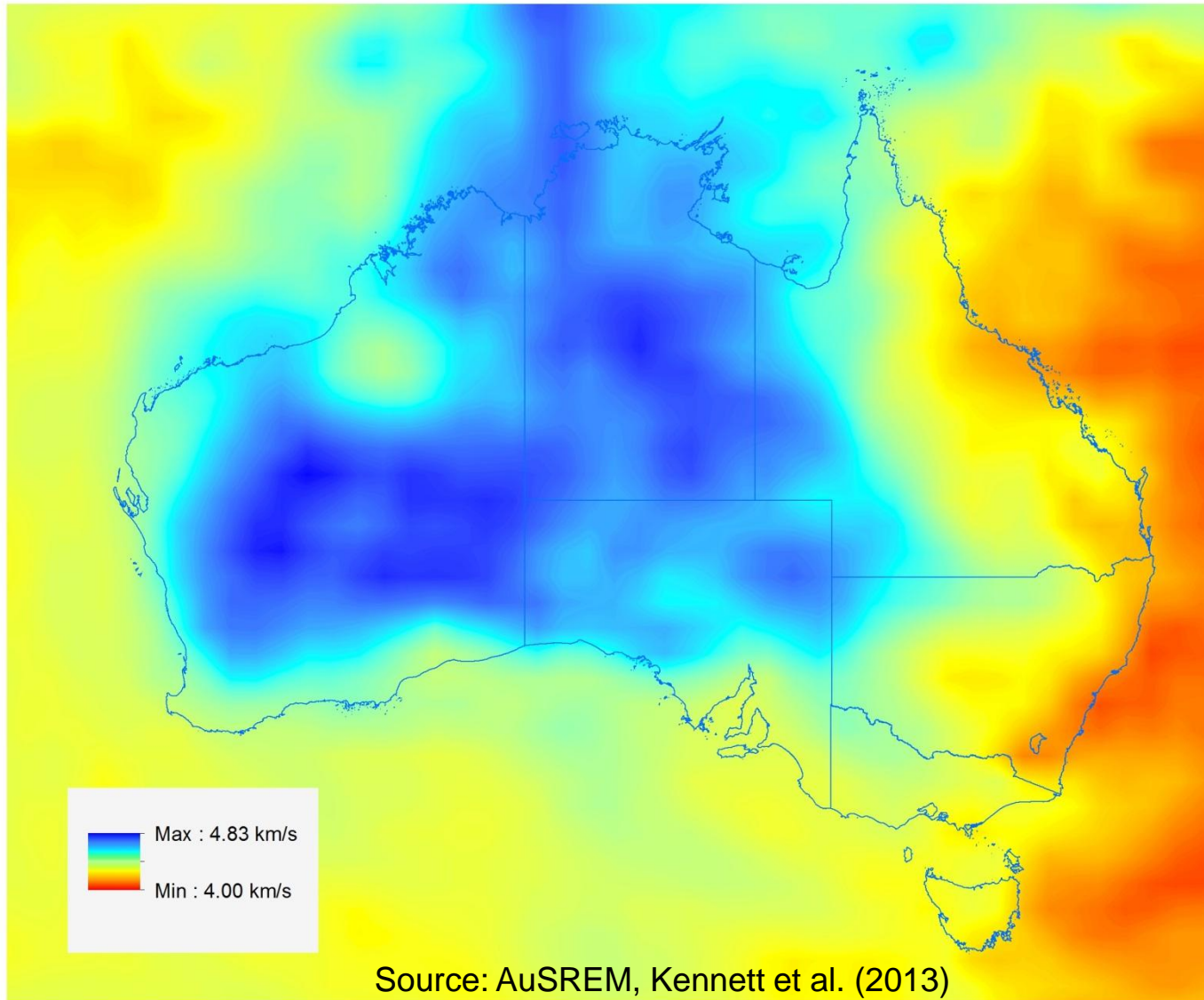
# Shear wave velocity ( $V_s$ ) slice at 250 km



Milligan

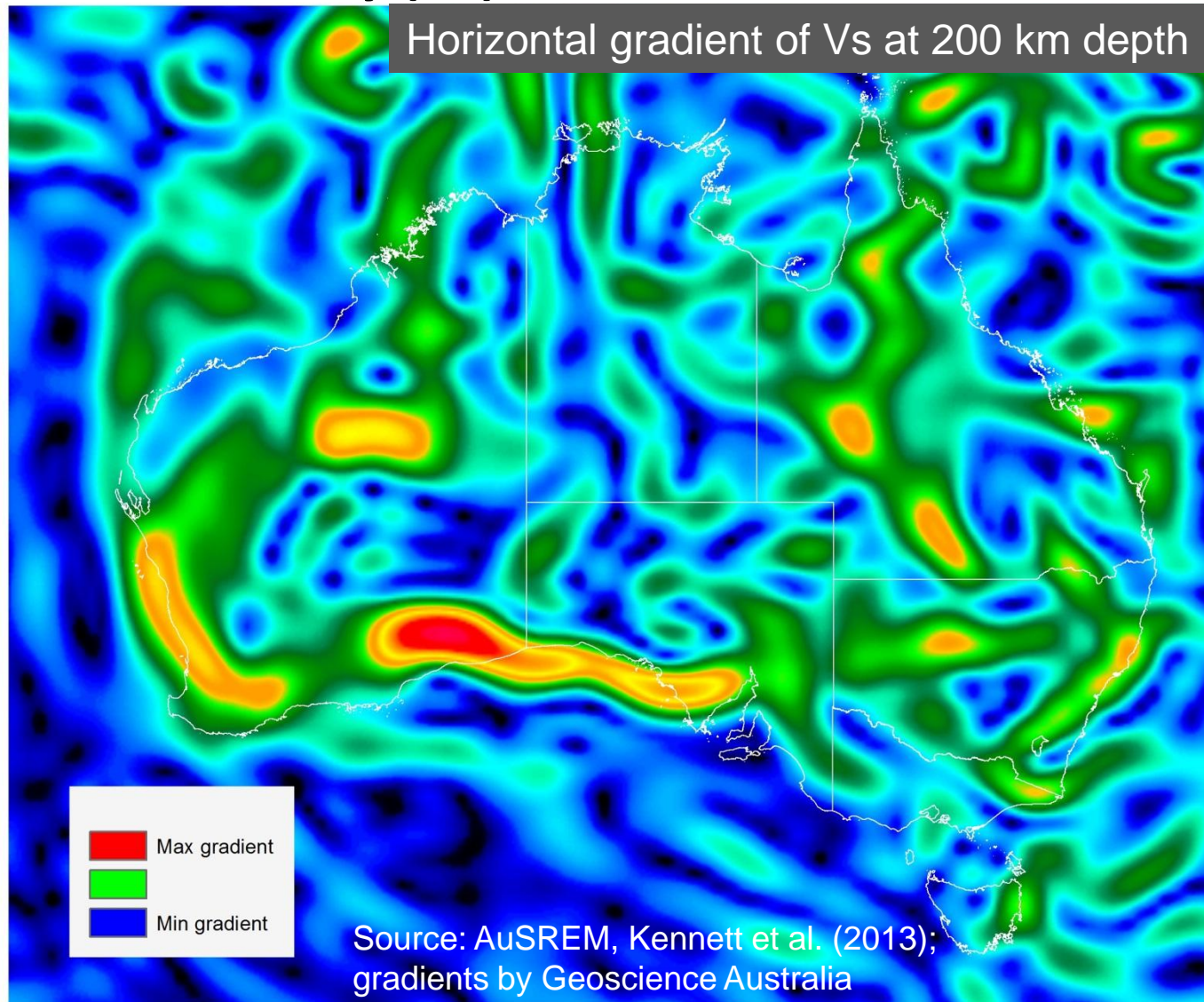


# Shear wave velocity ( $V_s$ ) slice at 200 km



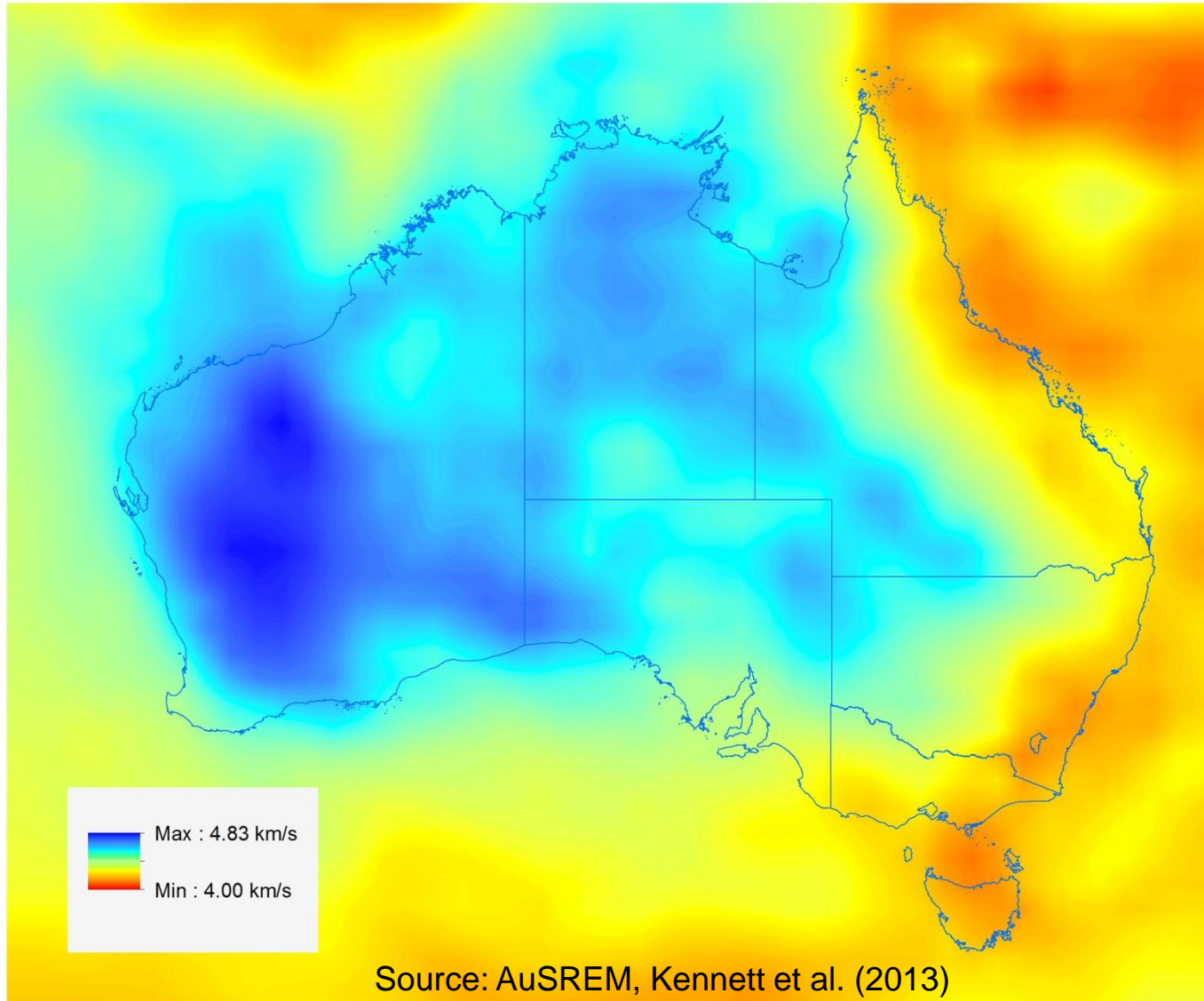
Milligan

# Shear wave velocity ( $V_s$ ) slice at 200 km



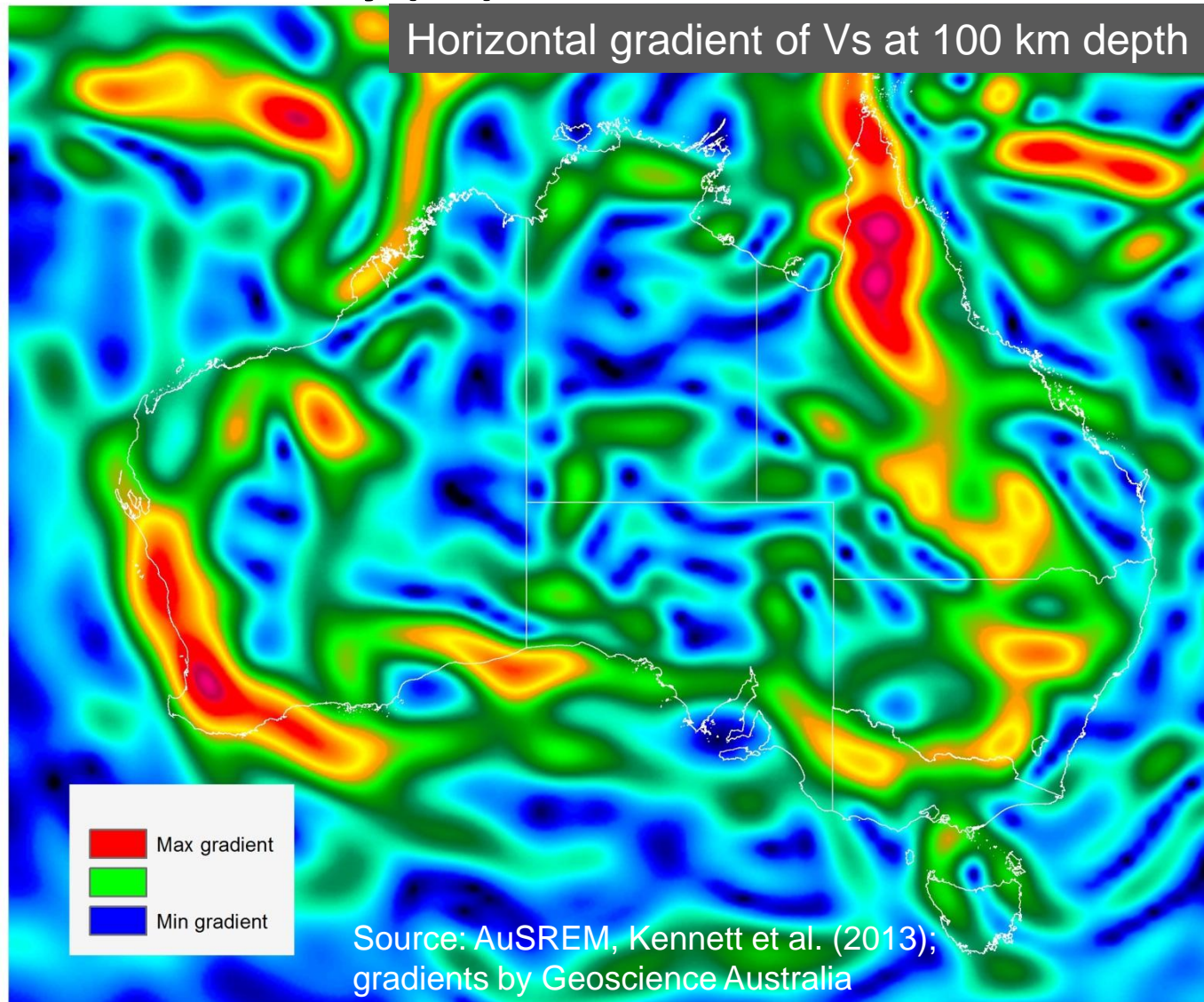
Milligan

# Shear wave velocity ( $V_s$ ) slice at 100 km



Milligan

# Shear wave velocity ( $V_s$ ) slice at 100 km



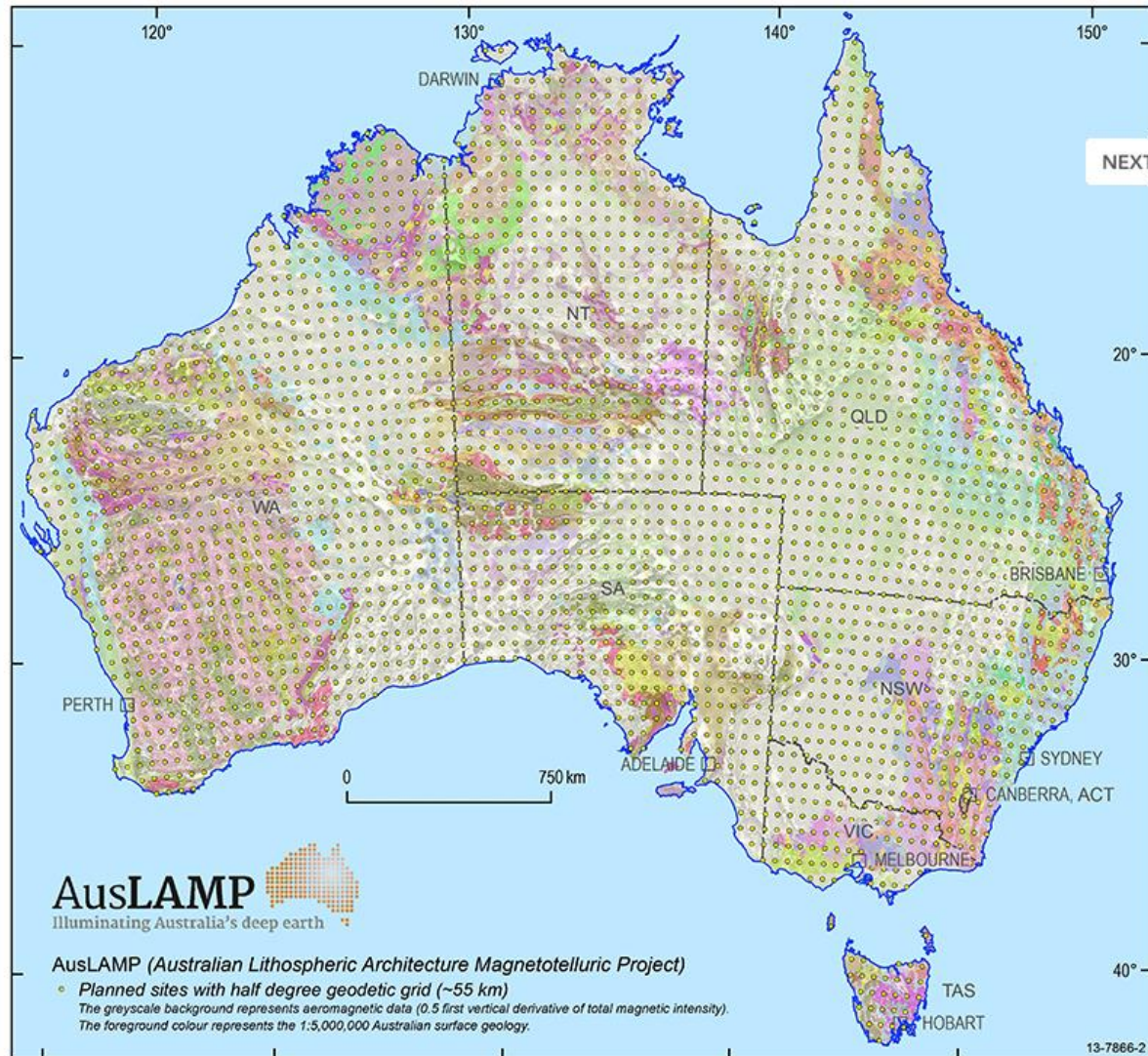
Milligan

# Velocity slices of mantle lithosphere

- Are these products providing useful ‘boundaries’?
- What is their resolution?
- How robust are the models?
- When did they form?
- Preserved old ones?
- Reworked younger ones?
- Timing re mineralisation??

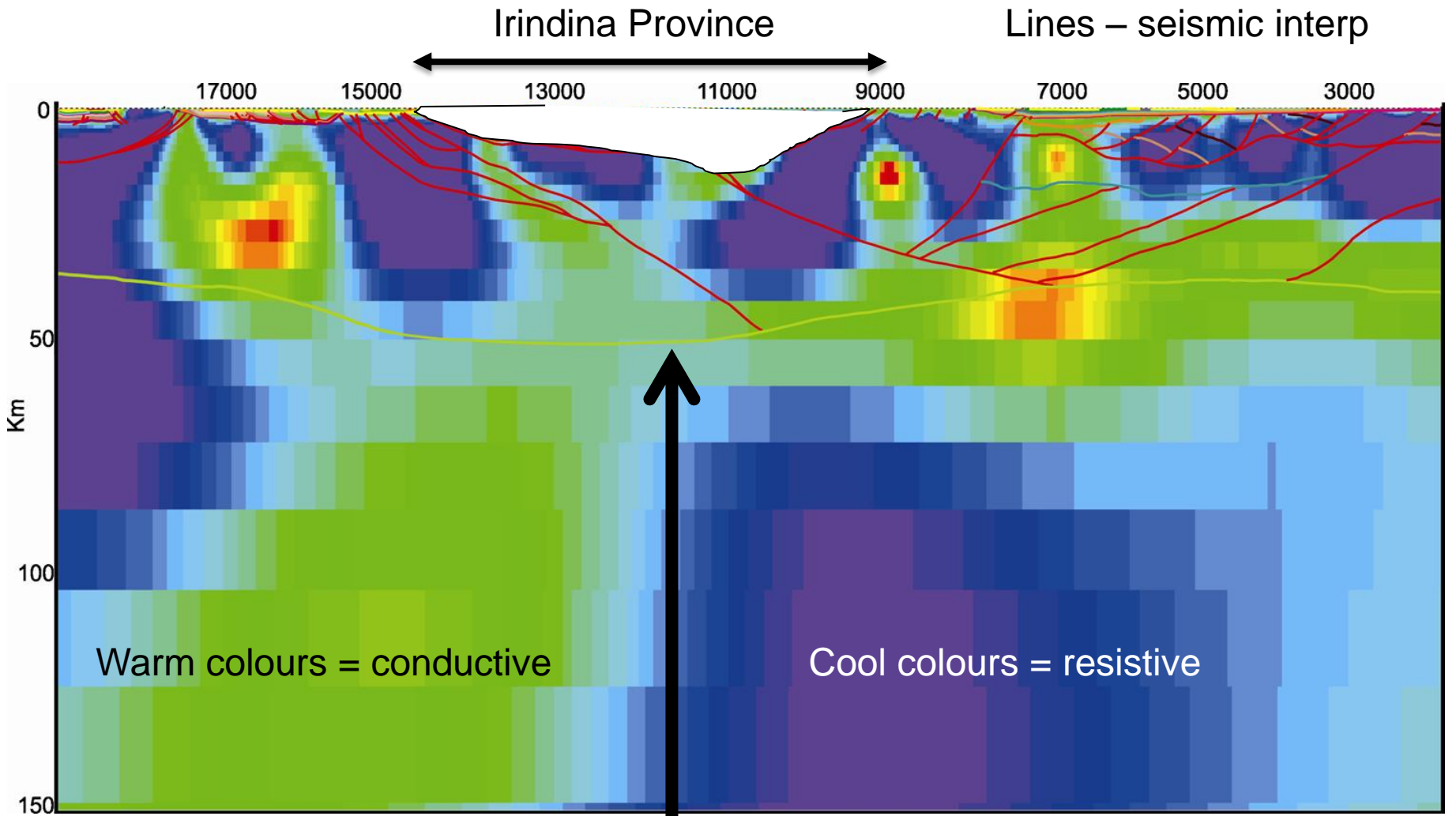


# AusLAMP: National long-period magnetotellurics



- Programme commenced
- Half degree grid spacing (~55 km) across continent
- Long-period instrument deployment one month approx.
- Map to base of lithosphere

# Magnetotellurics: mapping SCLM architecture



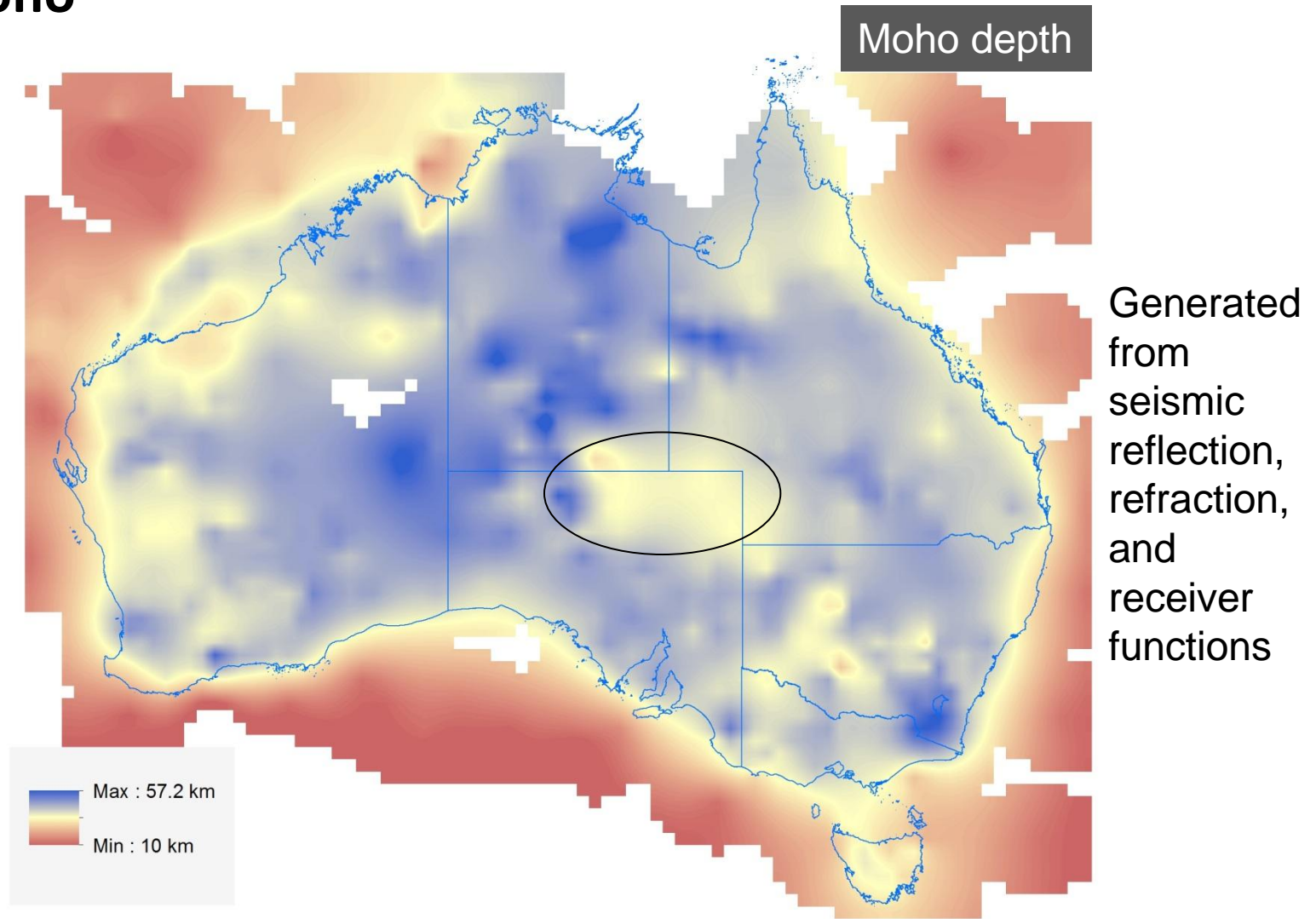
Warm colours = conductive

Cool colours = resistive

NTGS and Geoscience Australia

Duan, 2010

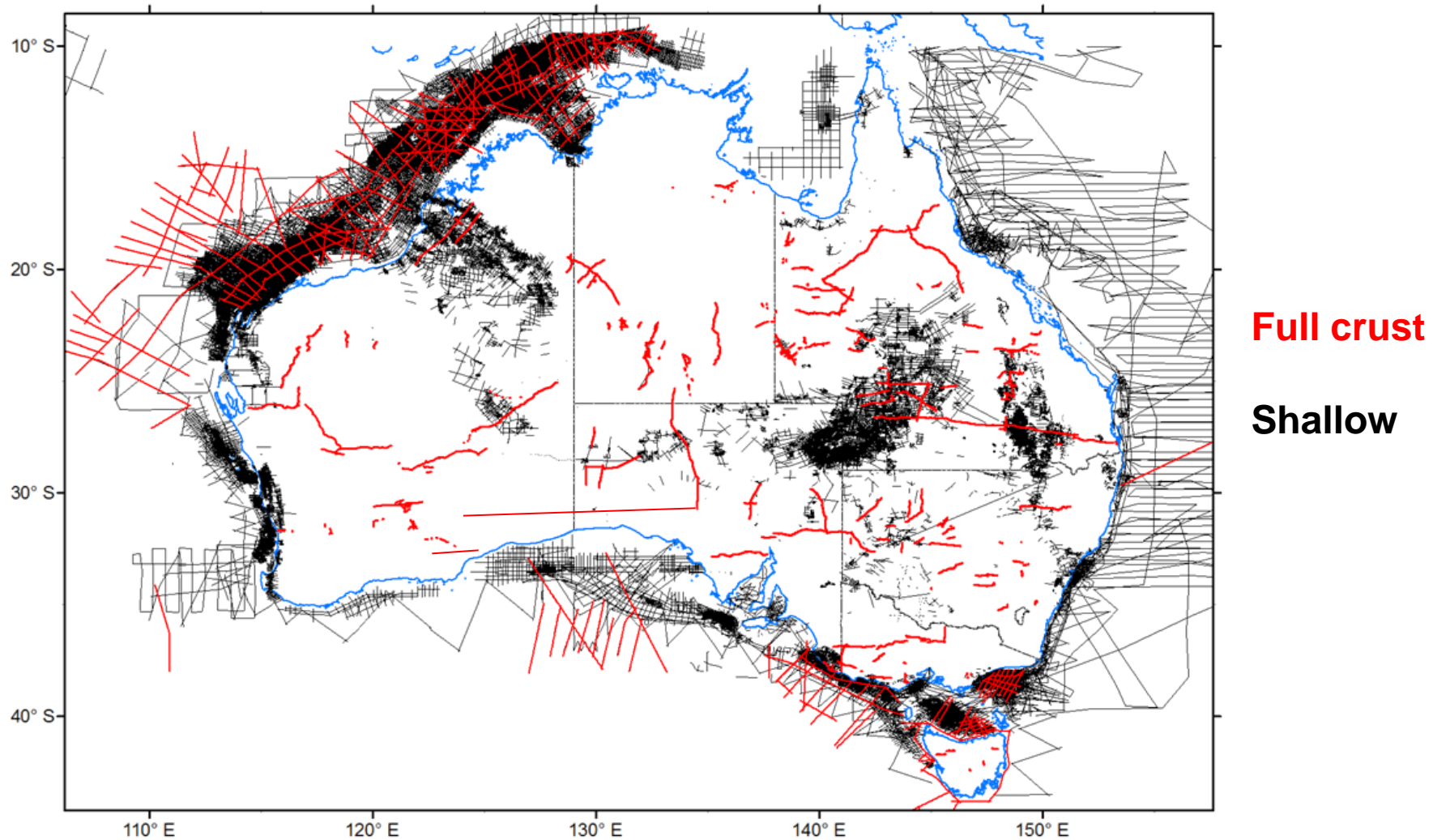
# The Moho



Source: AusMoho, Kennett et al. (2011)

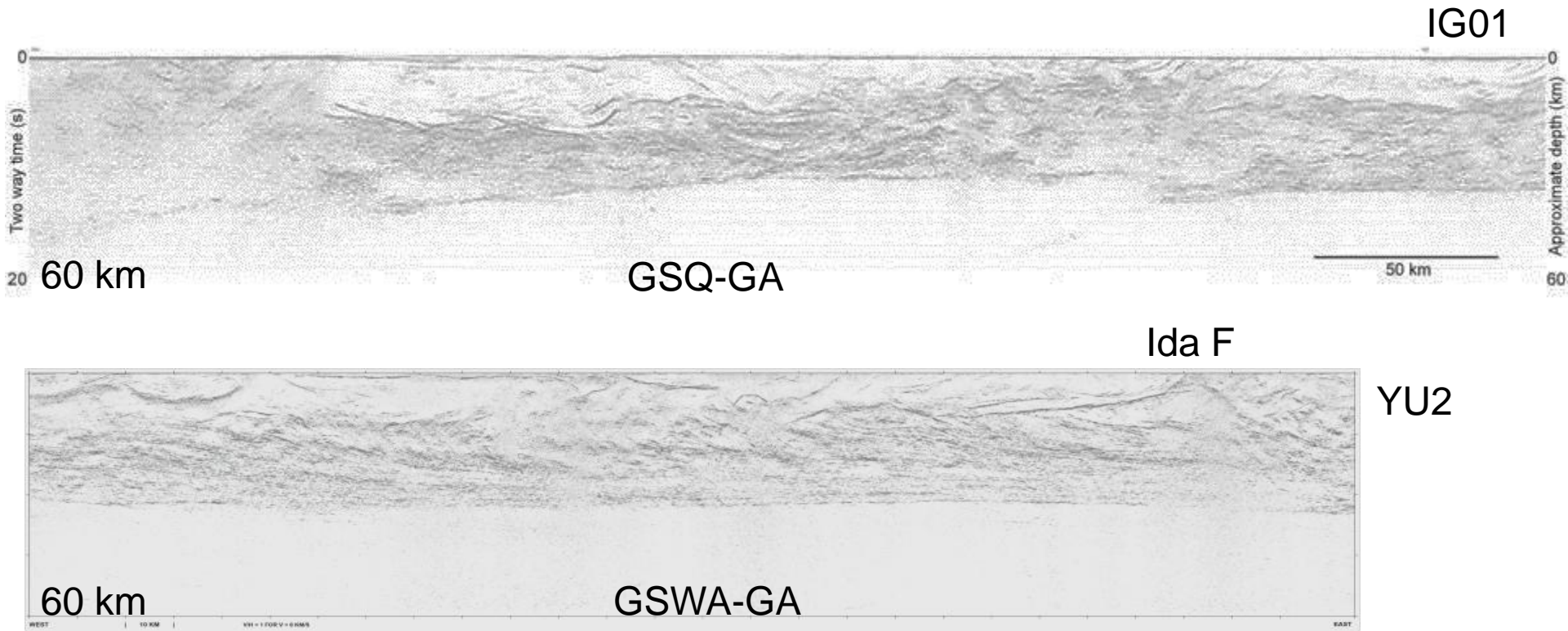


# Public-domain seismic reflection coverage in Australia



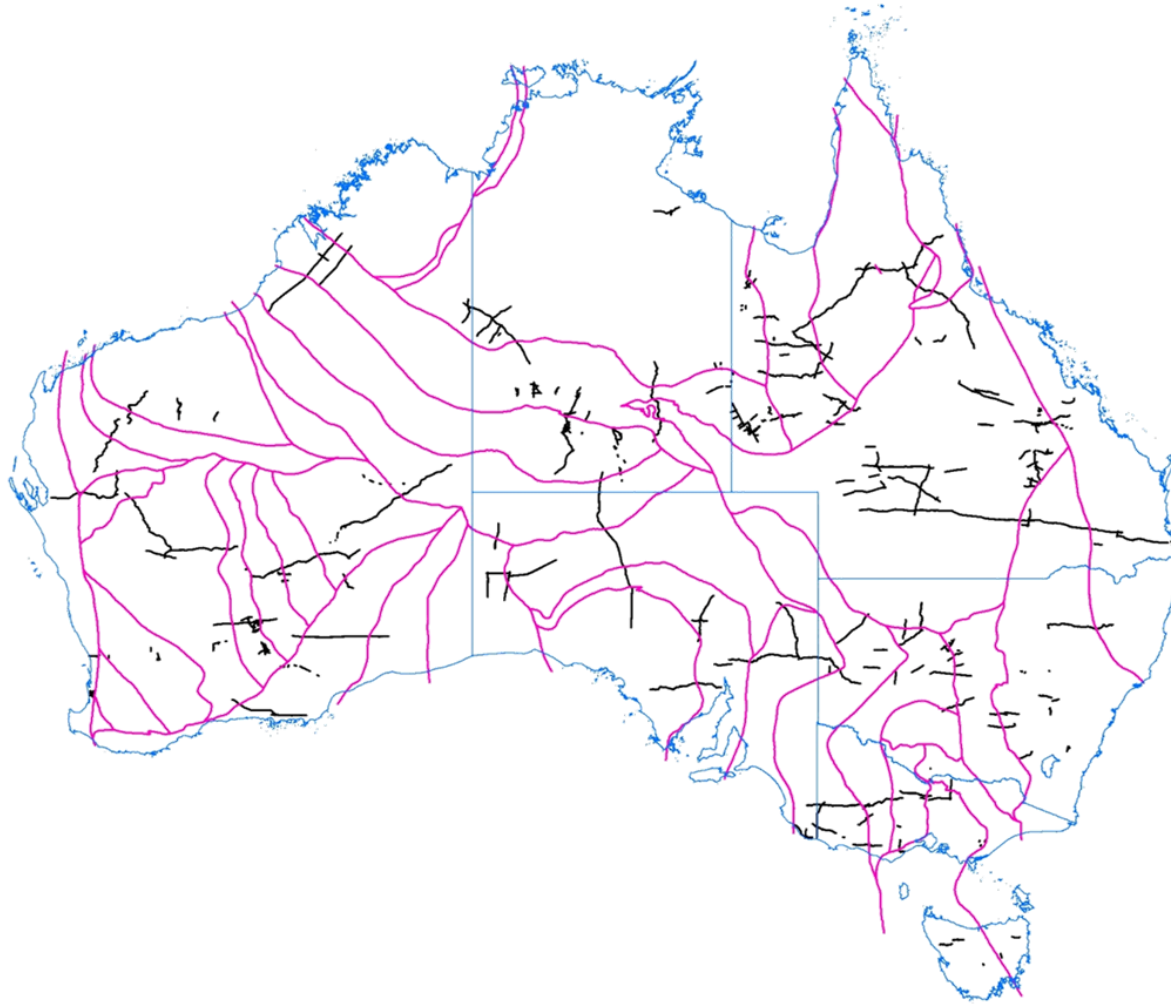
Czarnota, 2014

# The seismic Moho and seismic provinces



- Moho character highly variable (sharp to diffuse = crust/mantle velocity contrast)
- Moho topography variable (steps and 'dangles')
- Lower crust highly variable – seismic provinces don't see surface
- Can map the major domain boundaries (Korsch and Doublier, 2014)

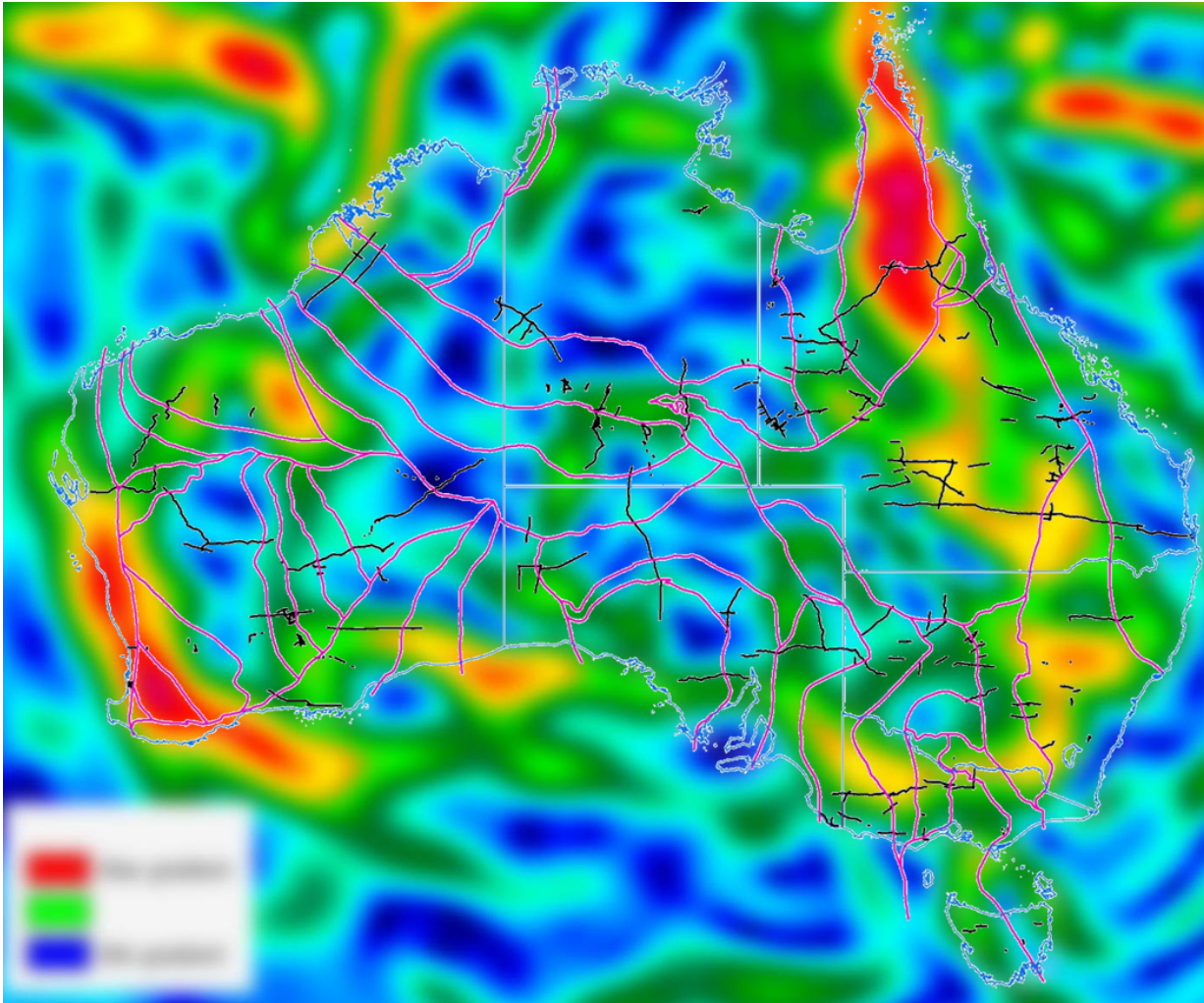
# Seismic provinces and crustal domain boundaries



- Mapped all crustal penetrating structures
- Structures bounding seismic domains
- Extrapolated with mag-grav-geo

Korsch & Doublier, 2014

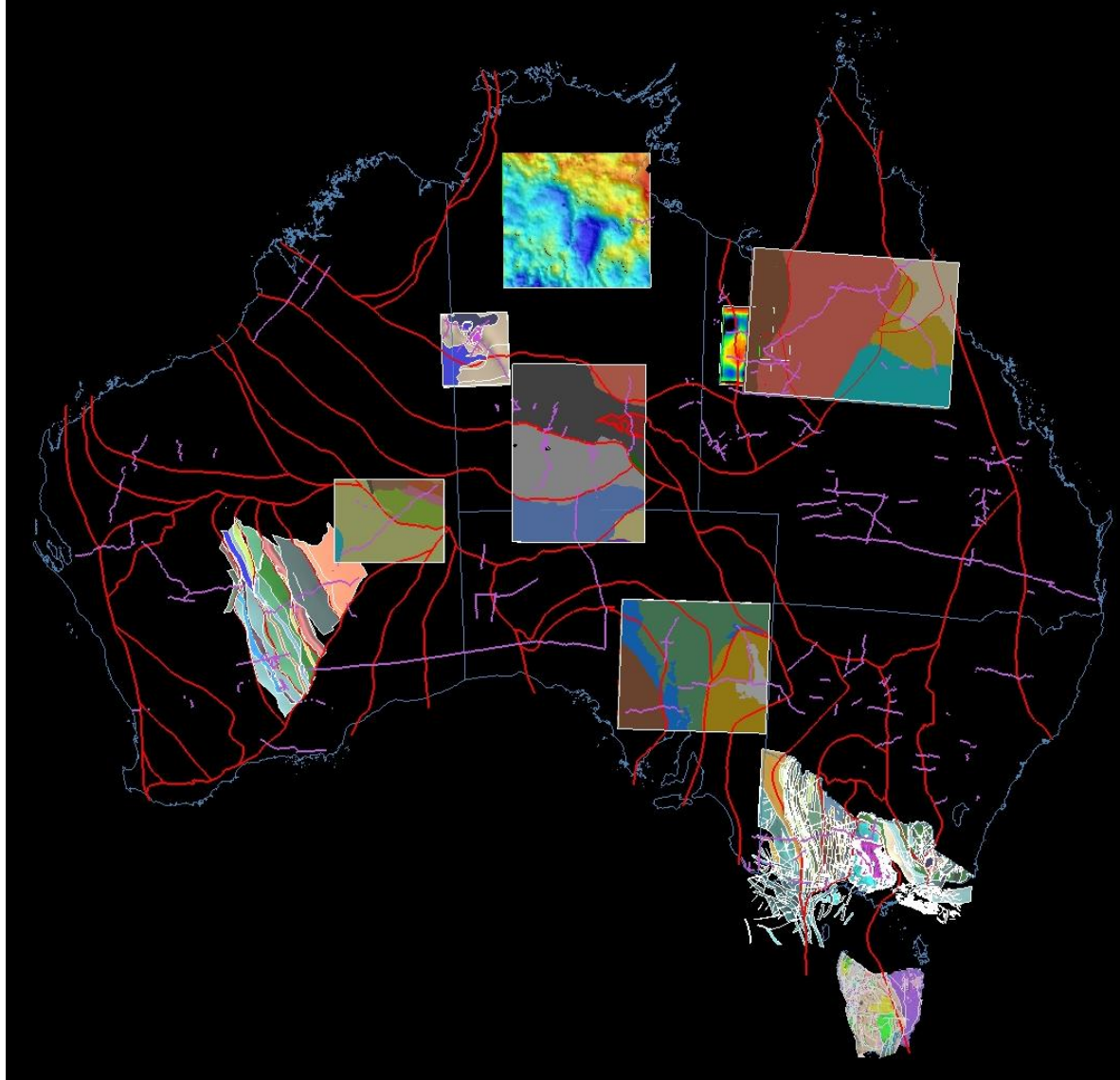
# Seismic provinces and crustal domain boundaries



- This seismic crustal fabric sits on a SCLM fabric (eg. 100 km Vs slice)
- Boundaries match in places, highly oblique in others
- How does the 3D lithospheric jigsaw fit together through time?

Korsch & Doublier, 2014

# Towards a 3D crustal architecture map

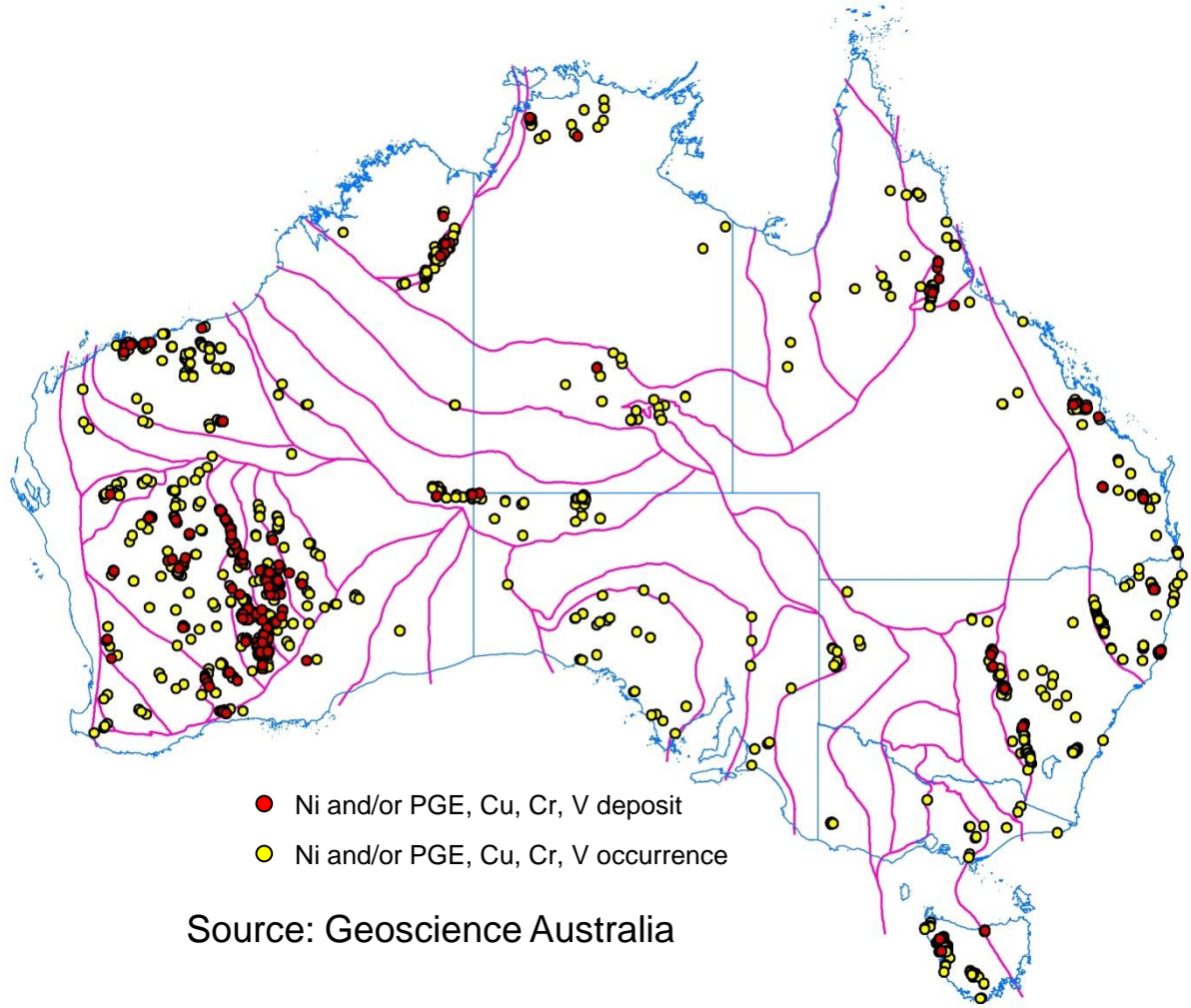


Selection of regional 3D maps to be integrated in Korsch-Doublier framework

Plan to link with offshore maps too

T Brennan

# Crustal boundaries and mafic-ultramafic mineral systems



Source: Geoscience Australia

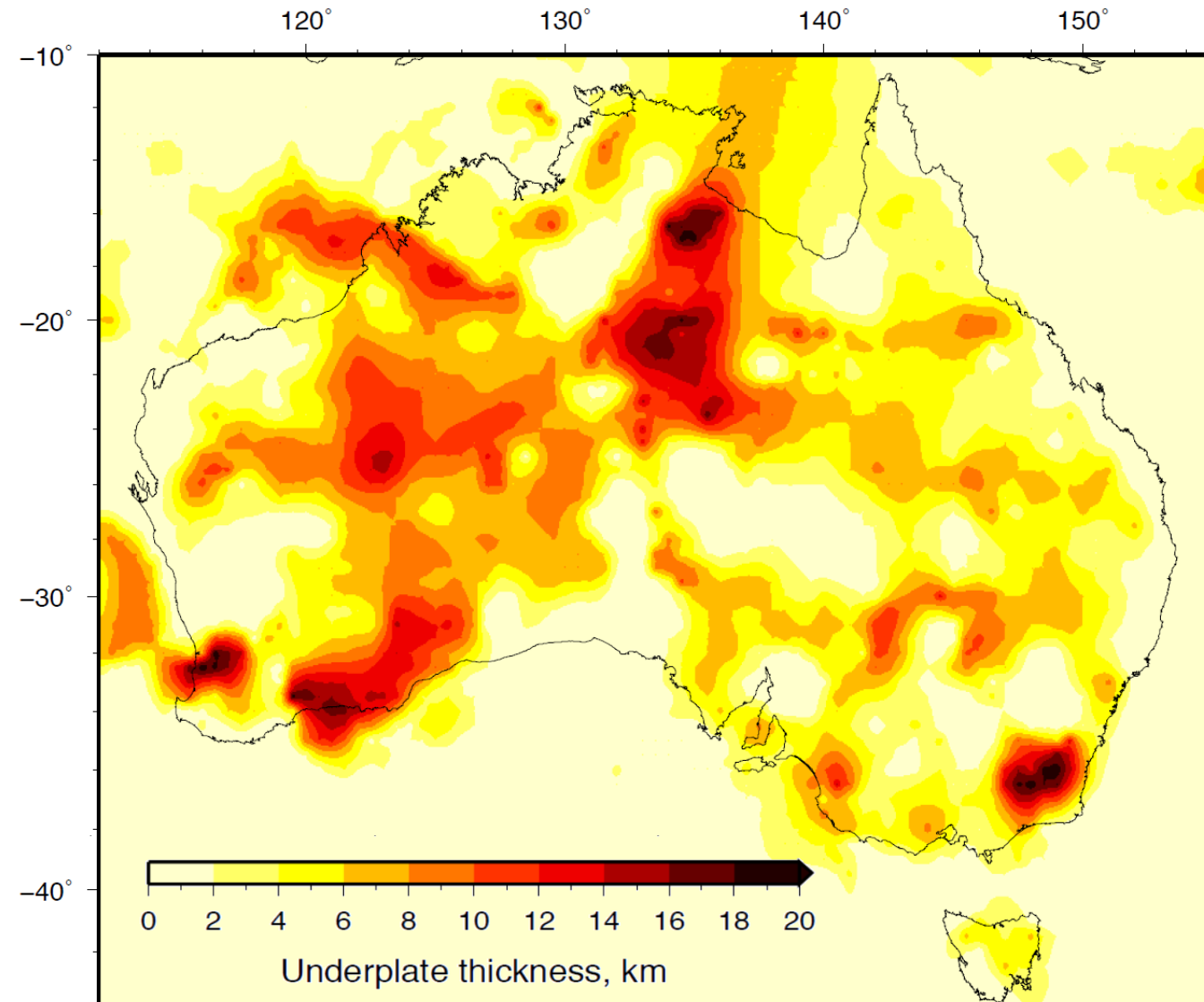
Can start to look at the crustal boundaries and location (at surface) of deposits

Note it is a 3D problem

This map not all major faults

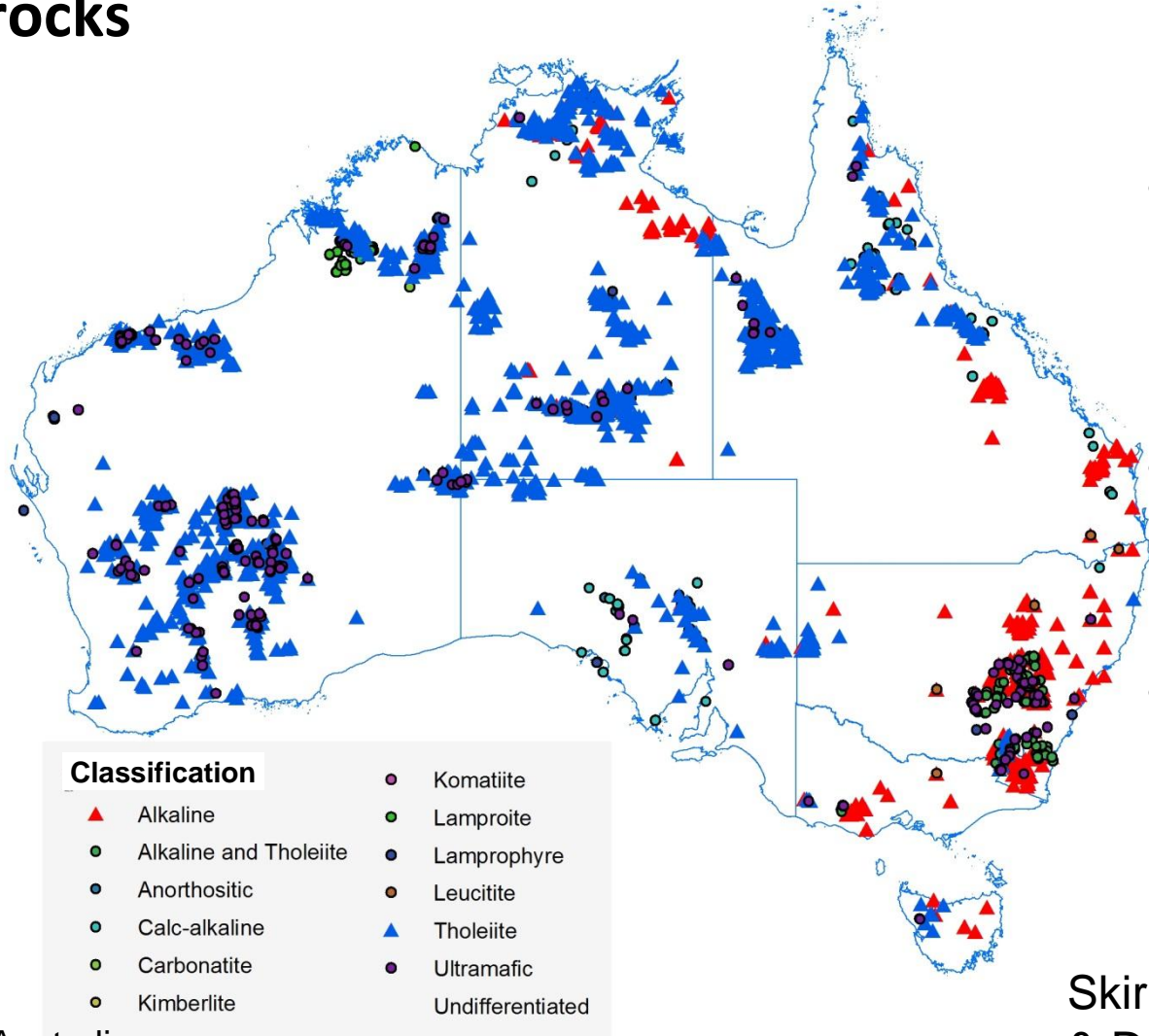
Crustal boundaries with nickel (PGE, Cu, Cr, V) deposits and occurrences

# Seismic velocity mapping lower crustal mafic 'underplate'



- AusREM velocity model (Kennett)
- Refraction, receiver function & ambient noise – map cumulative thickness >7.1 m/s above Moho
- Mafic underplate in lower crust?
- What age?
- Encircles cratons
- LIP Magma flux – for Ni systems?

# OZCHEM whole-rock geochemistry – mafic, ultramafic and alkaline rocks



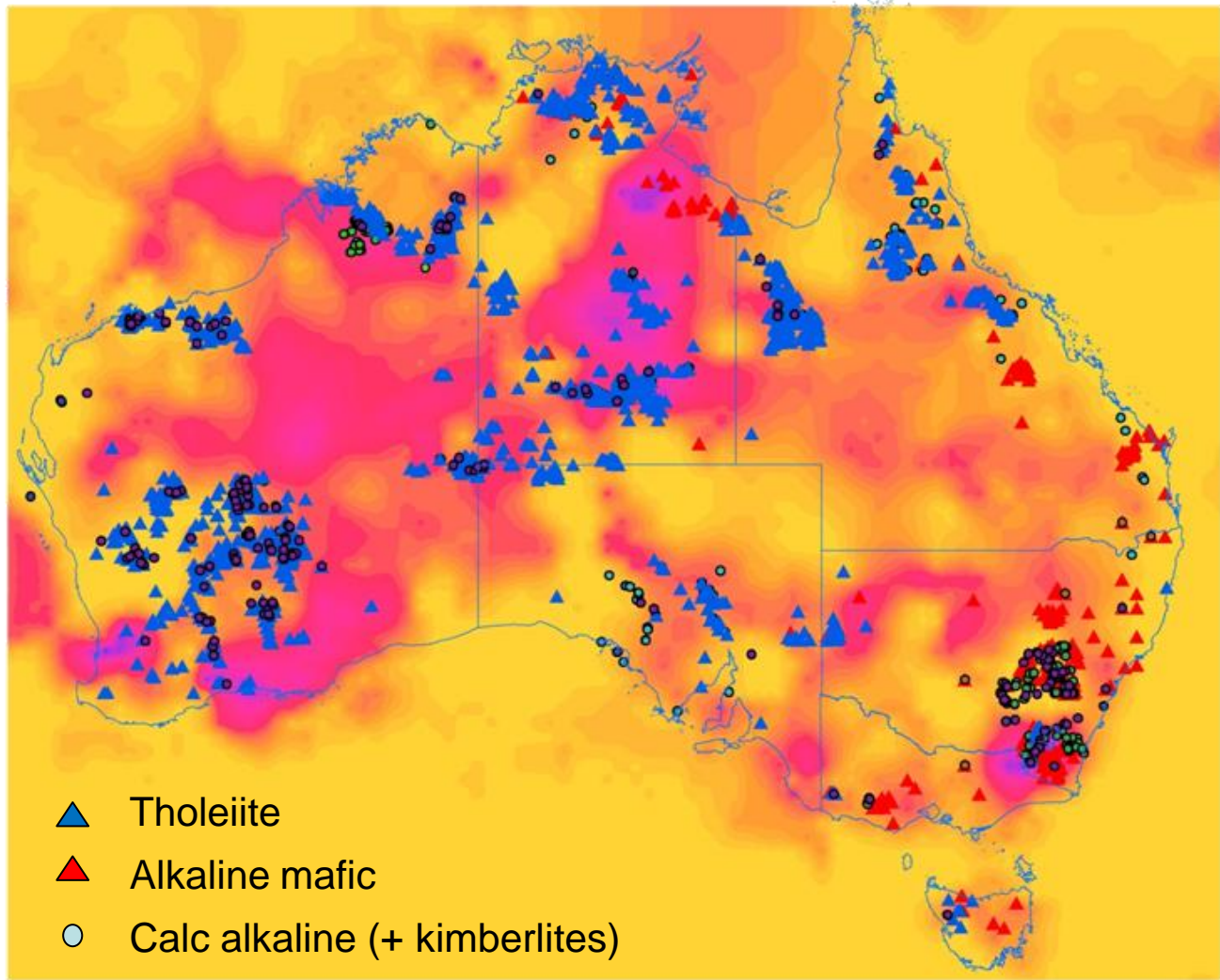
- Geochem in space and time
- Determine depth of melting
- lithosphere thickness through time

Skirrow, Champion & Dulfer

Source: Geoscience Australia



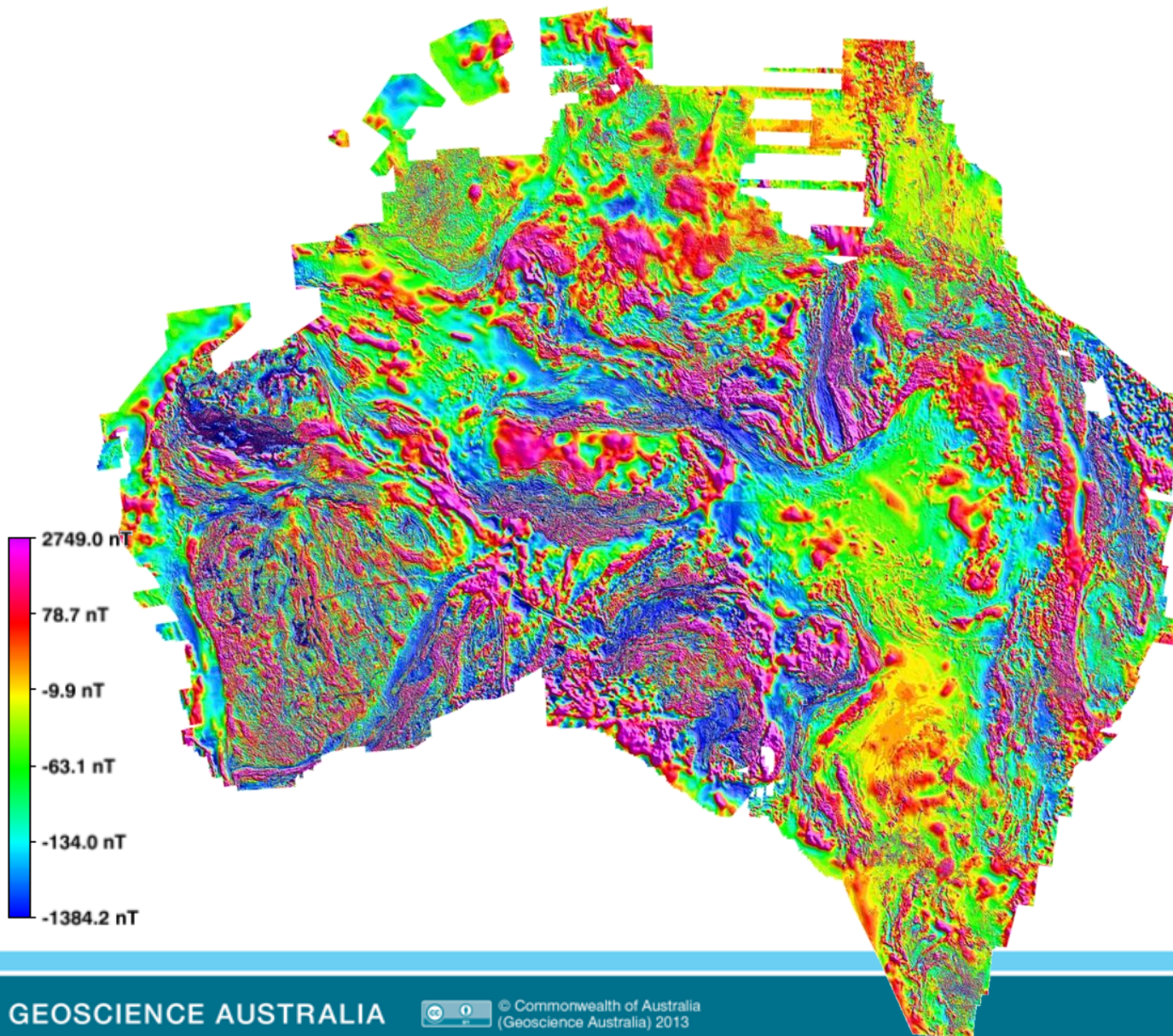
# Linking mafic-ultramafic chemistry to 'underplate'



- Work in progress to link LIPs with architecture
- Favourable zones on edge of underplate?
- Eg West Kimberley

Skirrow, Champion & Czarnota

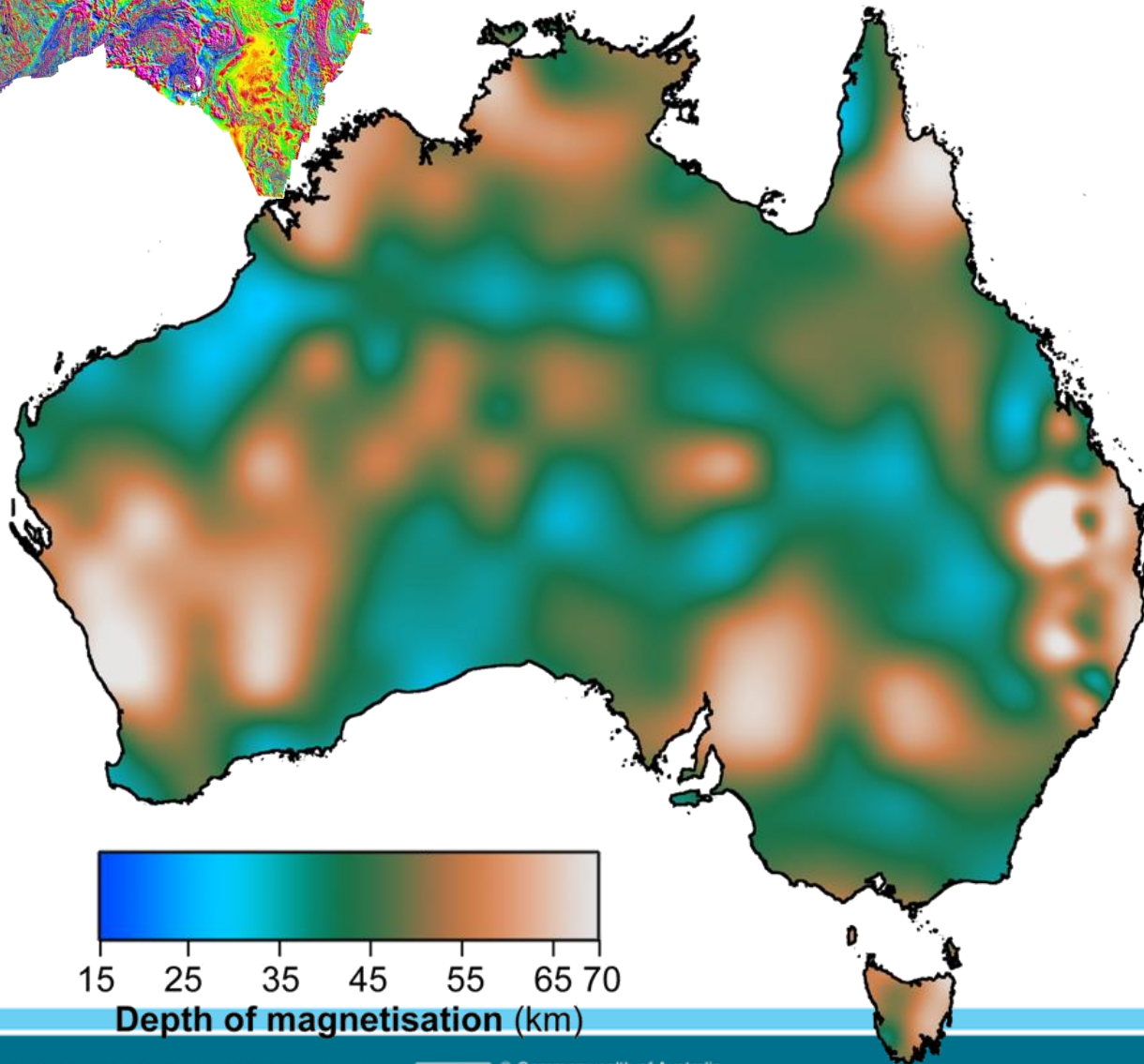
# Supercomputer calculation of variable RTP TMI



- Improved RTP that accounts for latitude
- Run on top 50 computer in world
- Full dataset
- We are familiar with these patterns, what depth info can we get?

Milligan, 2014

# (Curie) depth of magnetisation

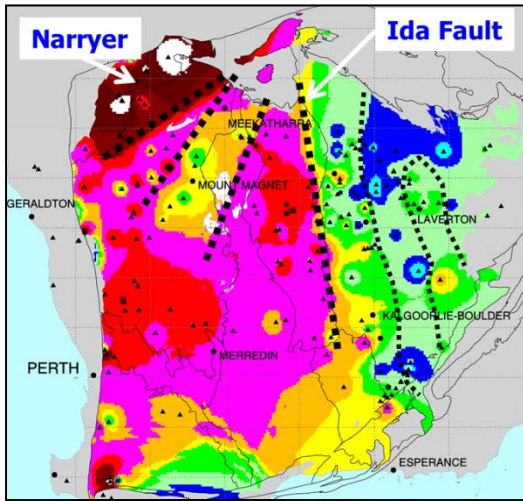


- Depth to bottom of magnetisation
- Curie temperature 670°C
- Deeper than Moho in Curnamona, Yilgarn, Cape York, New England??
- Heatflow?
- And/or major boundaries between different mid and lower crustal (mag) domains?

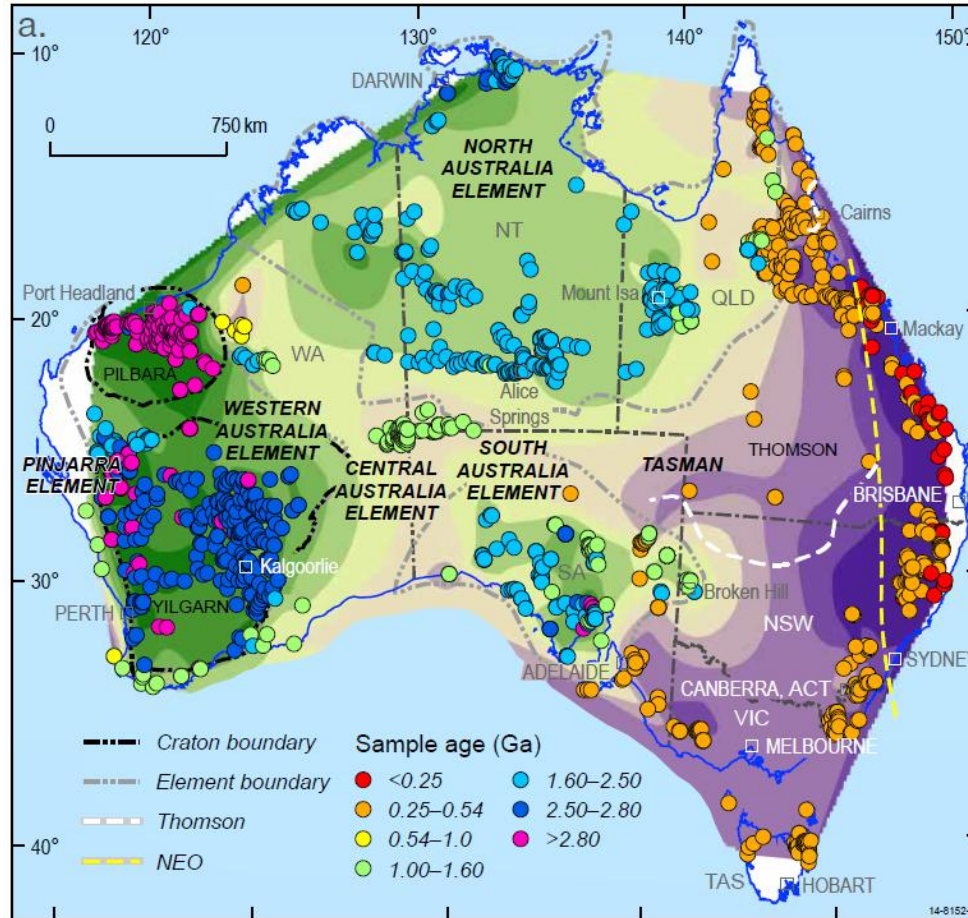
Chopping, 2014

# Big boundaries in crustal age (Sm-Nd)

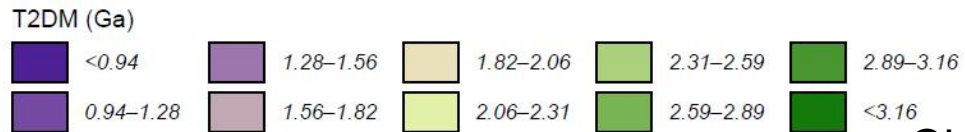
Yilgarn T<sub>DM</sub> map



Champion & Cassidy, 2004

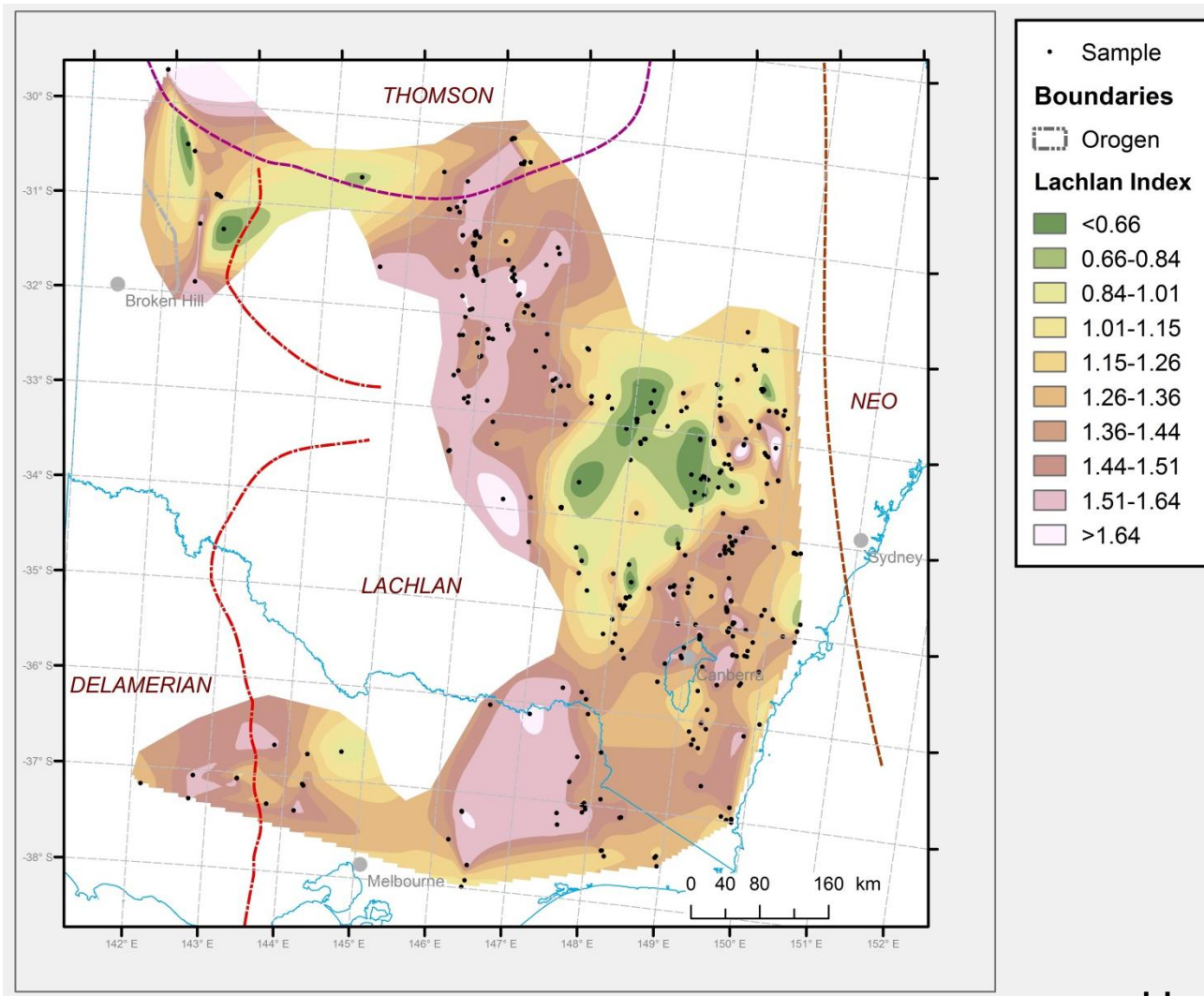


World first continental T<sub>DM</sub> Nd coverage



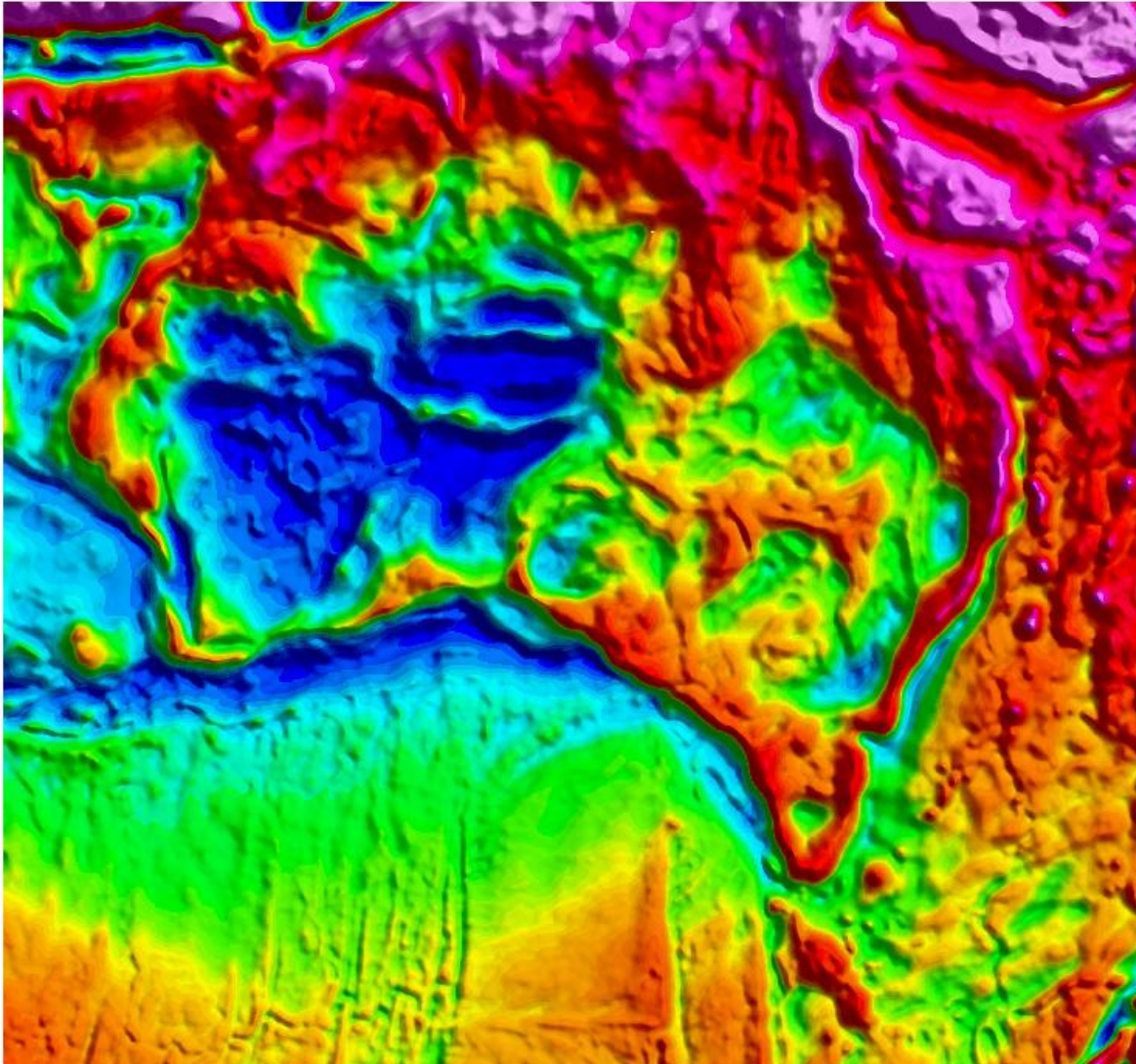
Champion, 2014

# Big boundaries in crustal age (Pb)



Huston et al. 2013

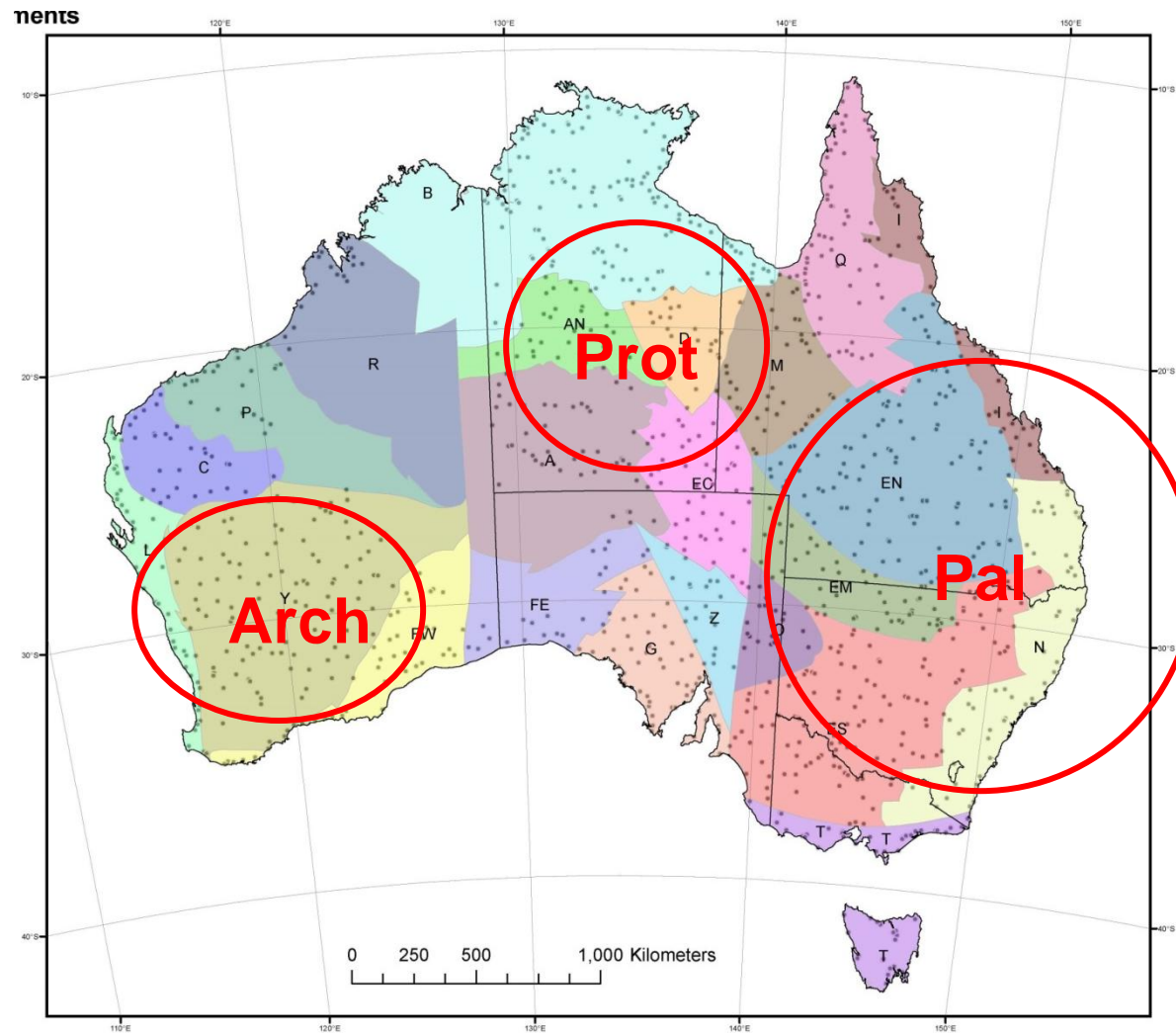
## Gravity: 25 km upward continued



- A different view to magnetics
- Deeper lithospheric keel in western 2/3rds of the continent?
- Used to make a deep crust interpretation

Milligan, 2012

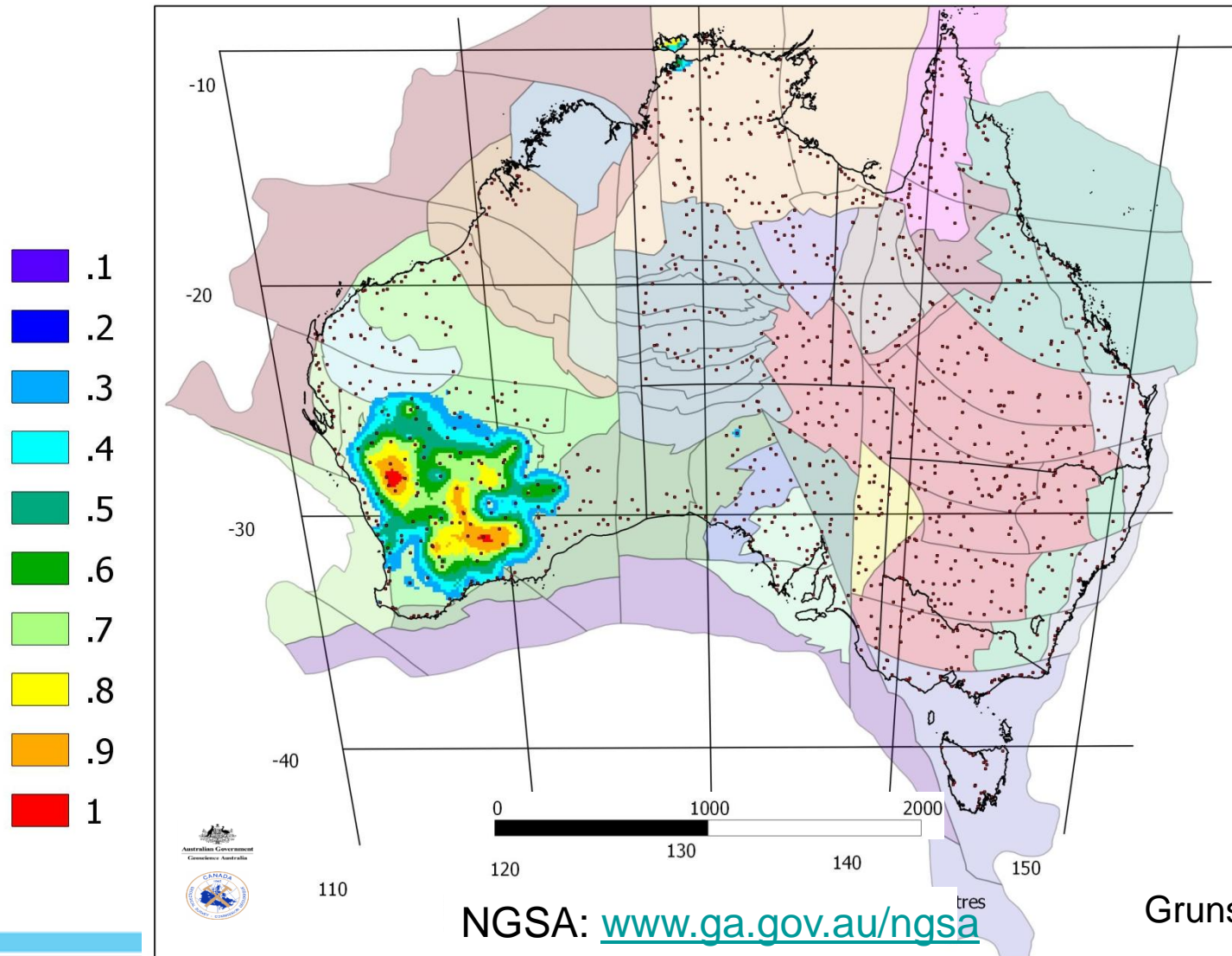
# Lithospheric Elements and surface geochemistry??



- Deep crust/ upper mantle sutures and lineaments
- Continental-scale geophysical (gravity) datasets
- Extend from the continent into the ocean to cover whole of plate
- Integrate with surface geochem (NGSA)

Claoué-Long in prep

# Probability of NGSAs map 'deep' Yilgarn?

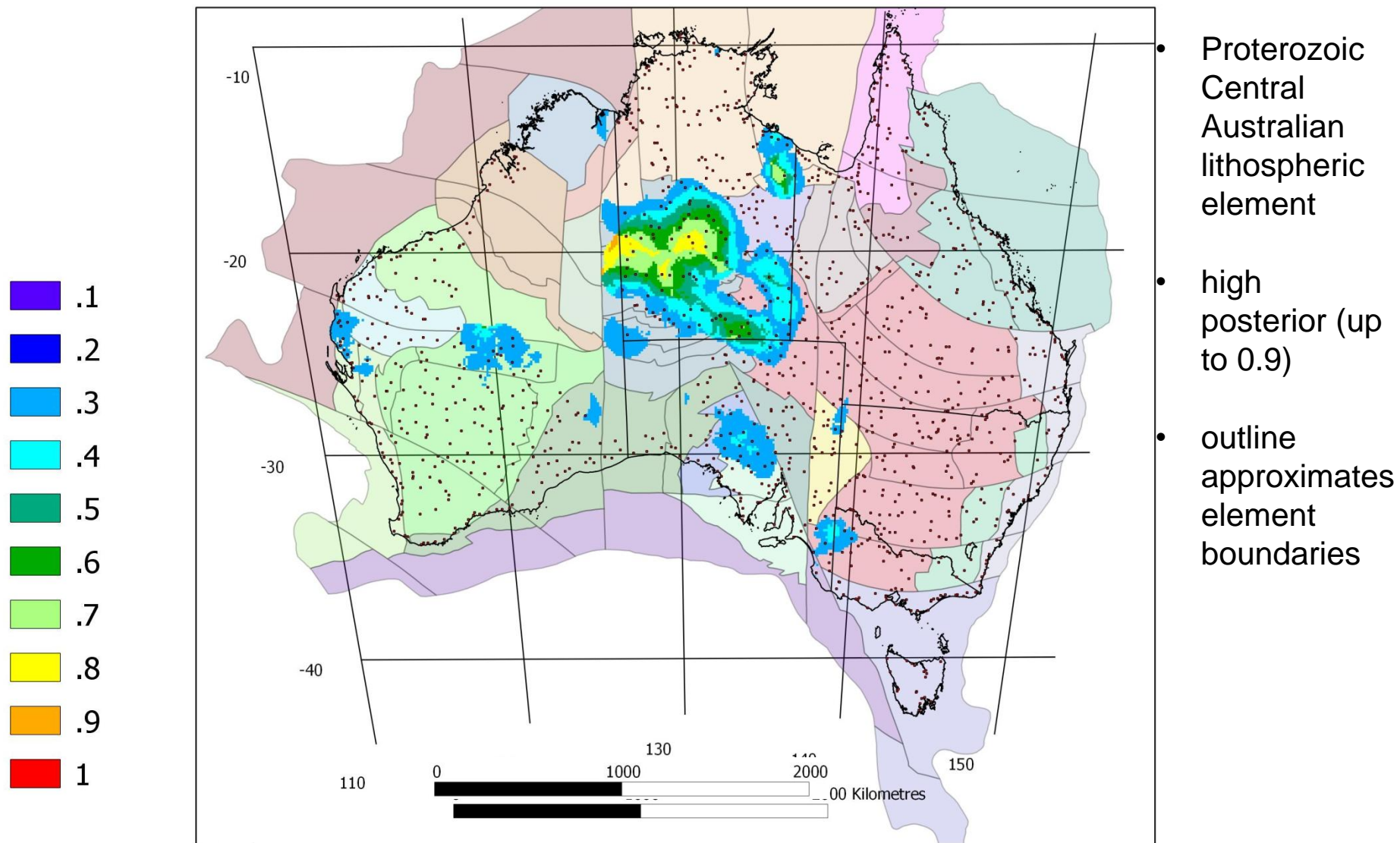


- Archaean Yilgarn lithospheric element
- very high posterior probability (up to 1.0)
- outline matches very closely the element boundaries

Grunsky & Caritat (in prep)



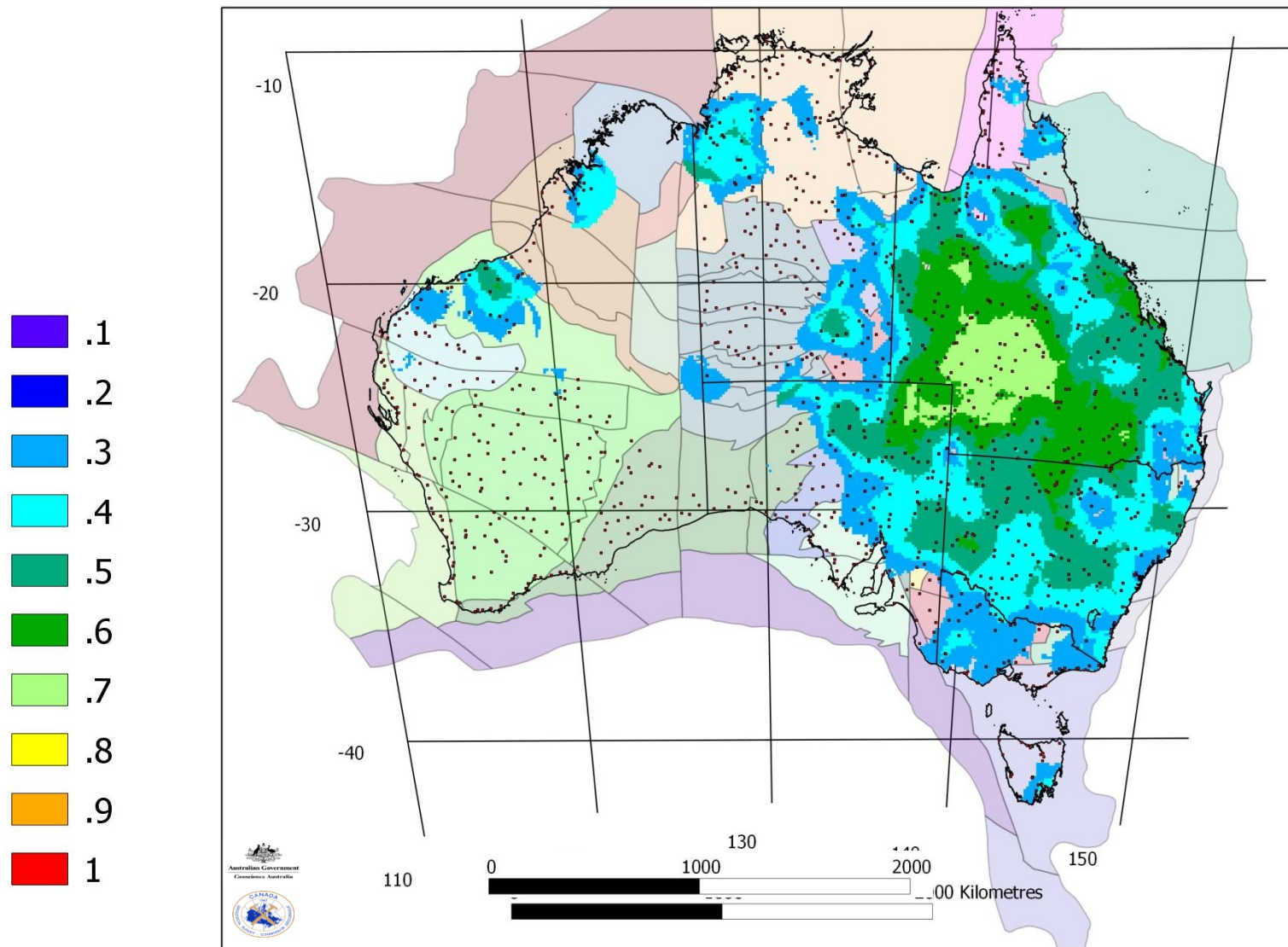
# Probability of NGSAs samples map 'deep' Arunta?



NGSA: [www.ga.gov.au/ngsa](http://www.ga.gov.au/ngsa)

Grunsky & Caritat (in prep)

# Probability of NGSA samples map 'deep' E Australia



- Palaeozoic
- moderate posterior probability (up to 0.7)
- outline approximates element boundaries
- I don't understand??
- Testing NGSA with Nd and Hf – looks promising

Grunsky & Caritat (in prep)

# Conclusions

- Architecture (structure) is a key ingredient of mineral systems thinking
- We are 6 blind men, but we do have more senses than touch
- Have plenty of structure, but which ones have the goodies?
- Need to integrate these elements into mineral systems thinking....
- through time and in 3D space at a range of scales
- Fantastic opportunity with the great data to make informed predictions about under cover resources in Australia
- Science Excellence is imperative



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# Thank you



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