AESC australian earth sciences convention

ARC MRIWA Proterozoic Multistage Basin Project

Mantle **density**, **temperature**, **composition**, and **water content** beneath **Greater McArthur Basin** in North Australian Craton

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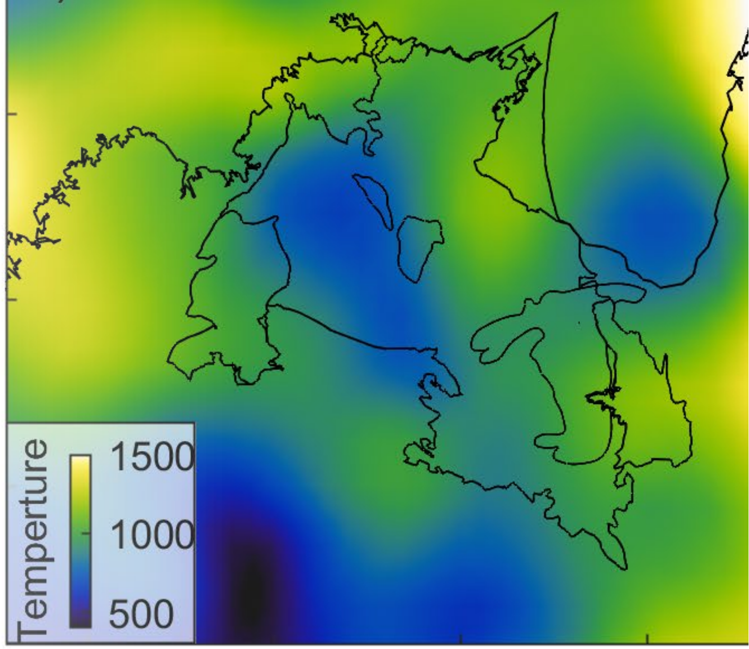

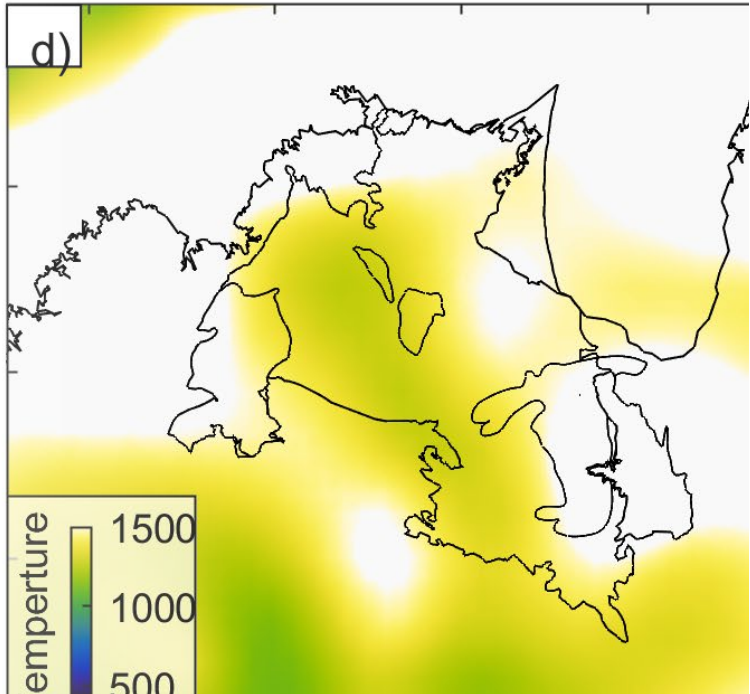

Centre for EXPLORATION TARGETING

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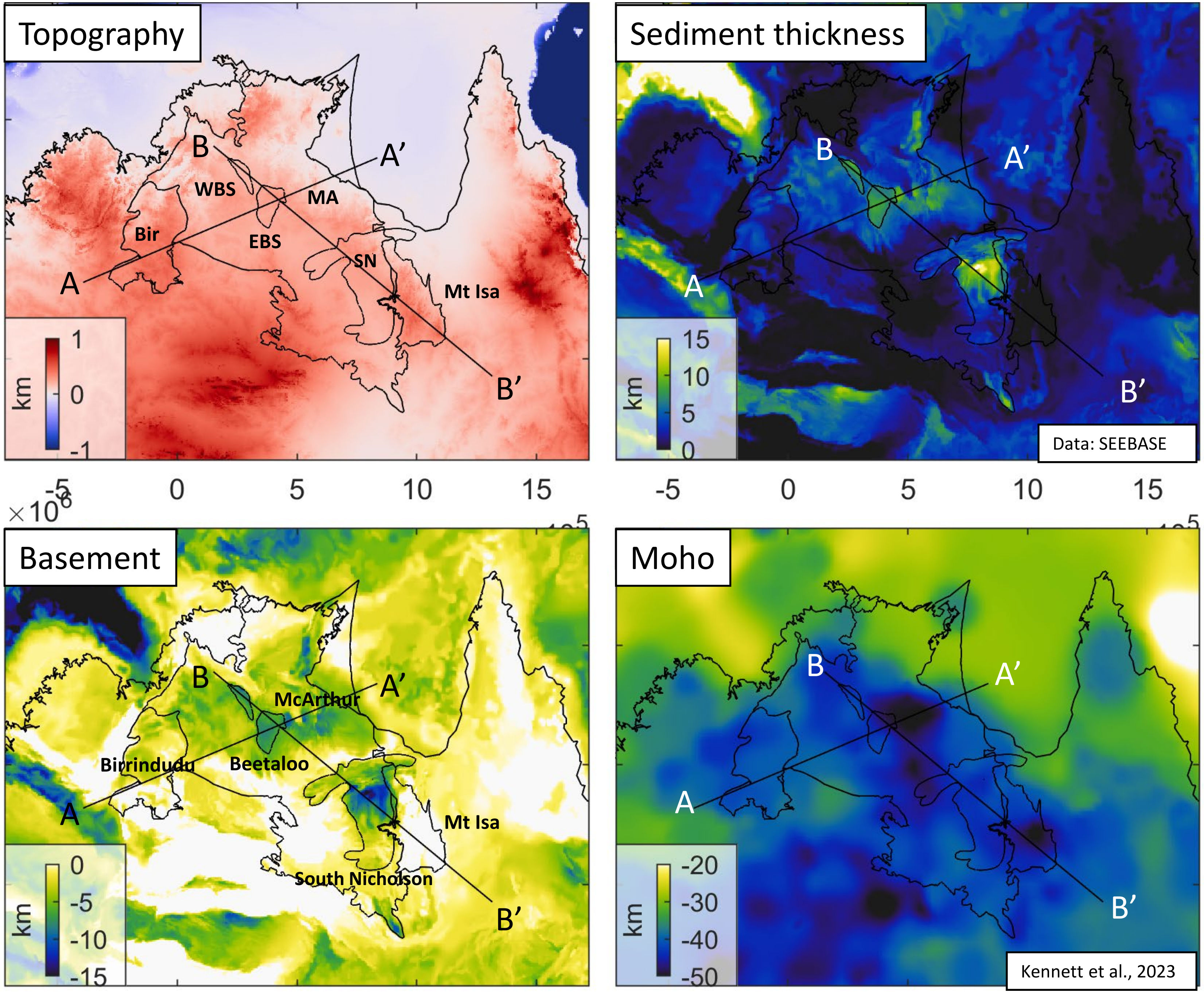
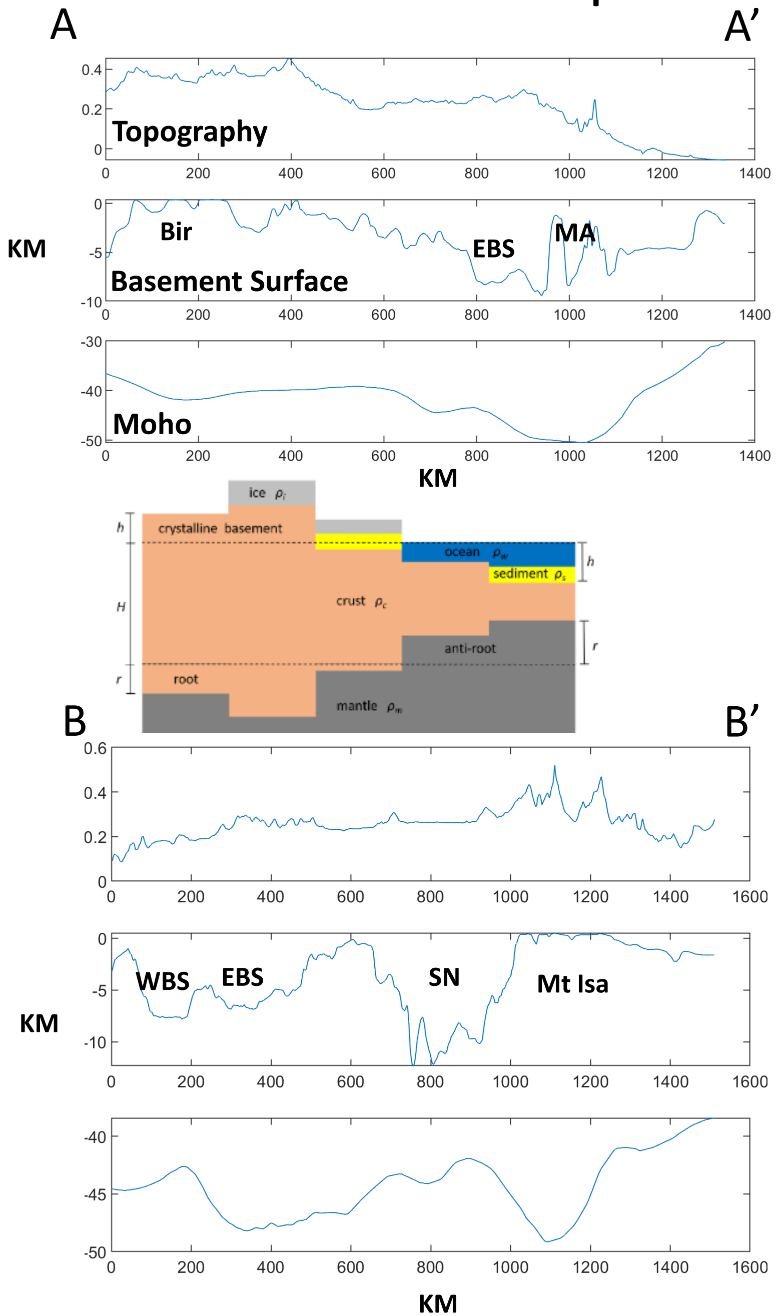
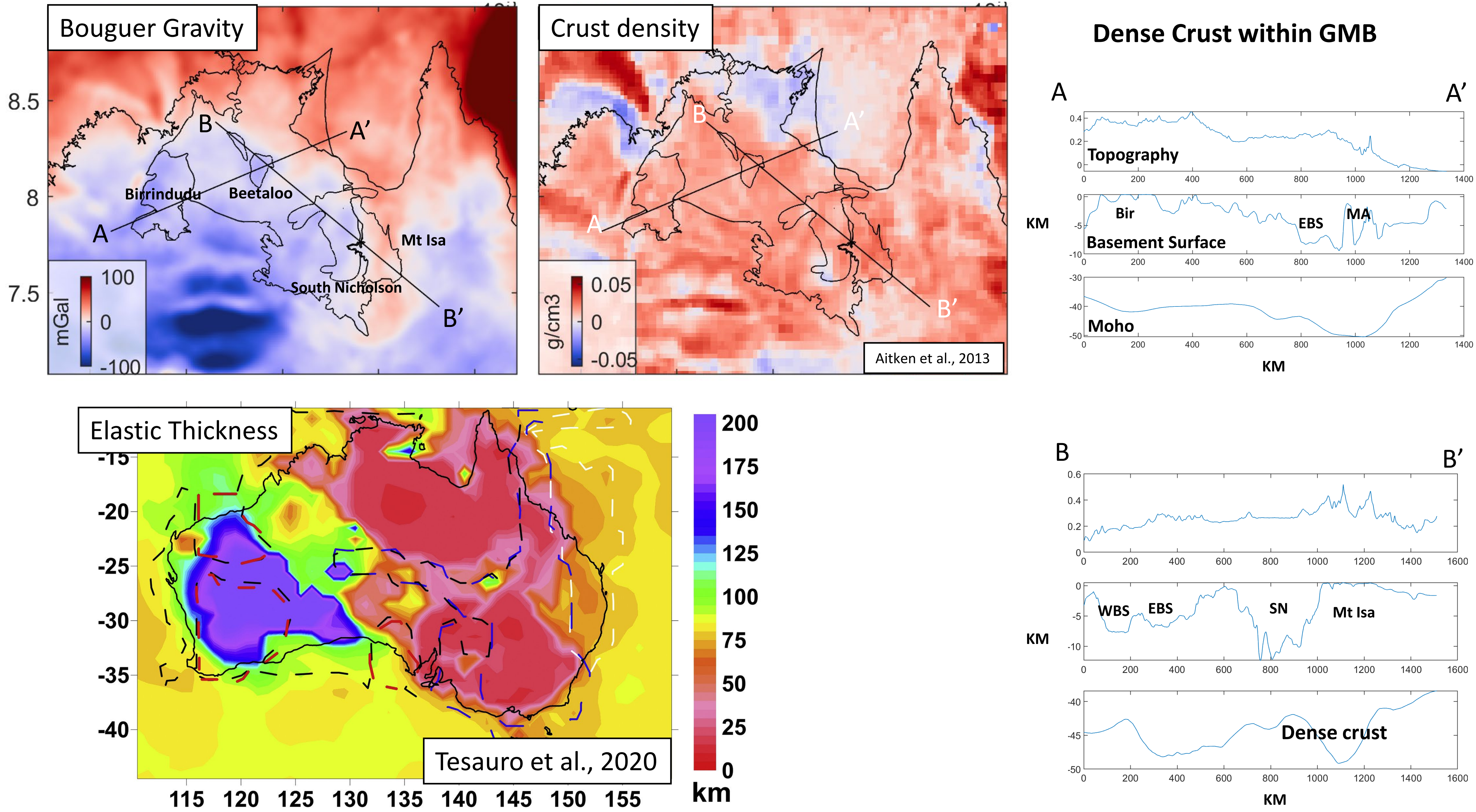
Moho and basement surface suggest different isostatic relationship







Bouguer Gravity
8.5
8
7.5
B
A′
A
B′
Birrindudu
Beetaloo
Mt Isa
South Nicholson
mGal
100
0
-100
Crust density
g/cm3
0.05
0
-0.05
Aitken et al., 2013
Dense Crust within GMB
A
A′
Topography
Bir
EBS
MA
Basement Surface
Moho
KM
KM
B
B′
WBS
EBS
SN
Mt Isa
Dense crust
KM
KM
Elastic Thickness
-15
-20
-25
-30
-35
-40
115
120
125
130
135
140
145
150
155
Tesauro et al., 2020
200
175
150
125
100
75
50
25
0
km

Motivation – geodynamic process driven by mantle thermal conditions

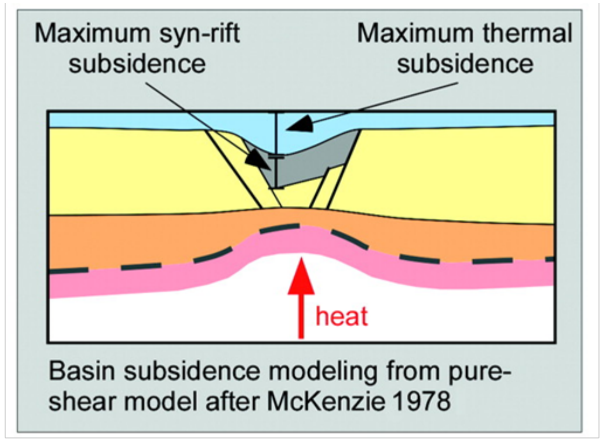


Image Lentini et al., 2010

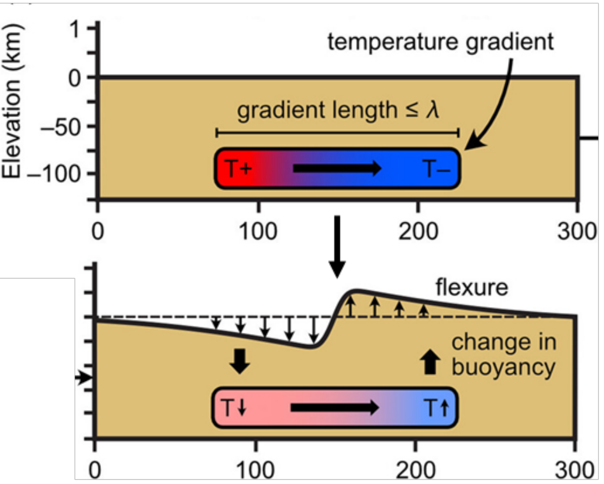


Image Paxman 2021

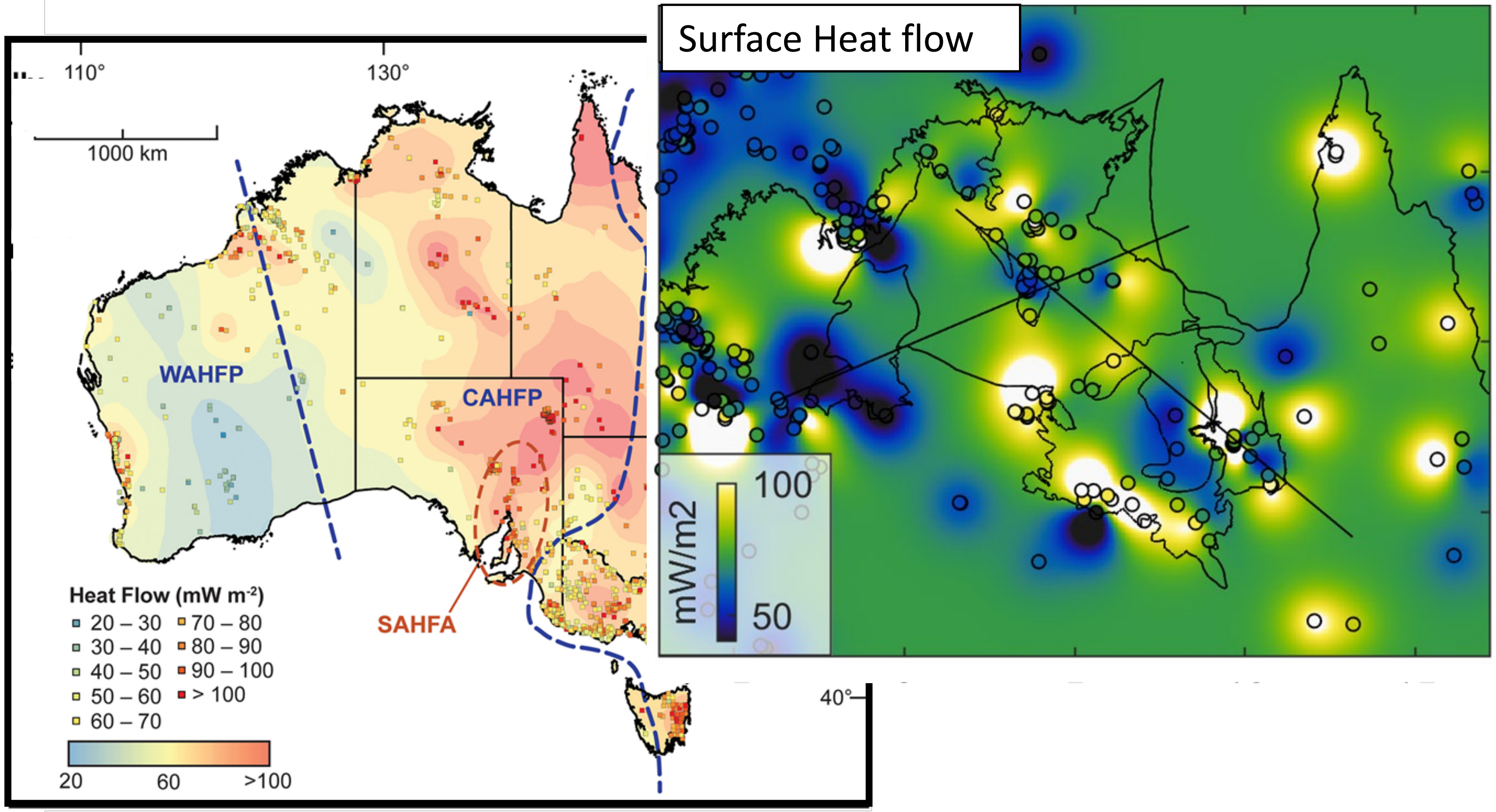


Image Pollett et al., 2017

Goal

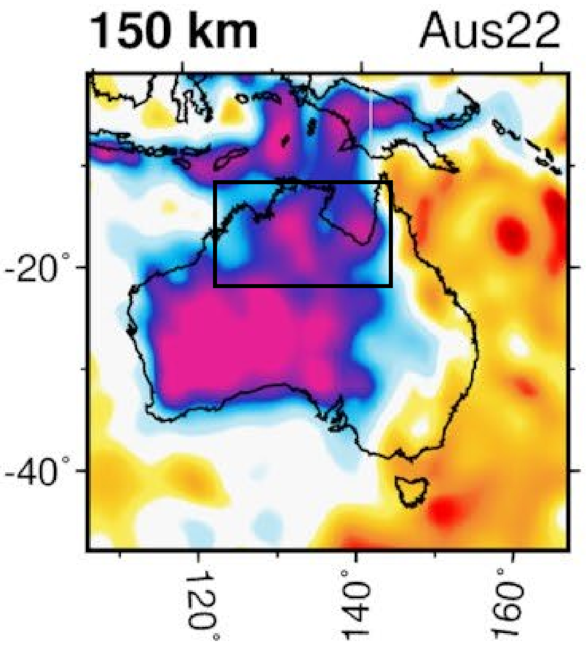
- Refine mantle properties using geophysics (with New tomography model)

- Understand Lithospheric heterogeneity beneath GMB

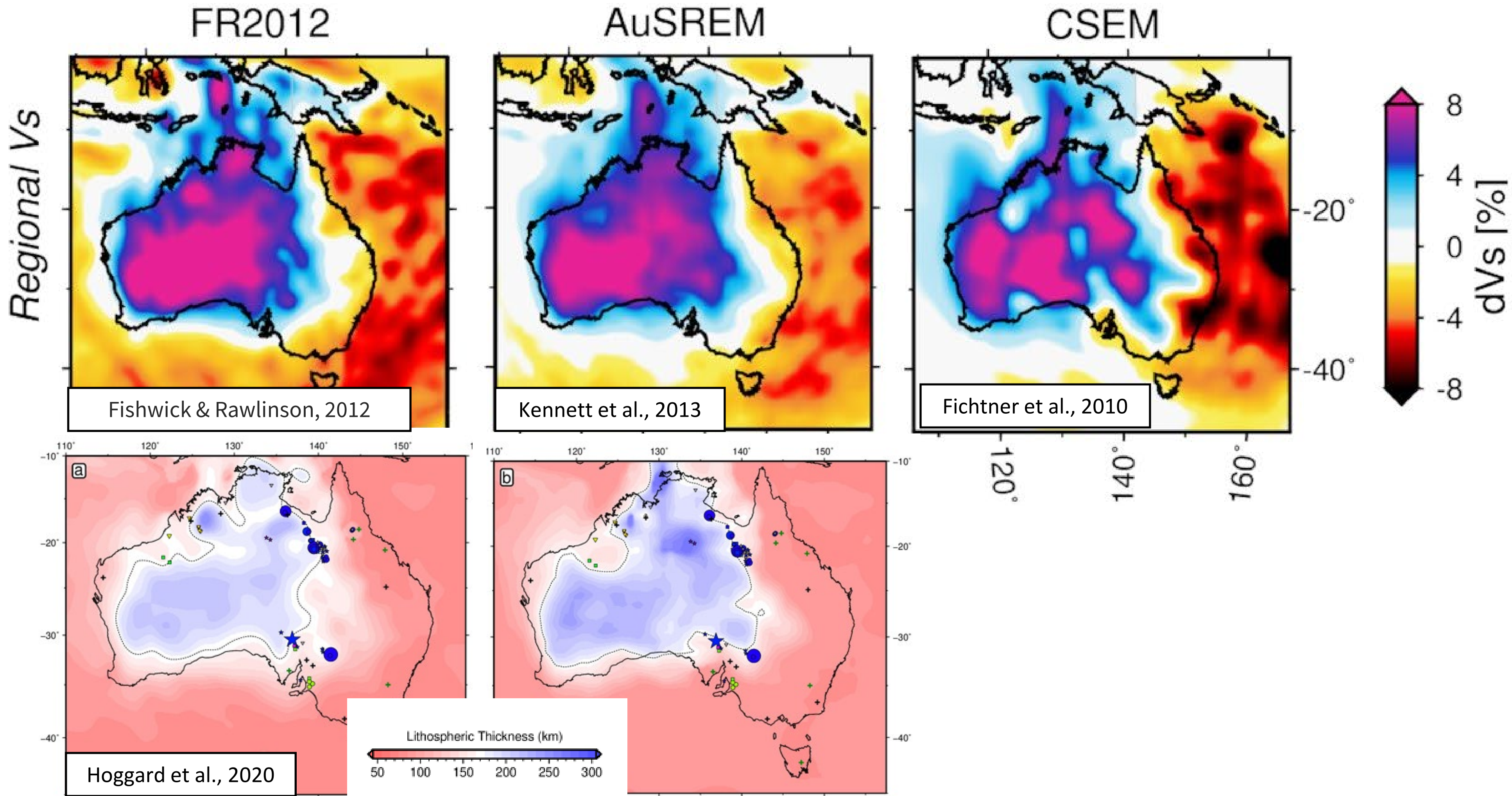
- How do we move forward?

Tomography variation

- New tomography model (Aus22) with higher resolution



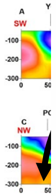
(de Laat et al., 2023)

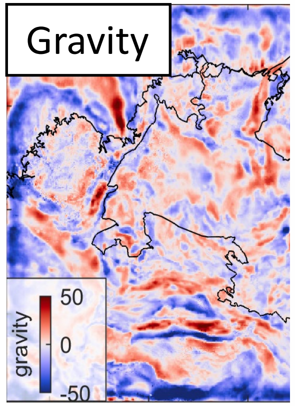


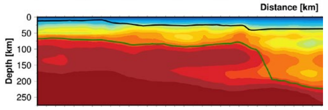
Link mantle properties from geophysics

Temperature
Composition

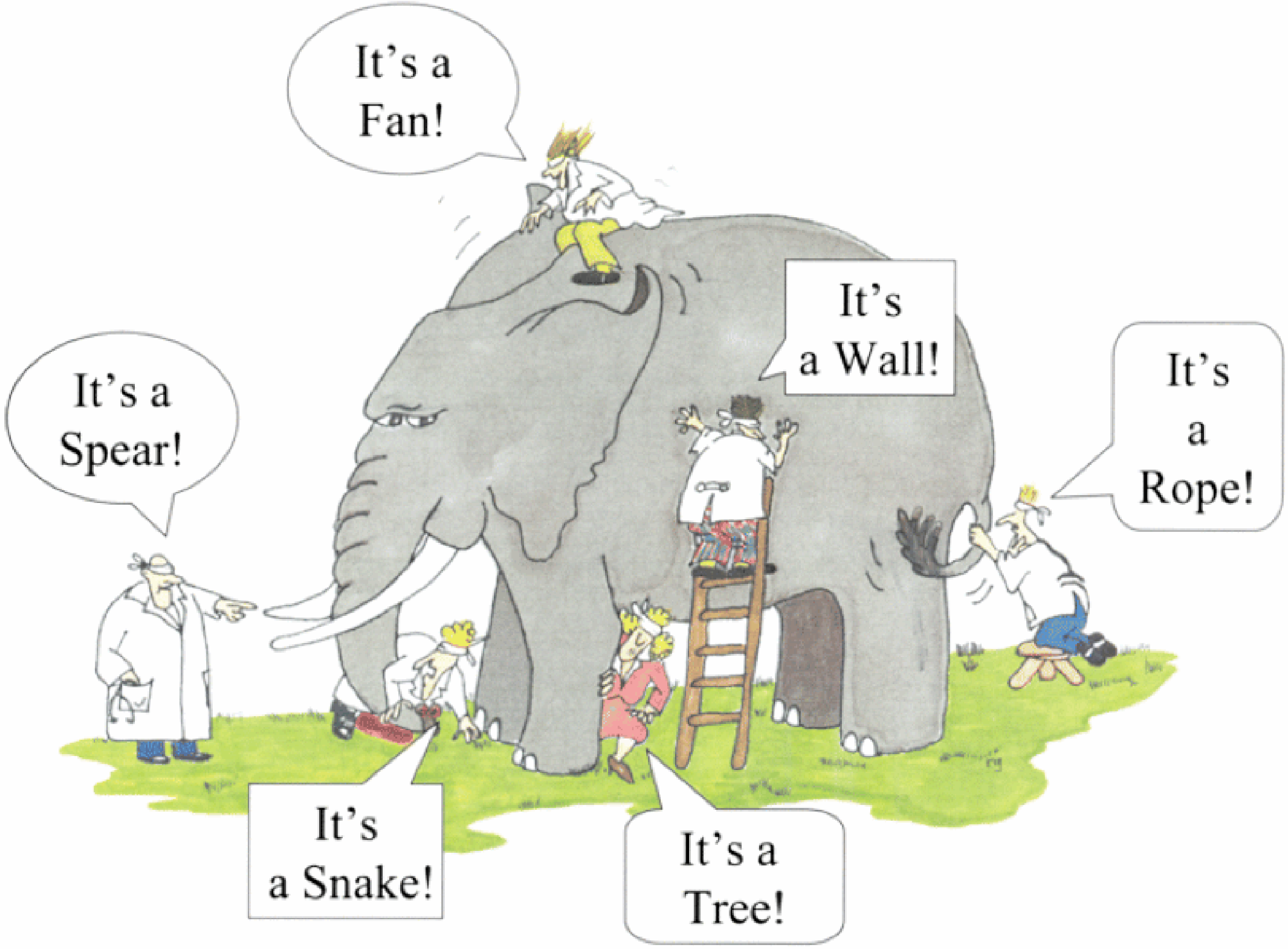
Tesauro et al., 2020







Pappa et al.



Himmelfarb J et al. Kidney International 2002; 62: 1524

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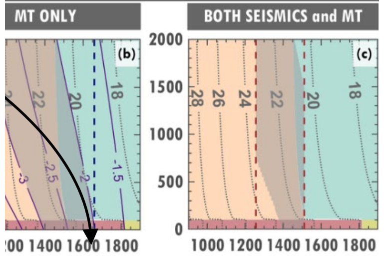
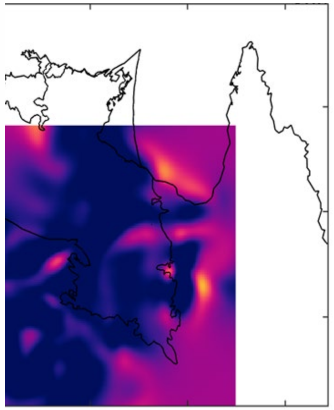
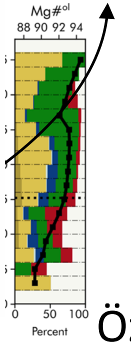
Ramirez et al., 2022



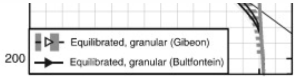




Temperature
Composition
Water content

Özaydın et al., 2022

Mather et al., 2011



Link mantle properties from geophysics

Temperature
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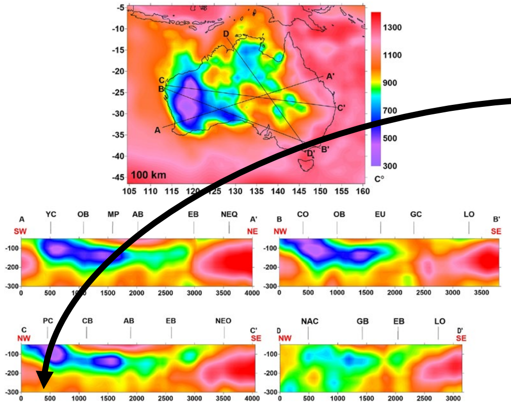
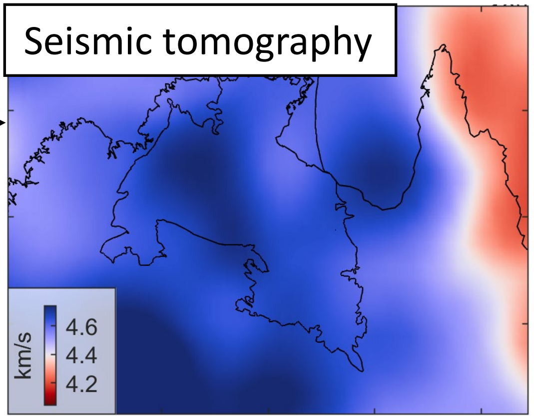


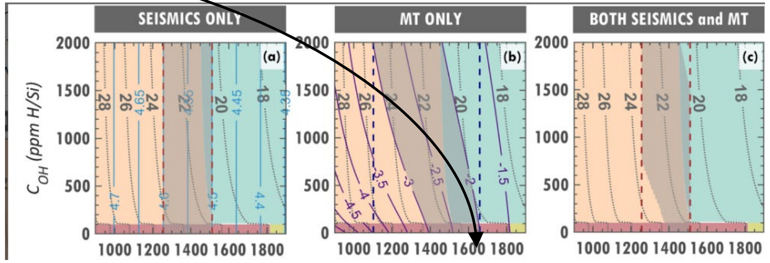
Density Thermal expansion

Seismic tomography

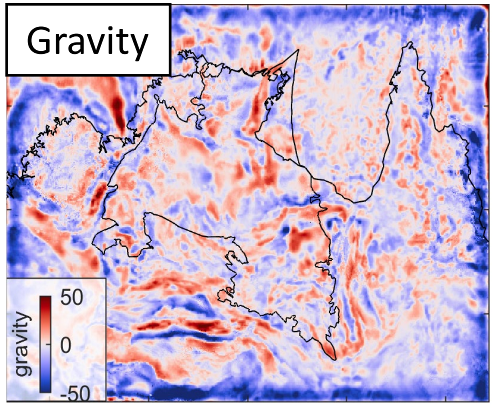


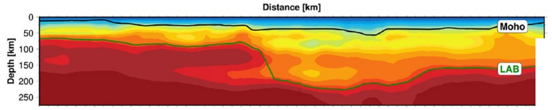
Temperature
Water content

Ramirez et al., 2022

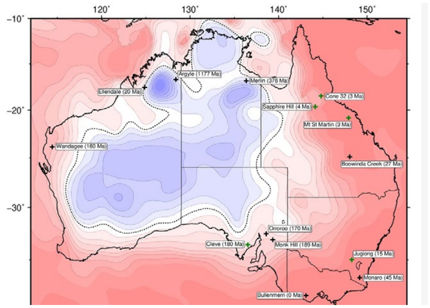


Gravity



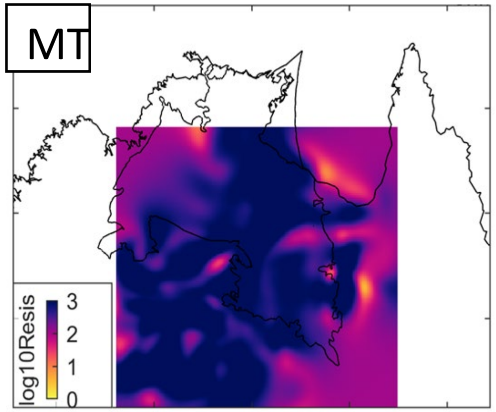


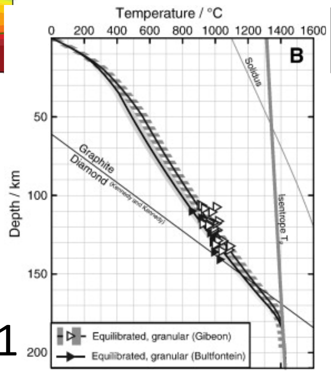
Pappa et al., 2020



Hoggard et al., 2020

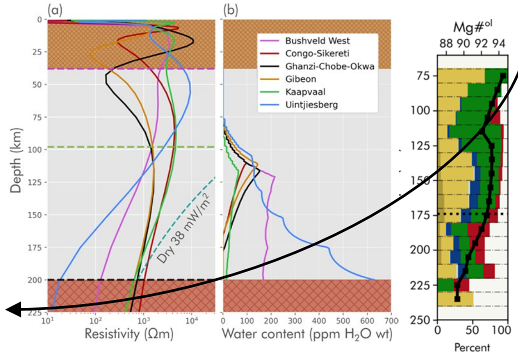
MT





Mather et al., 2011

Xenolith

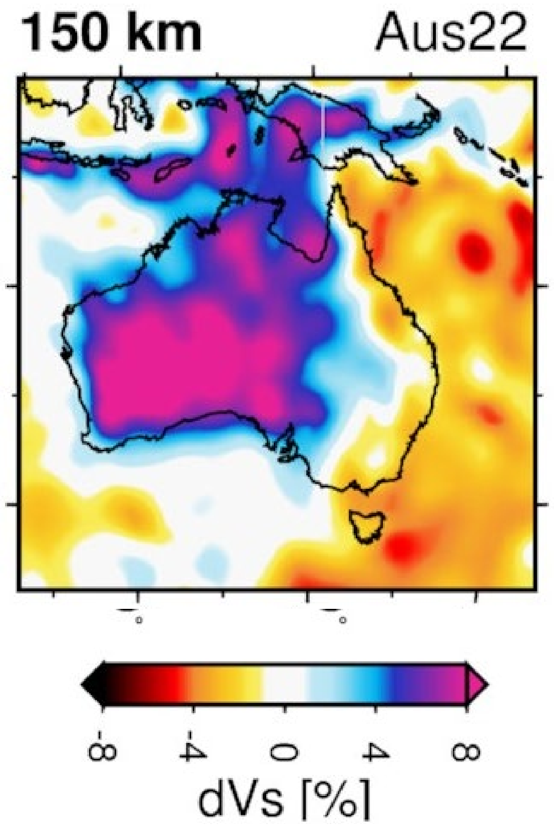


Temperature
Composition
Water content

Özaydın et al., 2022

Constrain mantle temperature

Seismology + Mineral physics

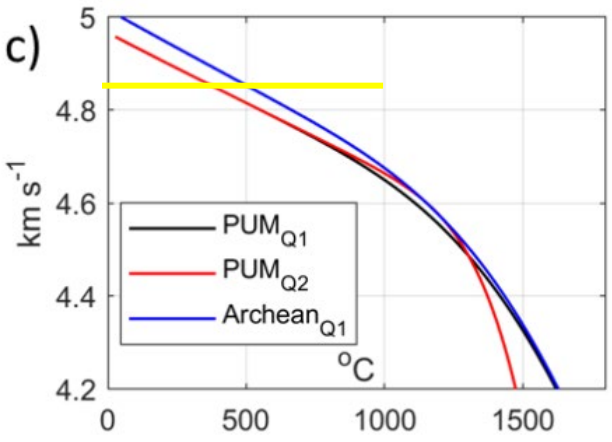


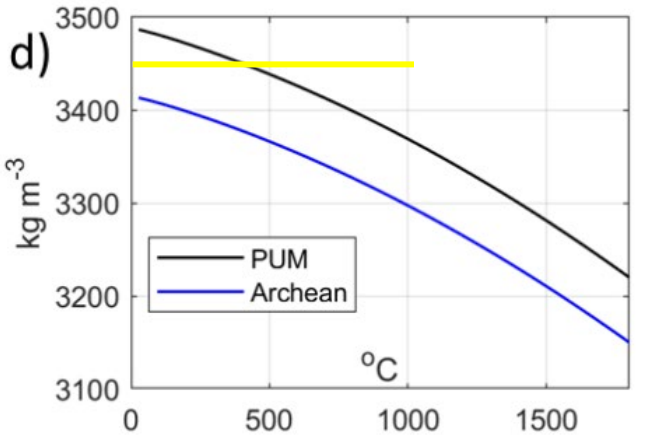
$$V_s = V_{s(anh)} \times V_{s(ane)}$$

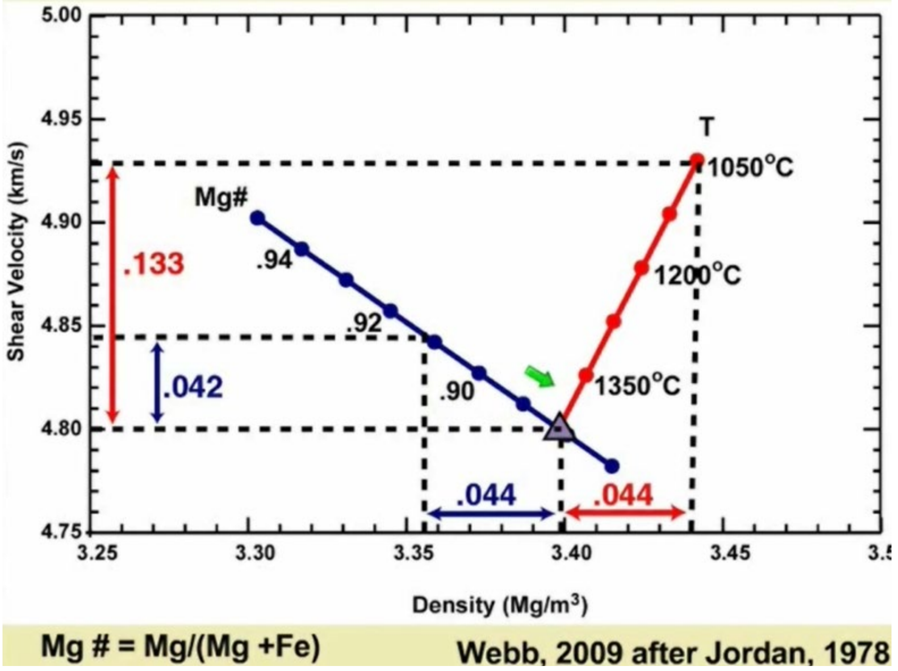
$$V_{s(anh)} = \sqrt{\frac{\mu}{\rho}}$$

$$\mu(P,T,X_{Fe}) = \sum_i [\mu_i(P_0,T_0) + (T-T_0)\frac{\partial \mu_i}{\partial T} + (P-P_0)\frac{\partial \mu_i}{\partial P} + X_{Fe}\frac{\partial \mu_i}{\partial X_{Fe}}] \times X_i$$

μ	dμ/dt	dμ/dP	dμ/dXFe
79.850	-0.013	1.458	-19.064
XFe ↑		Mg# ↓	
0.073-0.107		92.7-89.3	

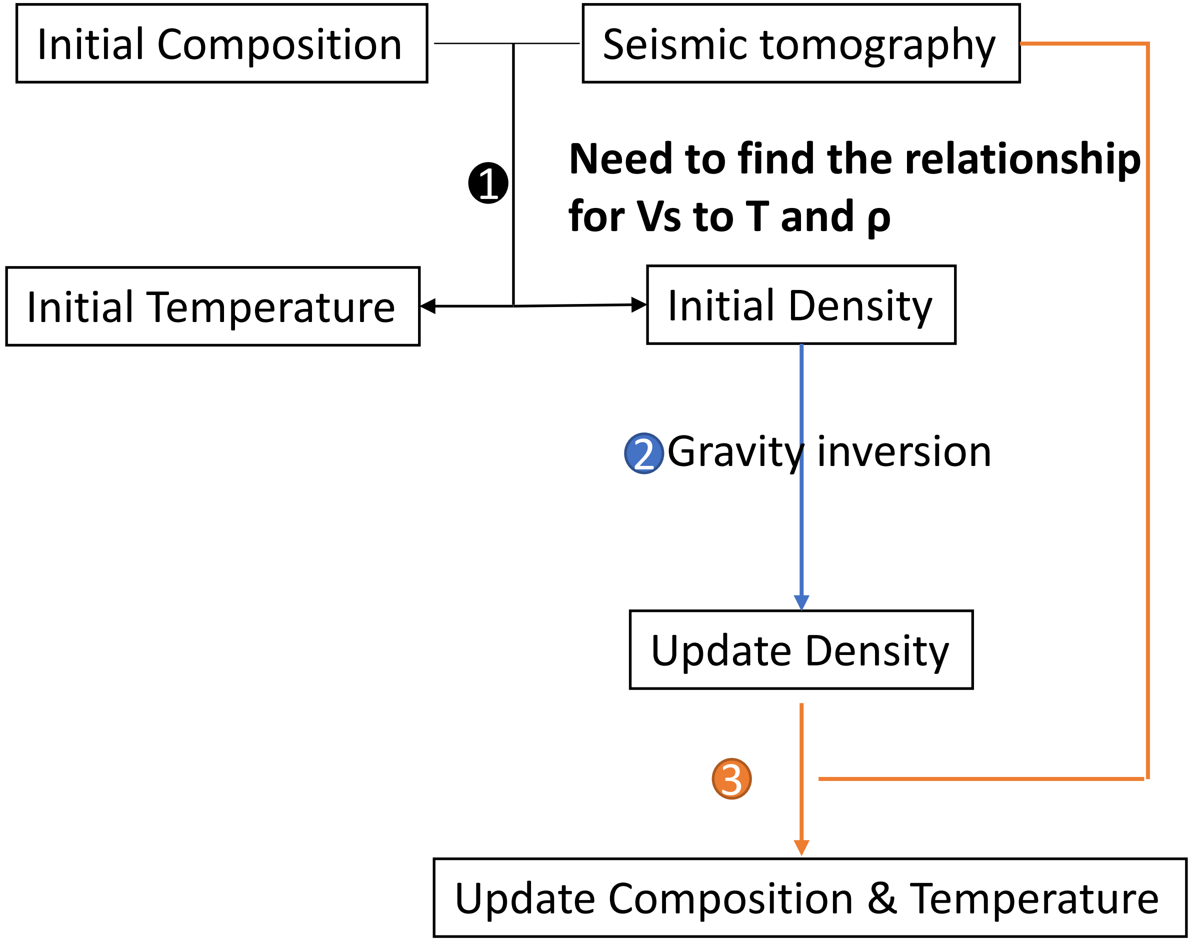


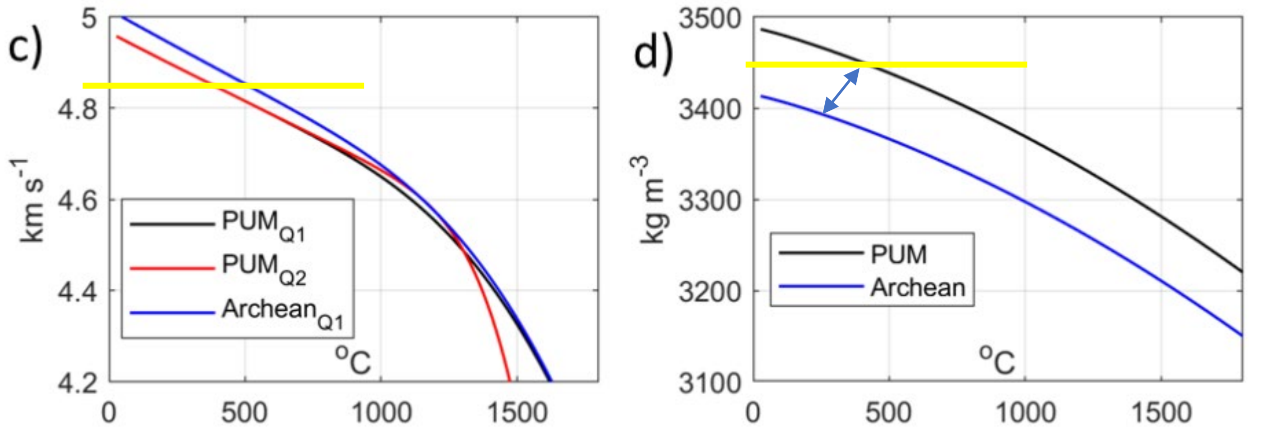


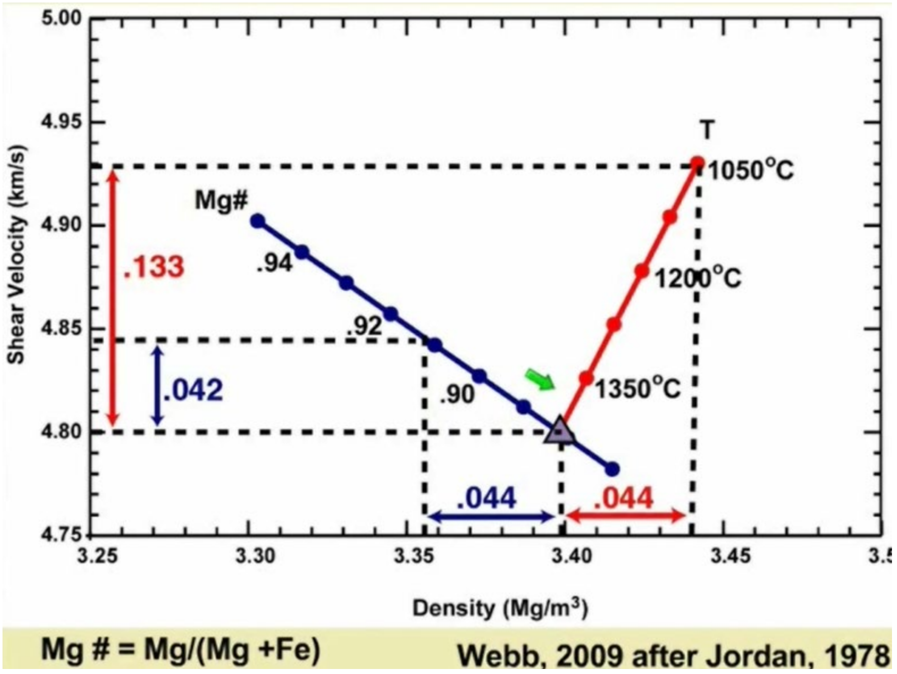


Goes, S., Govers, R., & Vacher, A. P. (2000). Shallow mantle temperatures under Europe from P and S wave tomography. Journal of Geophysical Research: Solid Earth, 105(B5), 11153-11169.

Constrain mantle temperature





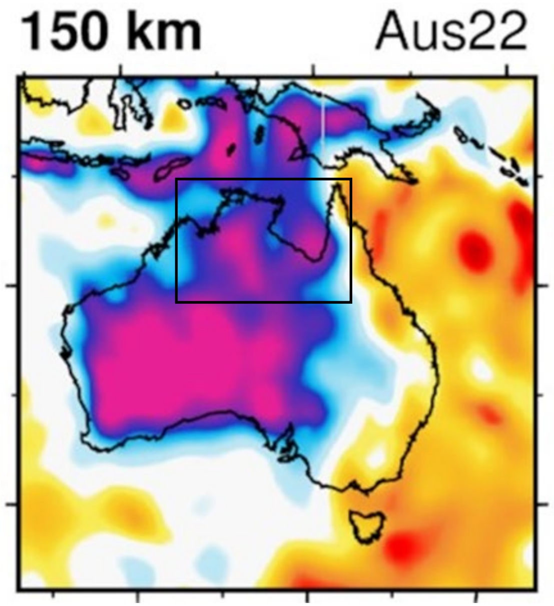


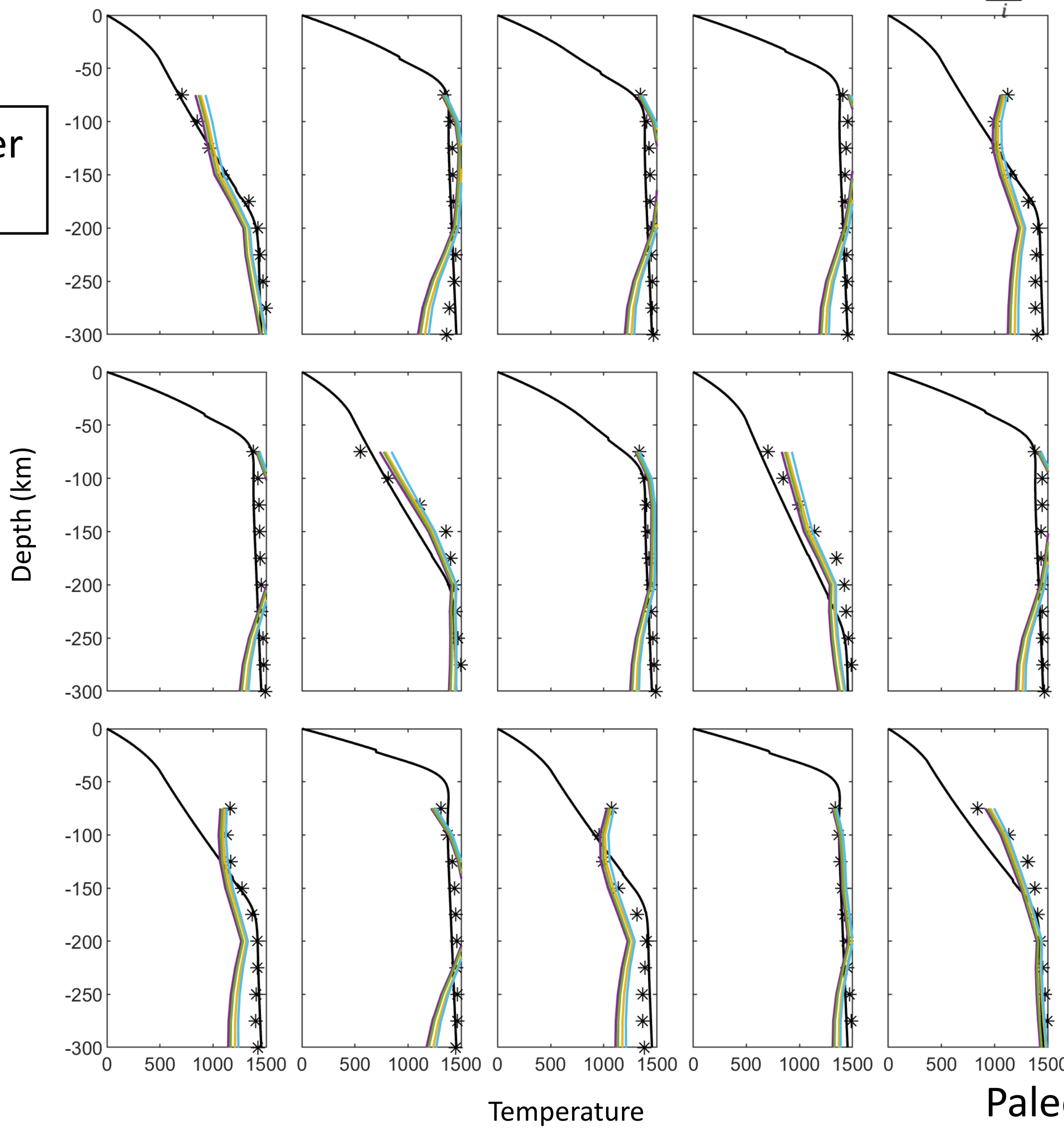
Inverse method to constrain conversion parameter

$$\mu(P,T,X_{Fe}) = \sum_i \left[\mu_i(P_0,T_0) + (T-T_0)\frac{\partial \mu_i}{\partial T} + (P-P_0)\frac{\partial \mu_i}{\partial P} + X_{Fe}\frac{\partial \mu_i}{\partial X_{Fe}}\right] \times X_i$$

Constrain conversion parameter in Continental scale model

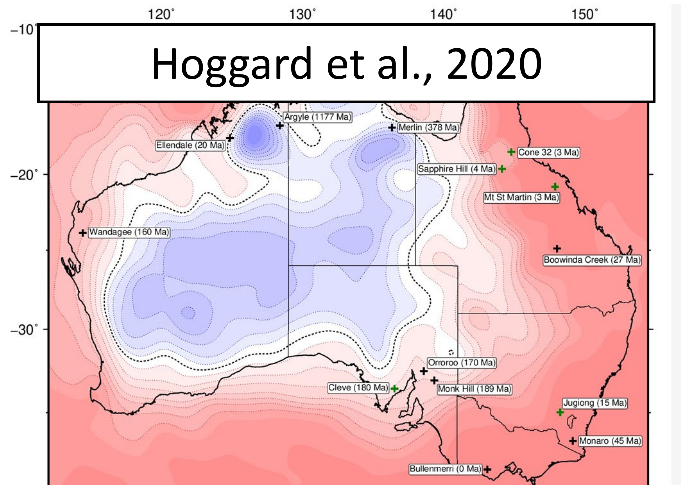
Refine solution in NAC





Richard et al., 2020;
Hazzard et al., 2023

Hoggard et al., 2020



Paleo-geotherm from Xenolith/Xenocrystal

Esys-escript

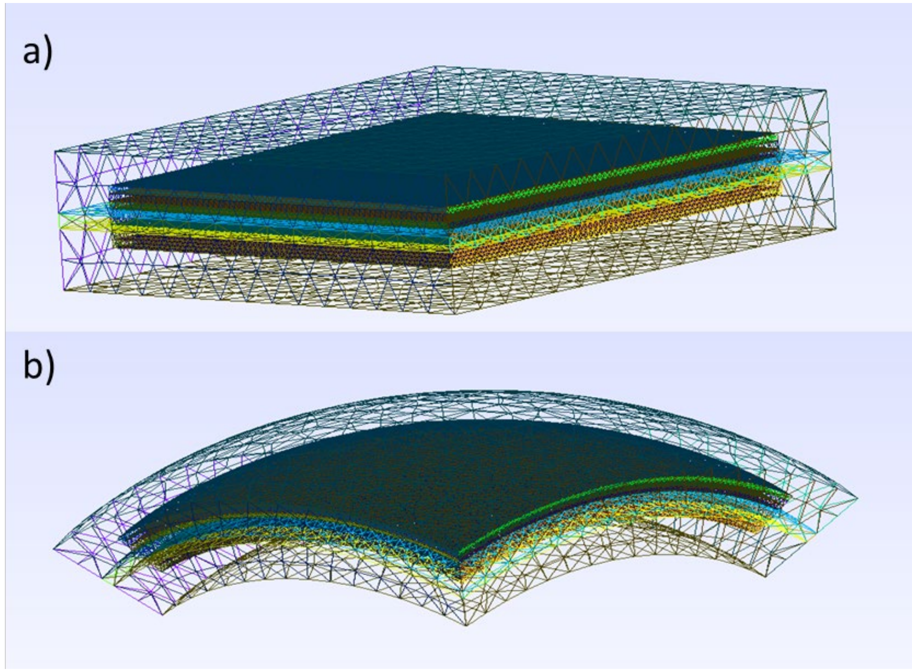


Table 3. Gravity: Parallel computing performance per inversion iteration step for the finest mesh 801 over different numbers of computer nodes. Compute time is given in seconds. Efficiency is the ratio of the product of time and number of cores to the product of time for 2 nodes and 40 cores .

Nodes	2	4	6	8	10	12	14	16
Cores	40	80	120	160	200	240	280	320
Time	95.9	43.3	30.3	21.9	17.7	14.8	12.3	10.7
Efficiency	1.00	1.11	1.05	1.10	1.07	1.07	1.11	1.12

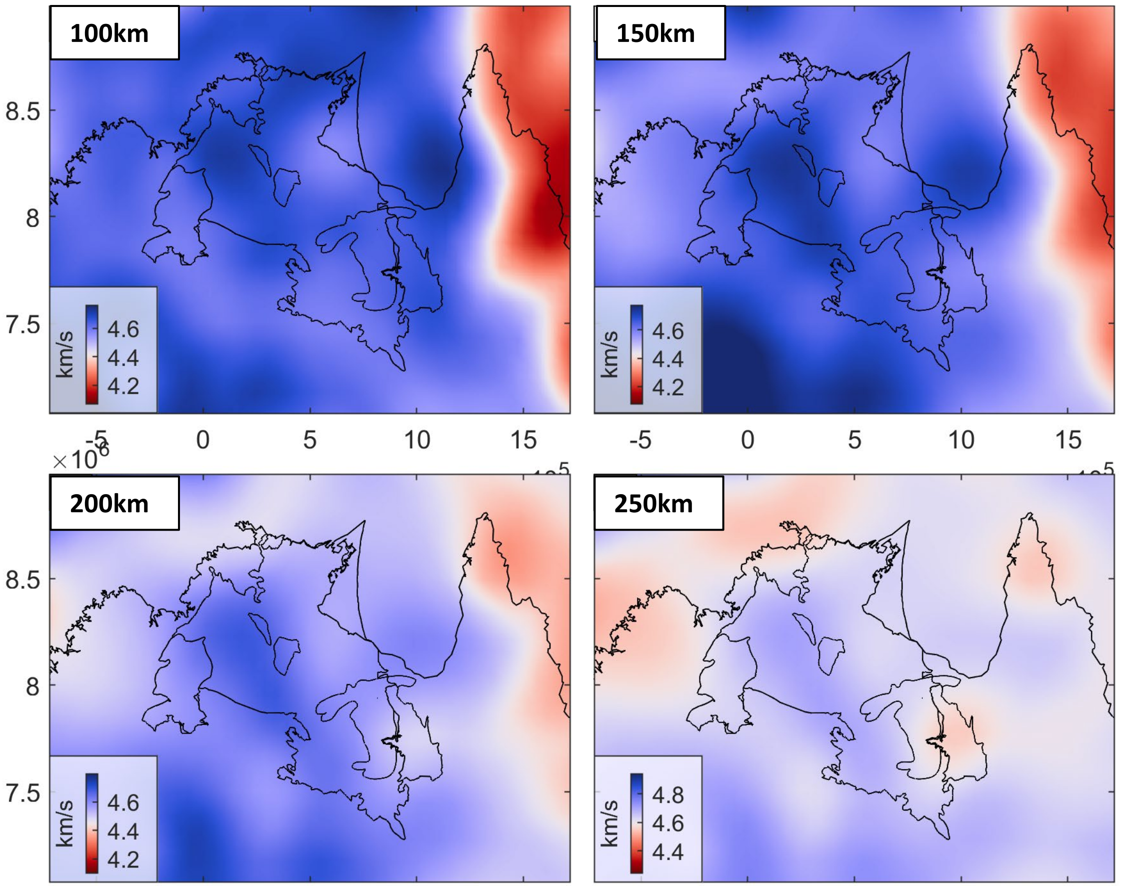
Esys-escript with a new solver (AMG-PCG matrix solver) using unstructured mesh (Codd et al., 2021) in Geodetic coordinate.

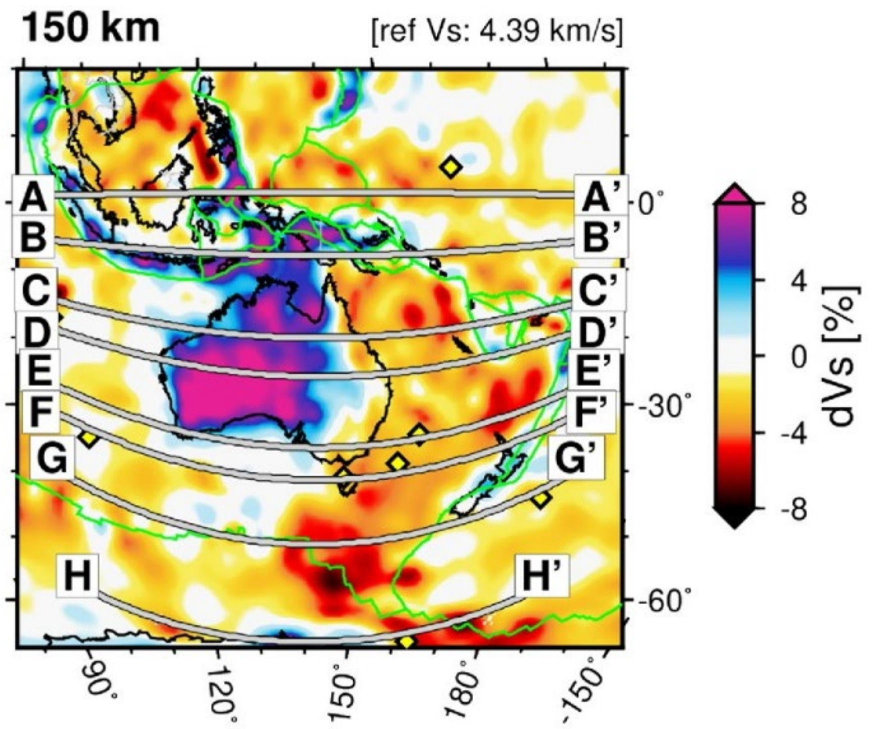
Preserve topography, earth curvature, crust structures in the model.

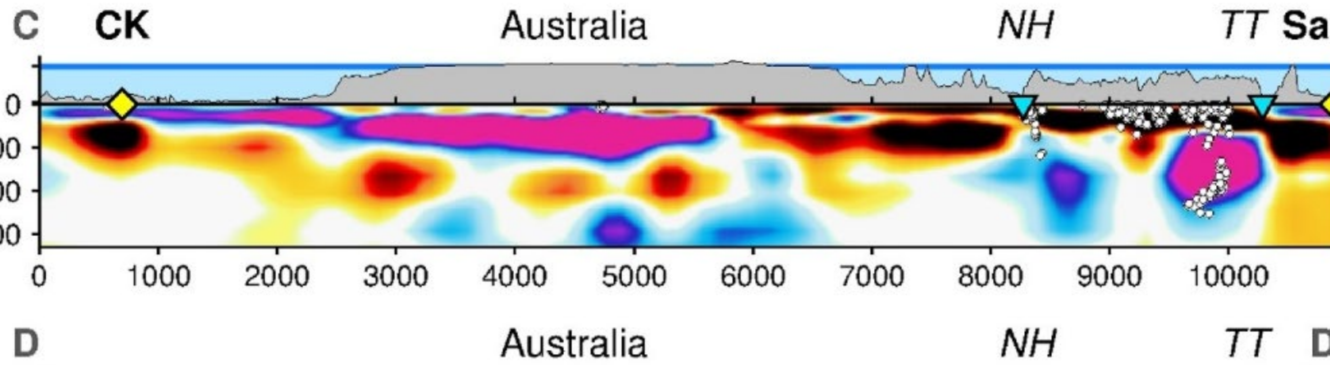
Codd, A. L., Gross, L., & Aitken, A. (2021). Fast multi-resolution 3D inversion of potential fields with application to high-resolution gravity and magnetic anomaly data from the Eastern Goldfields in Western Australia. Computers & Geosciences, 157, 104941.

https://esys-escript.github.io/ esys-escript

Aus22



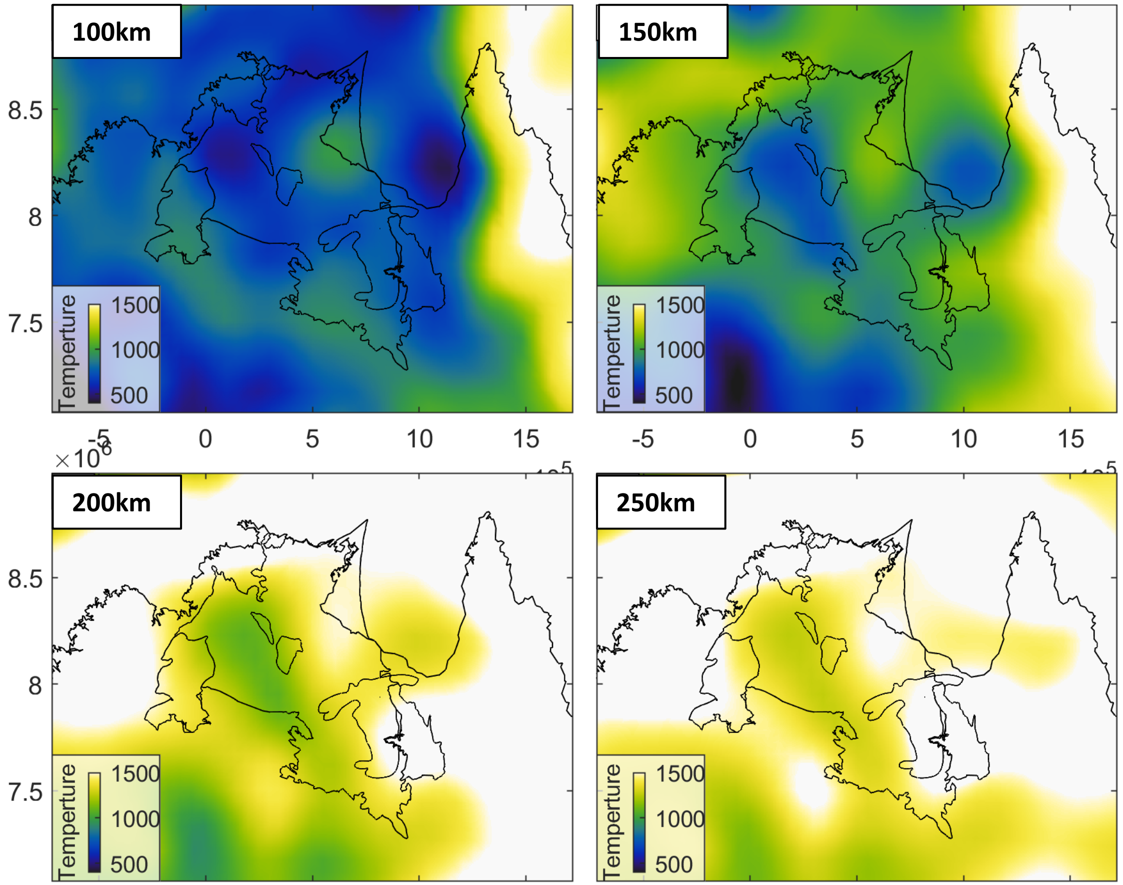


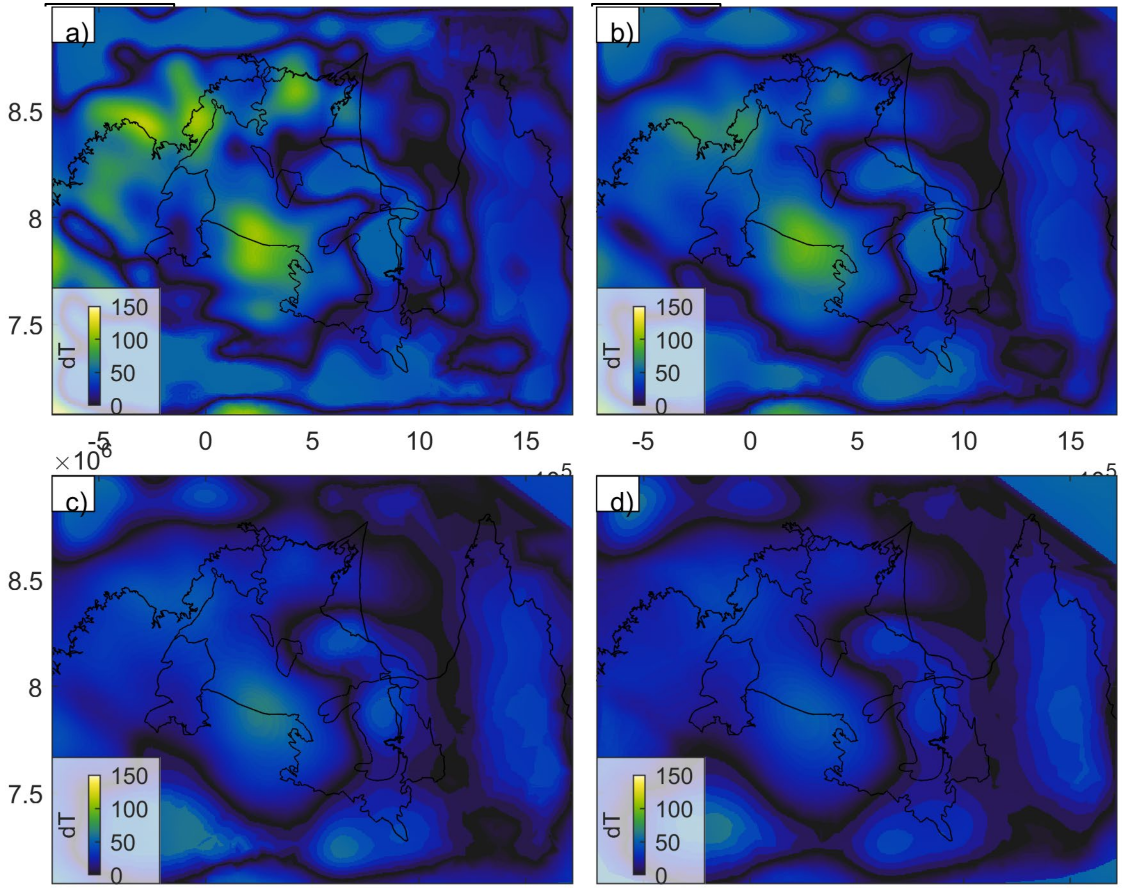


Aus22 (de Laat et al., 2023)

Temperature

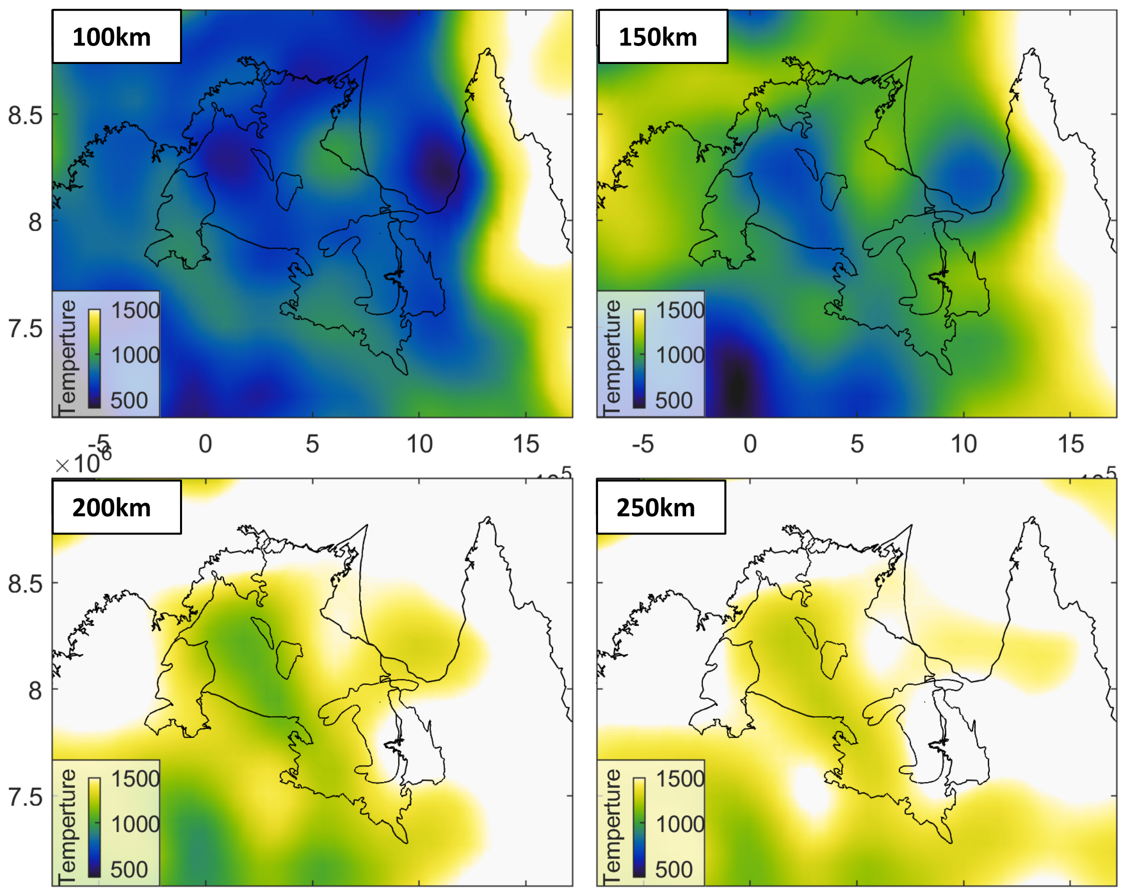
Temperature change after inversion



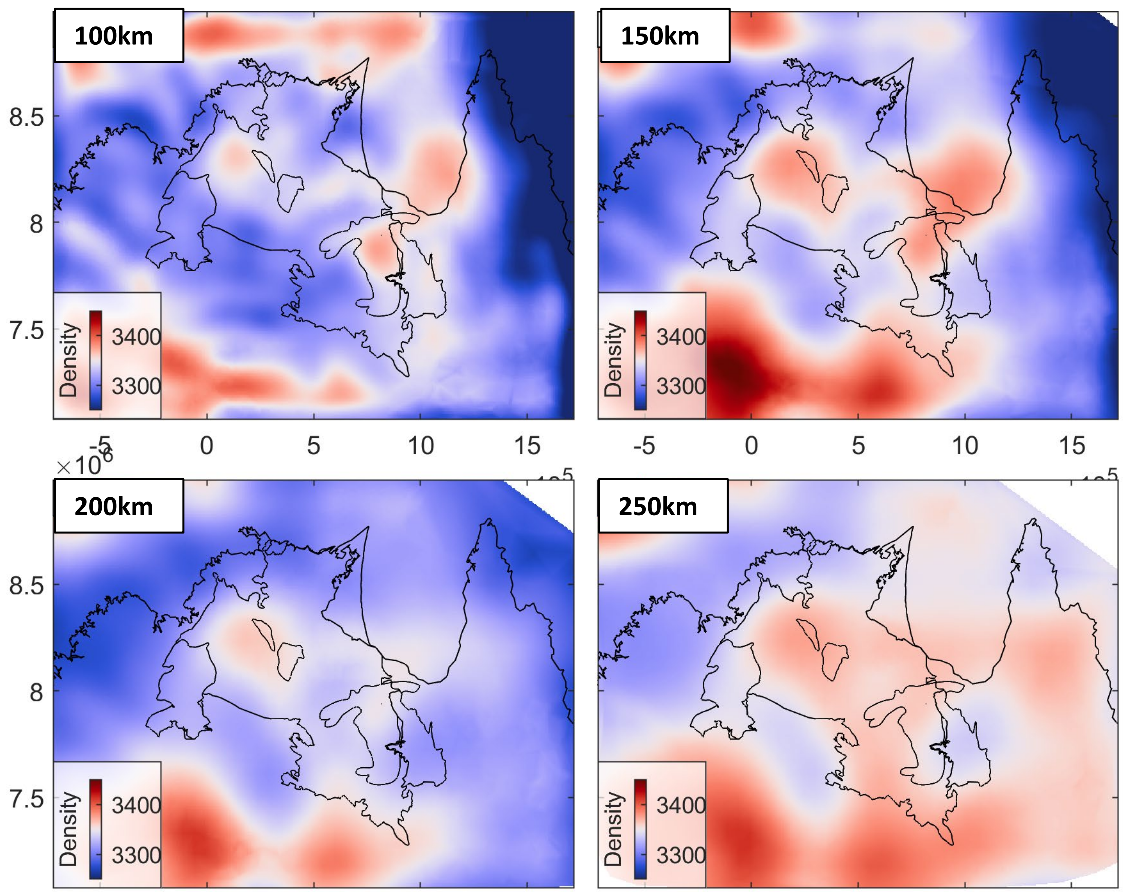


Aus22 (de Laat et al., 2023)

Temperature

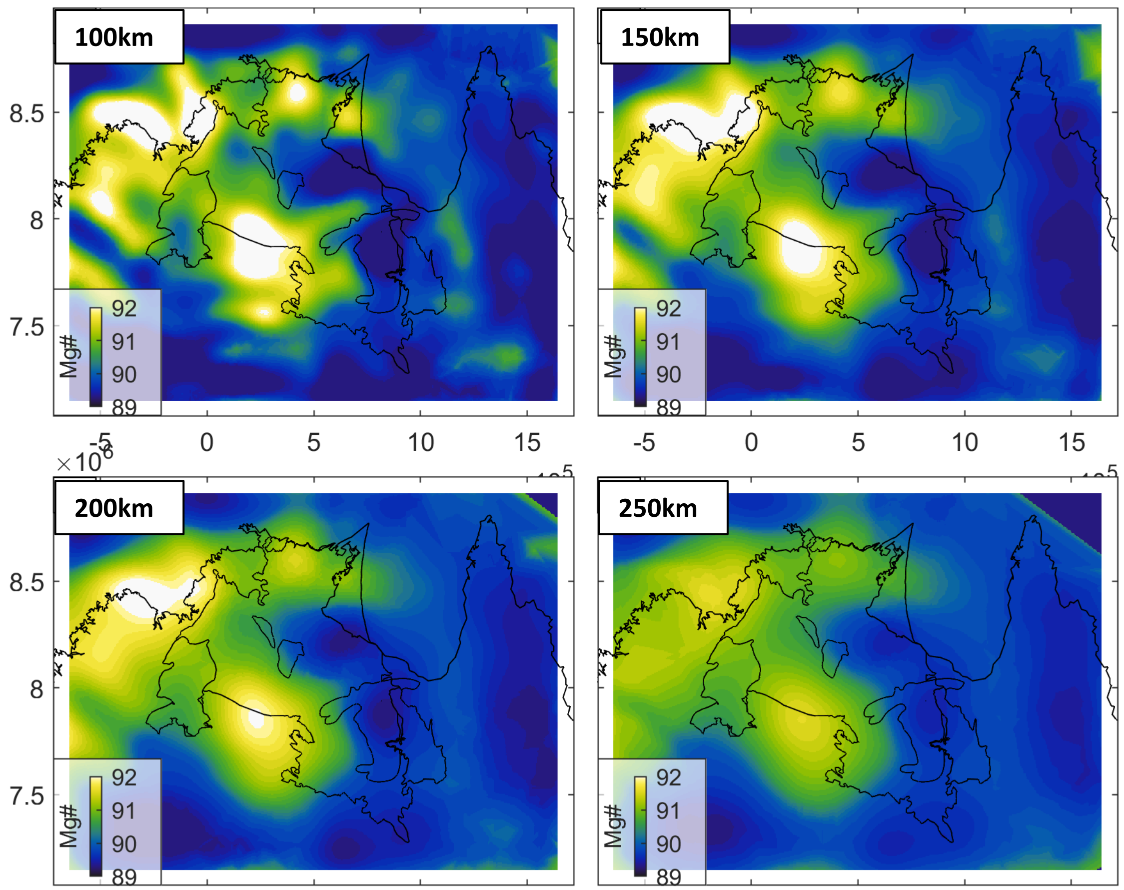


Density



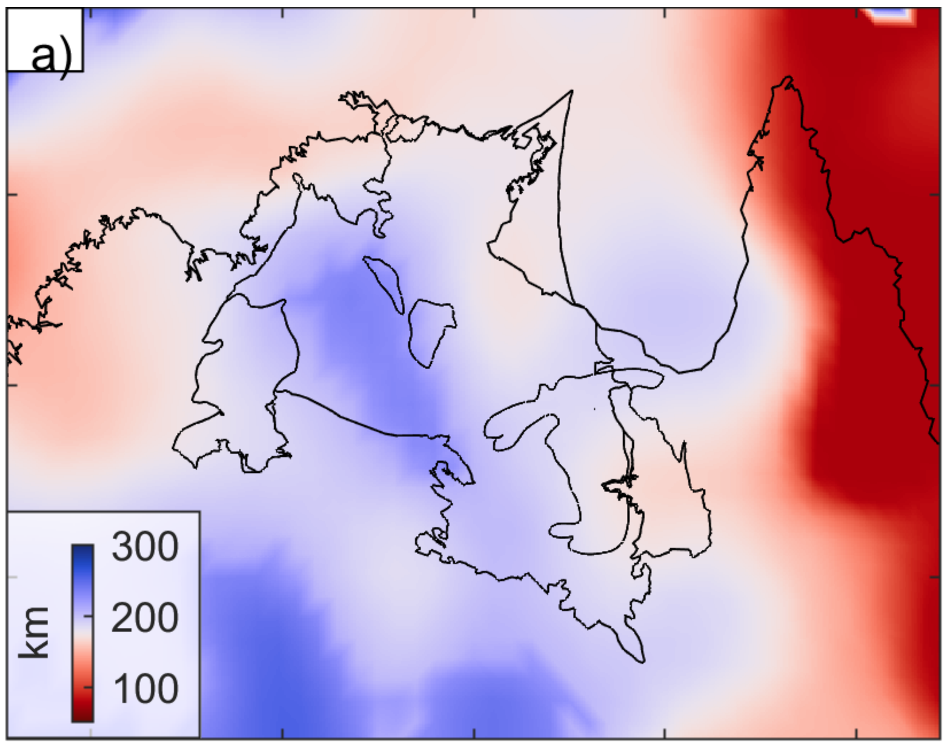
Aus22 (de Laat et al., 2023)

Mg#



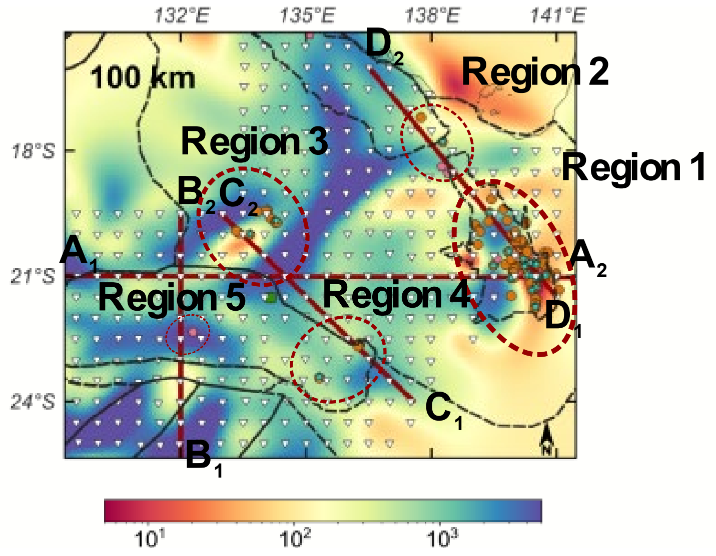
100km
150km
200km
250km
8.5
8
7.5
-5
0
5
10
15
$\times 10^6$
92
91
90
89
Mg#

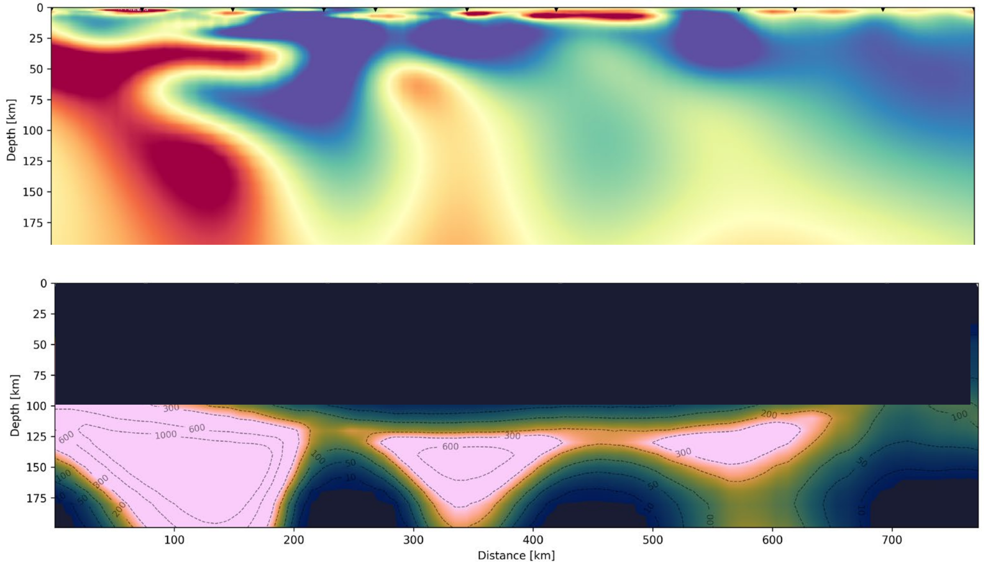
LAB



a)
300
200
100
km

Water Content



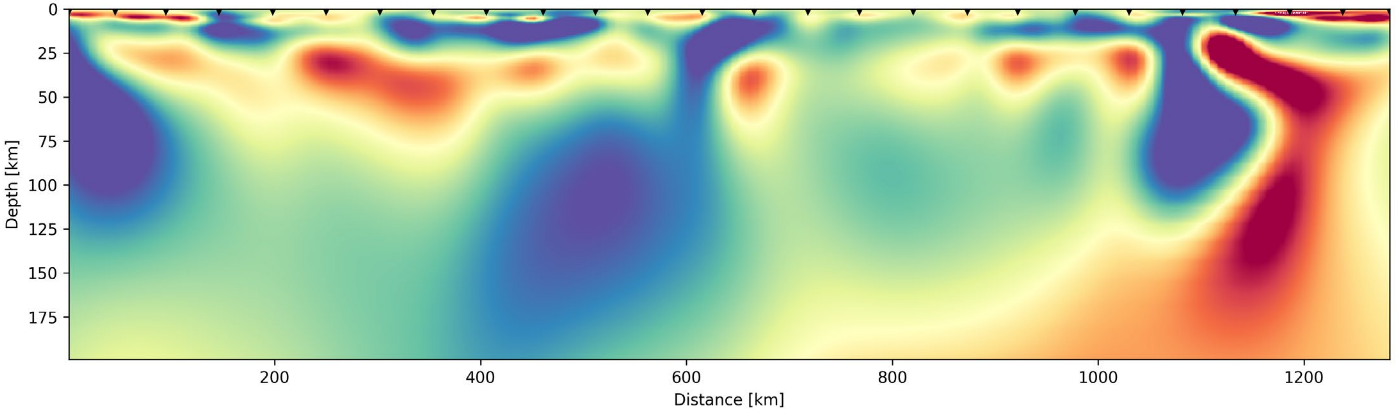


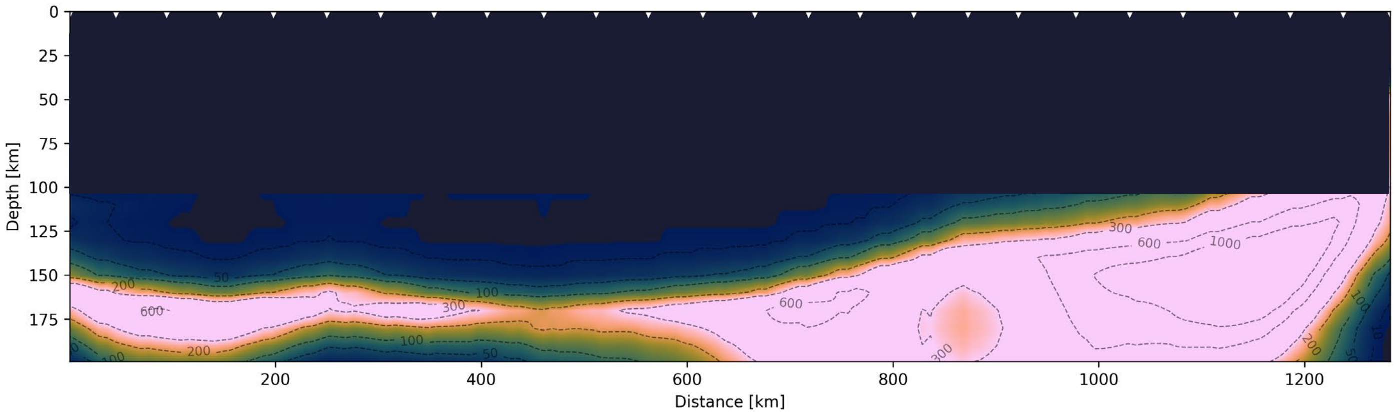
MATE

Mantle Analysis Tools for Electromagnetics

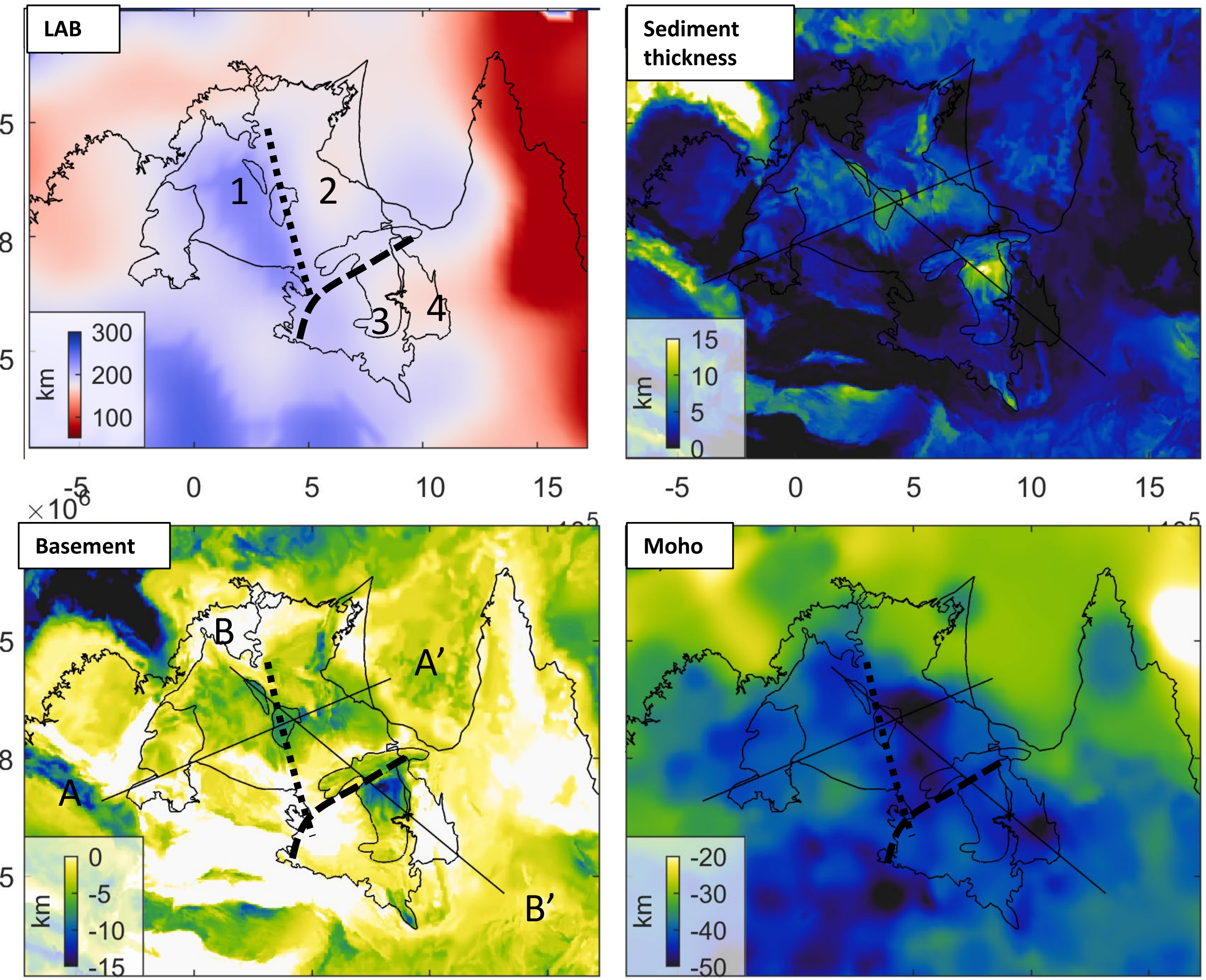
https://github.com/sinanozaydin/MATE

Mt Isa

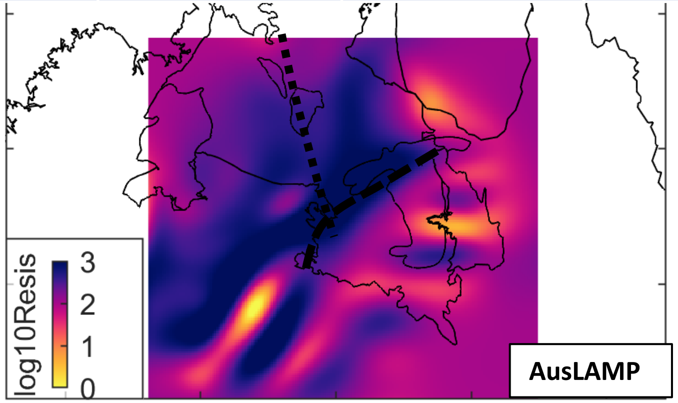




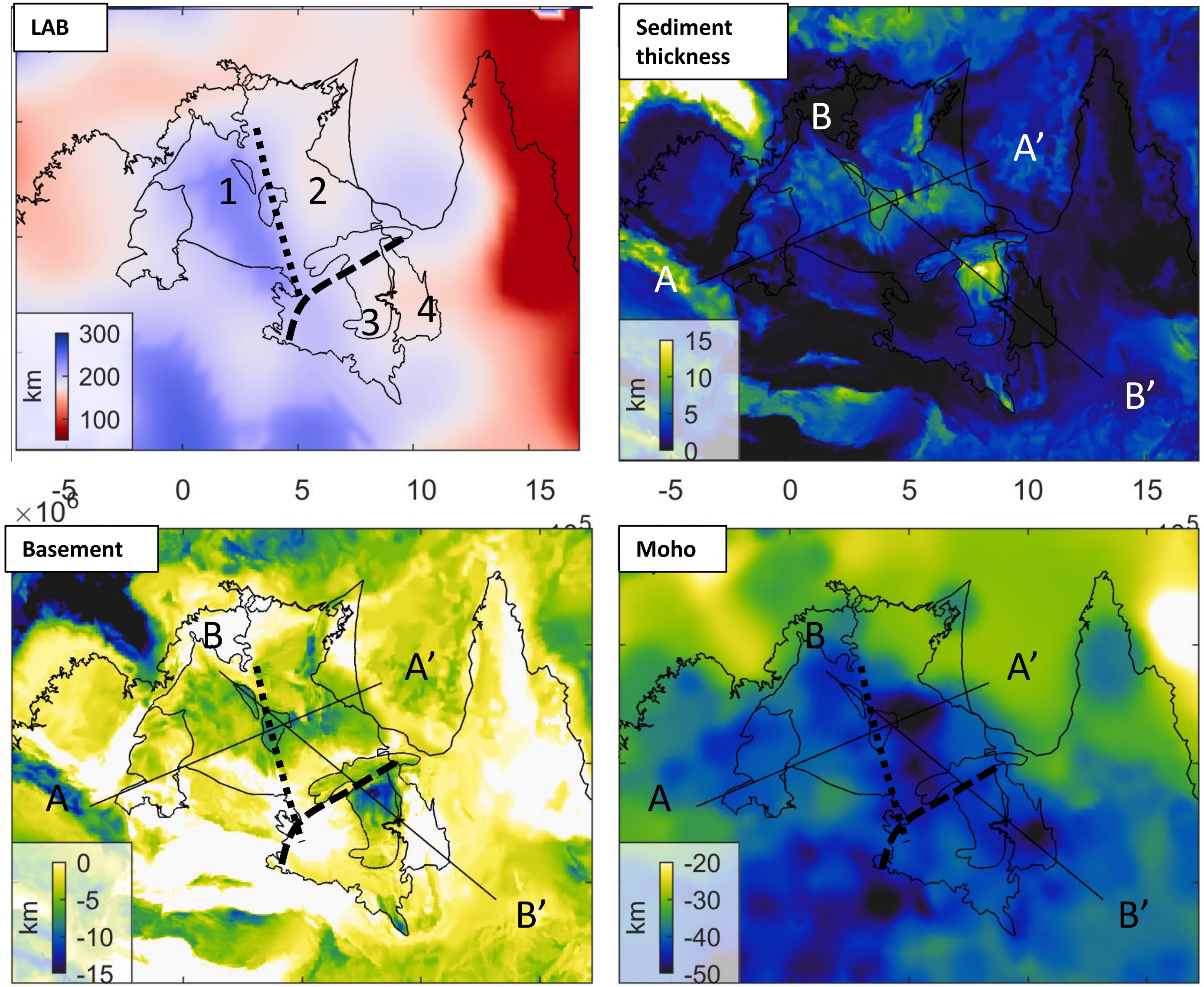
Domain boundary ?

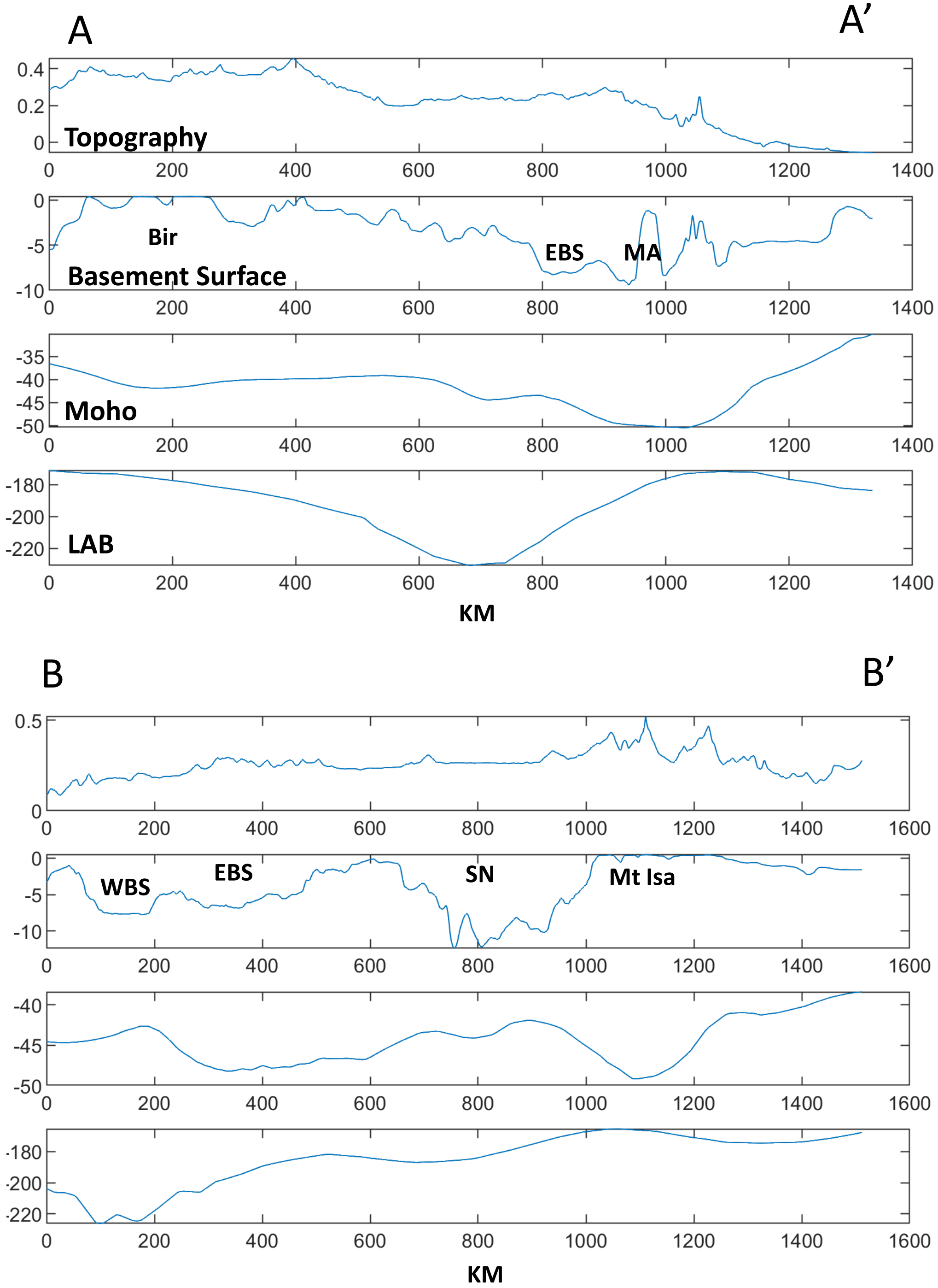


Domain	1	2	3	4
Basin name	Birrindudu, WBS	McArthur (EBS?)	South Nicolson	Mount Isa
Sediment thickness	Thin(<5 km)	Thick(>5km)	Thick (>5km up to 13 km)	Very thin(<1km)
Moho	Shallow (40 -42 km)	Deep (45 - 50 km)	Shallow (40 - 44 km)	Deep (45 - 50 km)
LAB	Deep (>220km)	Shallow (170 km)	Shallow (170 km)	Shallow (160 km)
Mantle Temperature	Low	High	High	High
Resistivity	Medium (No data)	Low	High	High
Surface Heat flow	High at edge of basin High WBS (86 mW/m^2)	High McArthur Low EBS (60 mW/m^2)	Low (56 mW/m^2)	High (75 – 95 mW/m^2)



Domain boundary ?





Geological implication – isostasy

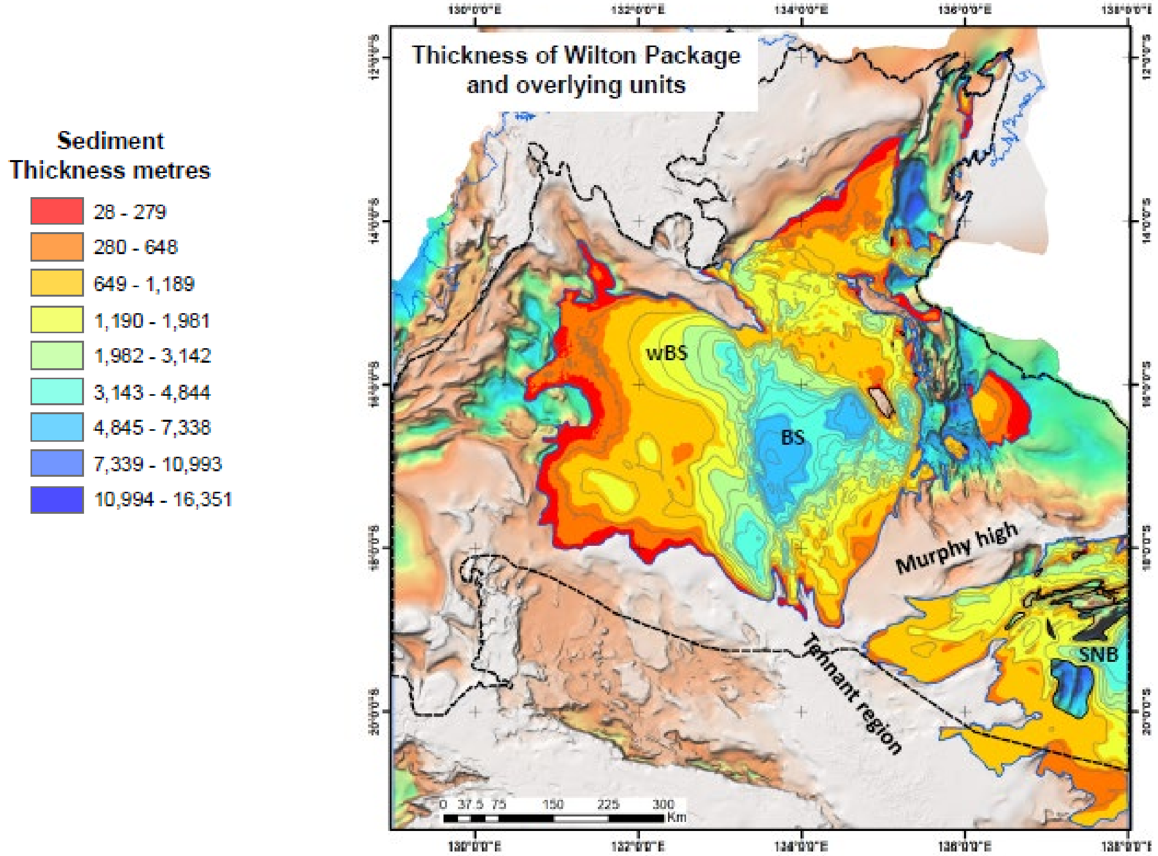
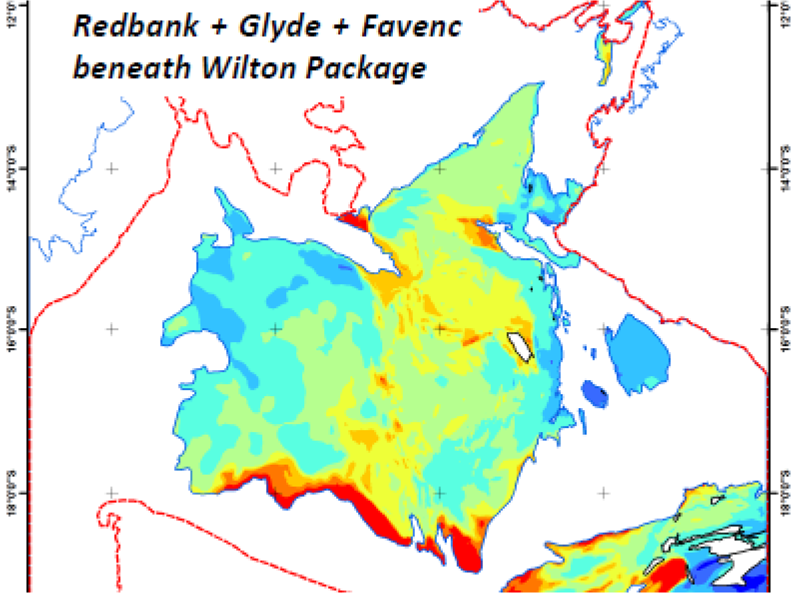
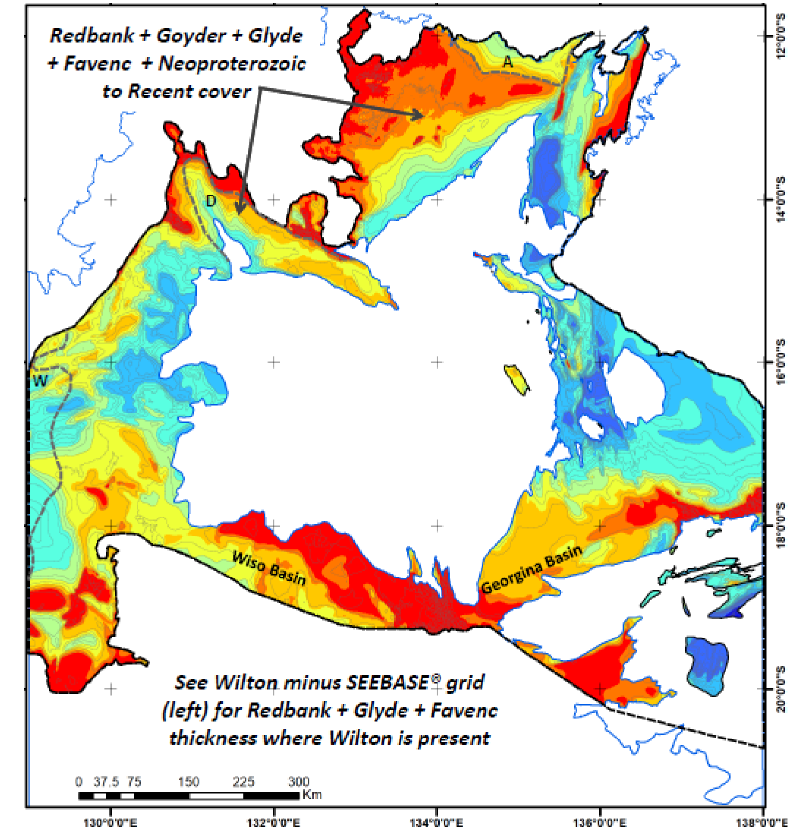


Figure: SEEBASE

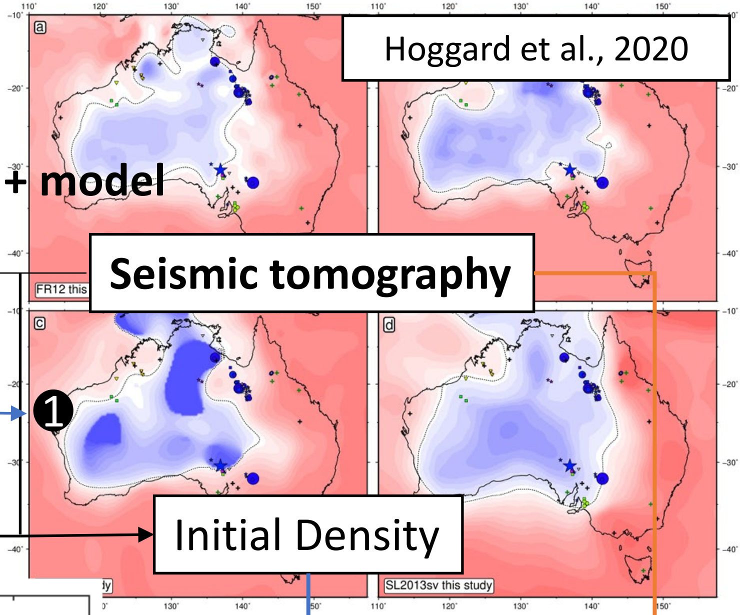




Move forward

Model + model

Hoggard et al., 2020



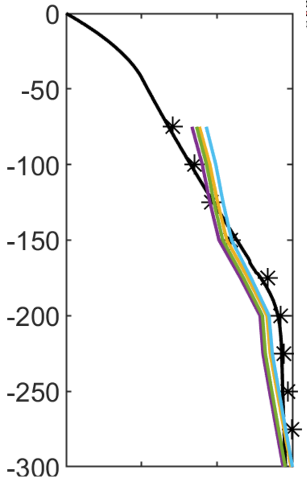
Initial Composition

Seismic tomography

Xenolith, Plate cooling etc.. ❶

Initial Temperature

Initial Density



② **Gravity** inversion

Update Density

③

MT resistivity model

Update Composition & Temperature

Water Content etc…

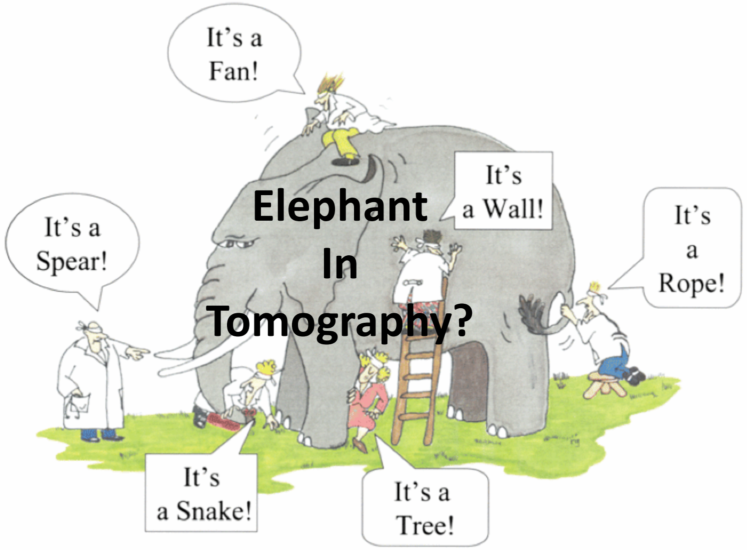
Seismic Wave

Thermal dynamic

MT measurement

Gravity

Joint inversion?



Himmelfarb J et al. Kidney International 2002; 62: 1524

Conclusion

- Generate a new mantle temperature model beneath NAC
- Broder lithospheric architecture indicate 4 lithospheric domains
- Relationship between Basin thickness, Moho and LAB indicate different isostasy mechanism in different domains

Thanks you!

Acknowledgment

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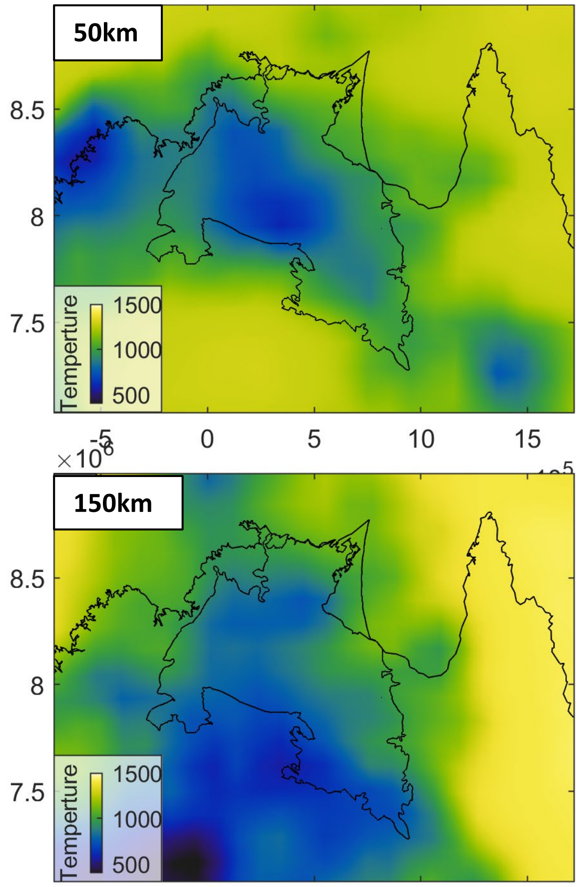
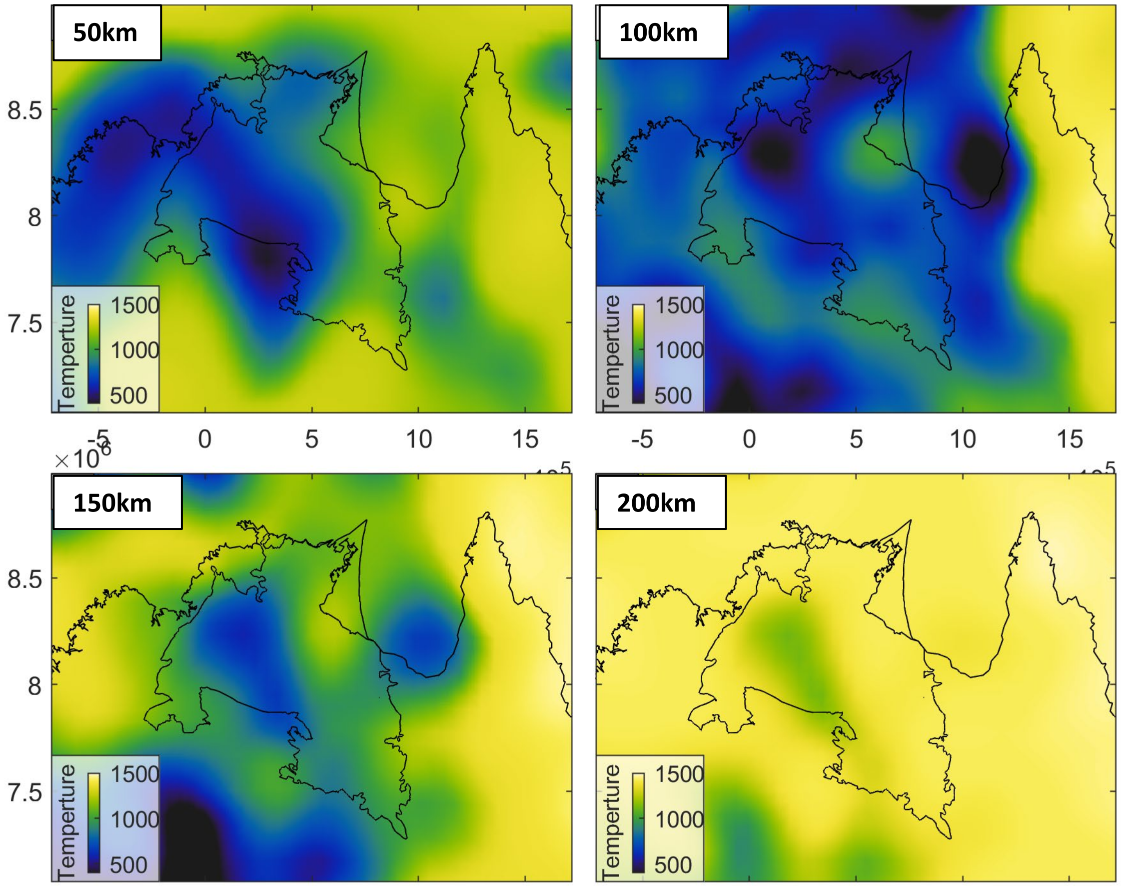
Centre for EXPLORATION TARGETING
mriwa Minerals Research Institute of Western Australia
FMG Fortescue The New Force in Iron Ore
FIRST QUANTUM MINERALS LTD.

AuSREM vs Aus22

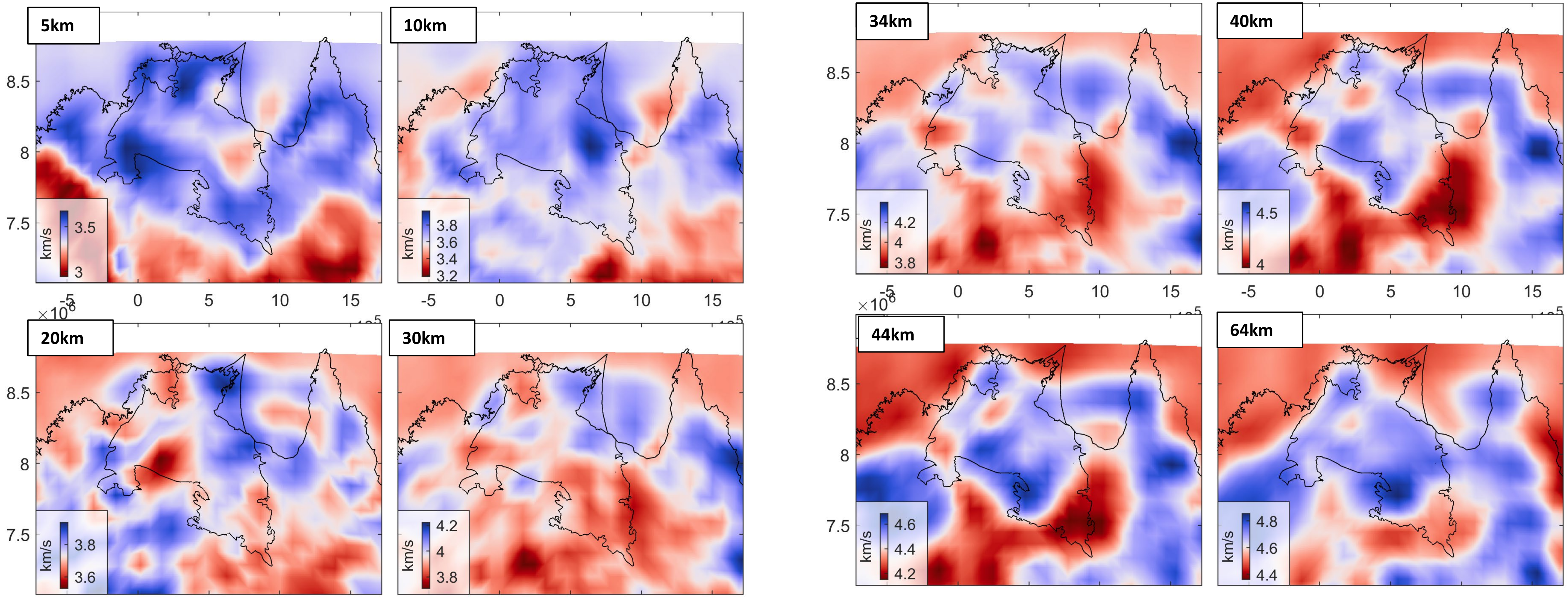


AuSREM



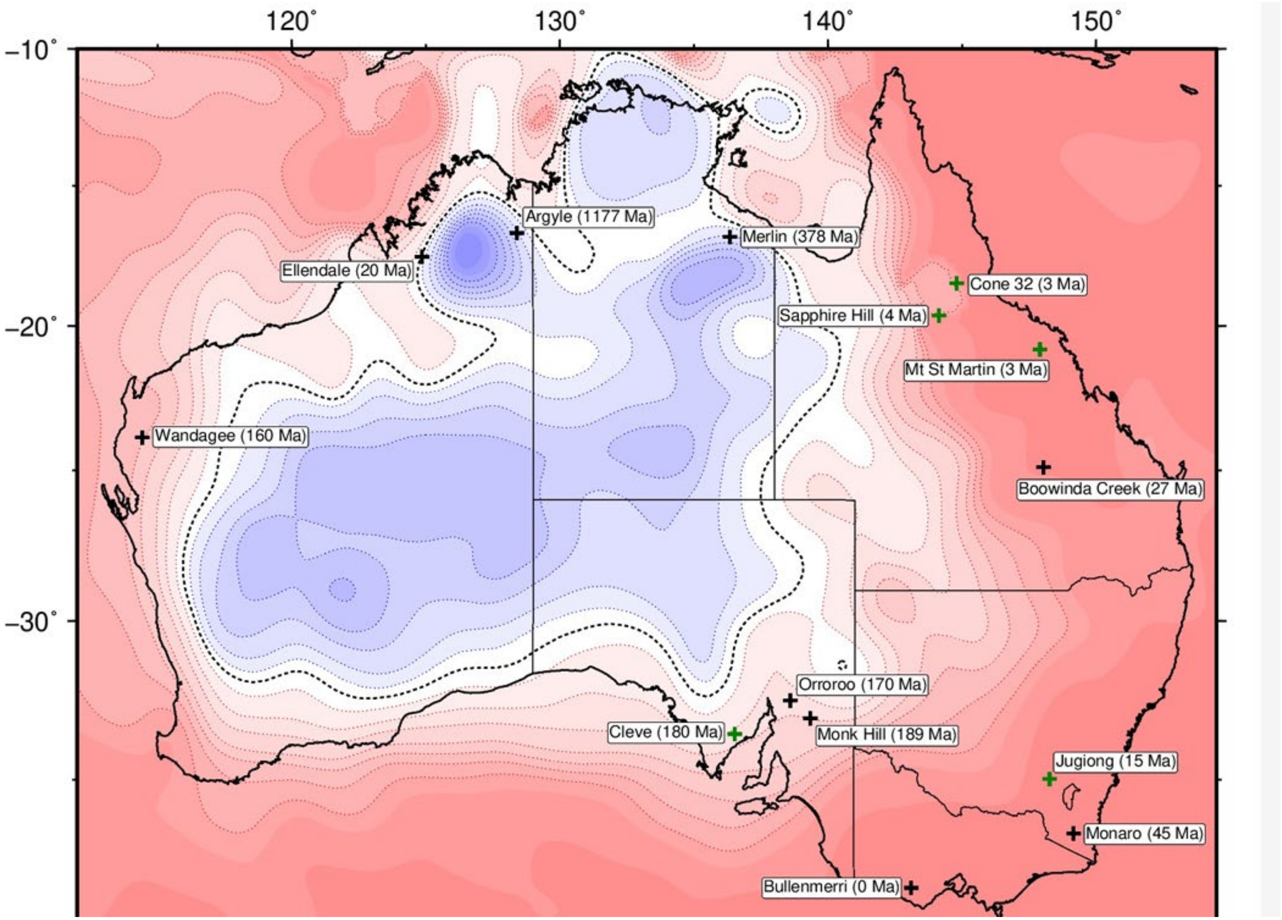
Aus22

AU23

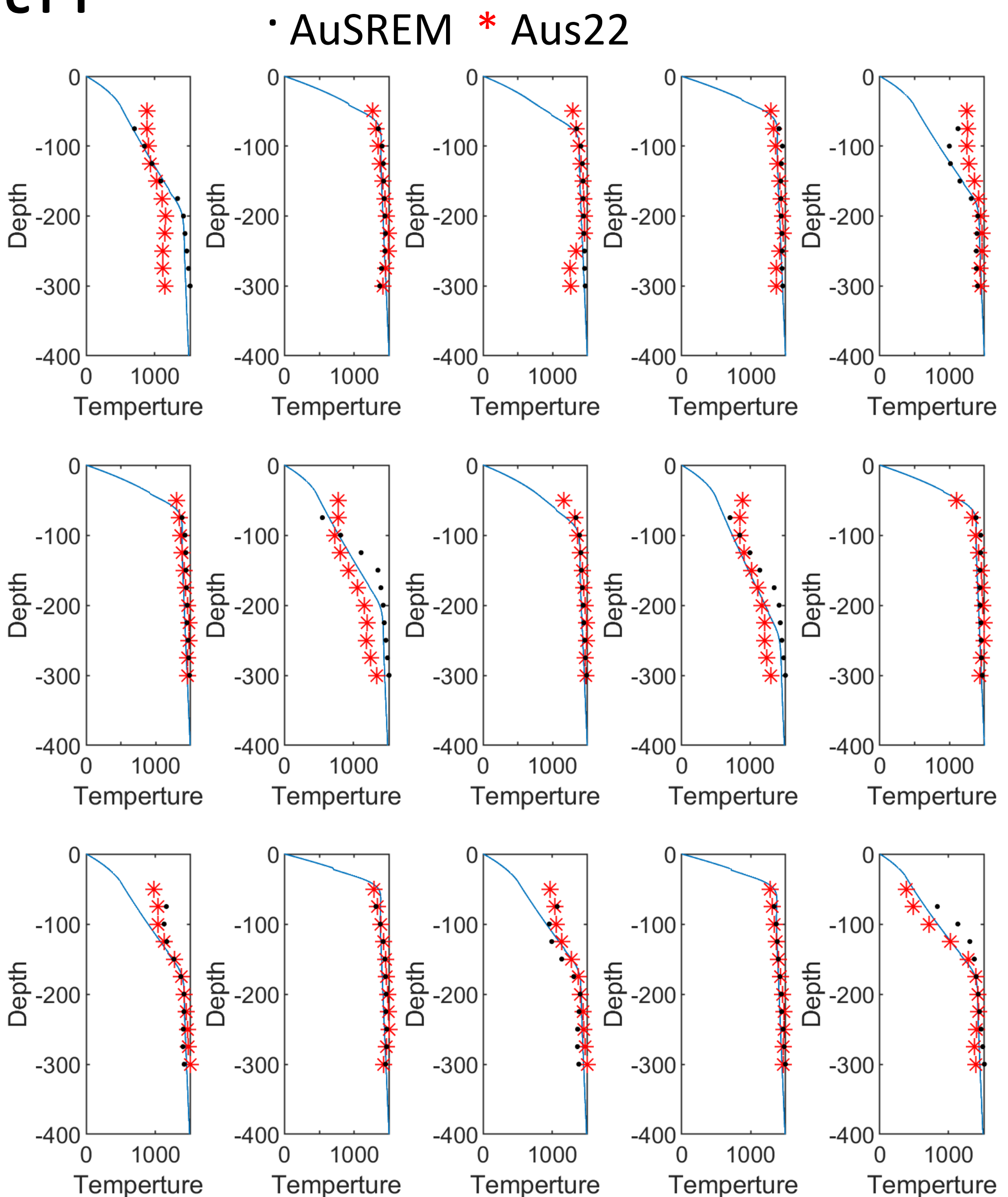


AU23 (Chen et al., 2023)

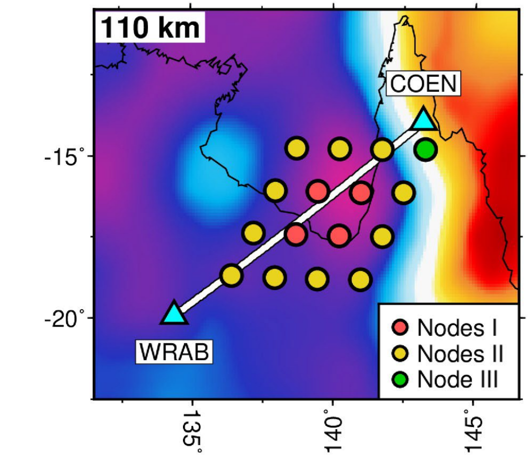
Calibrate with mantle xenolith

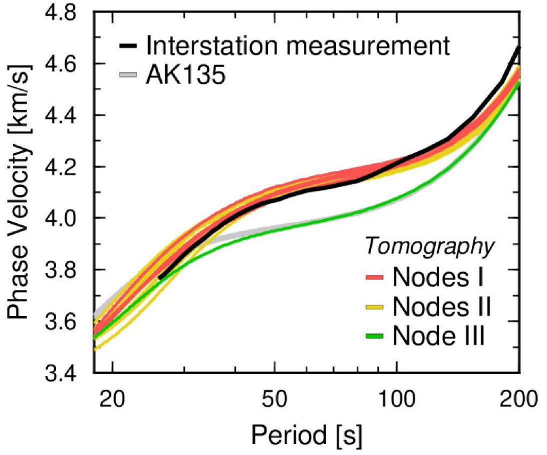


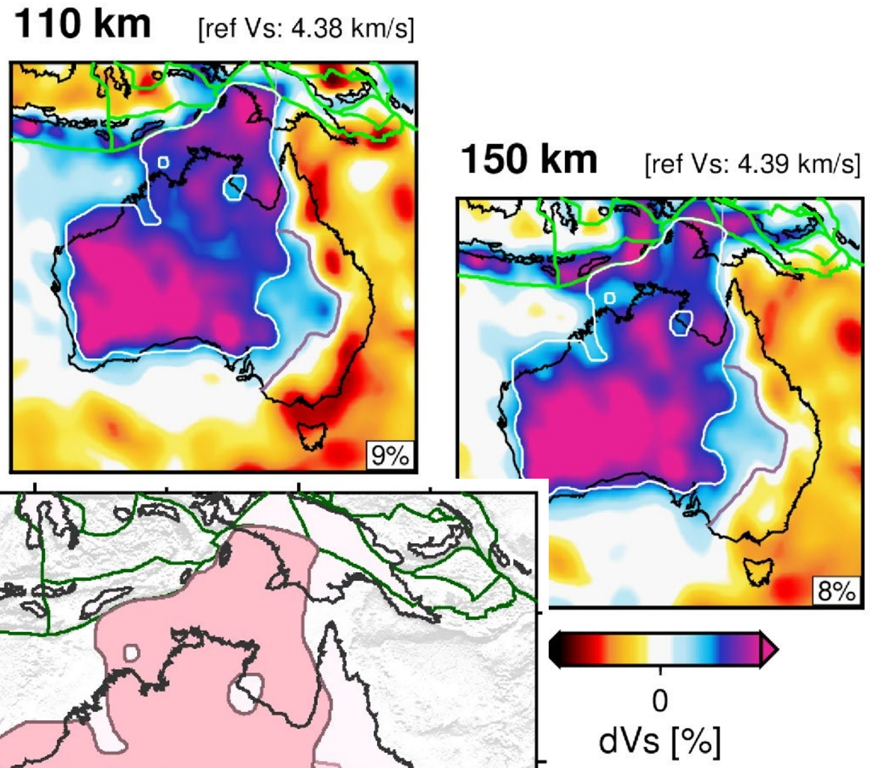
Hoggard et al., 2020

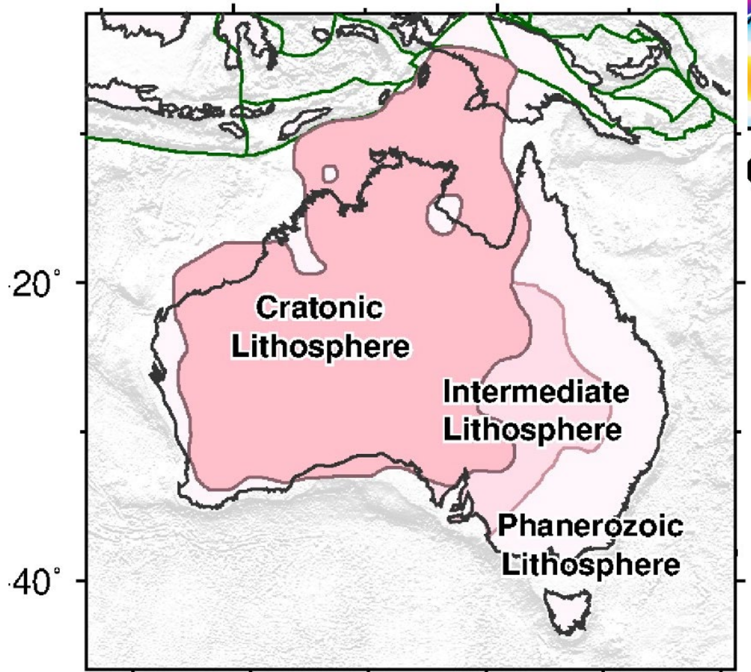


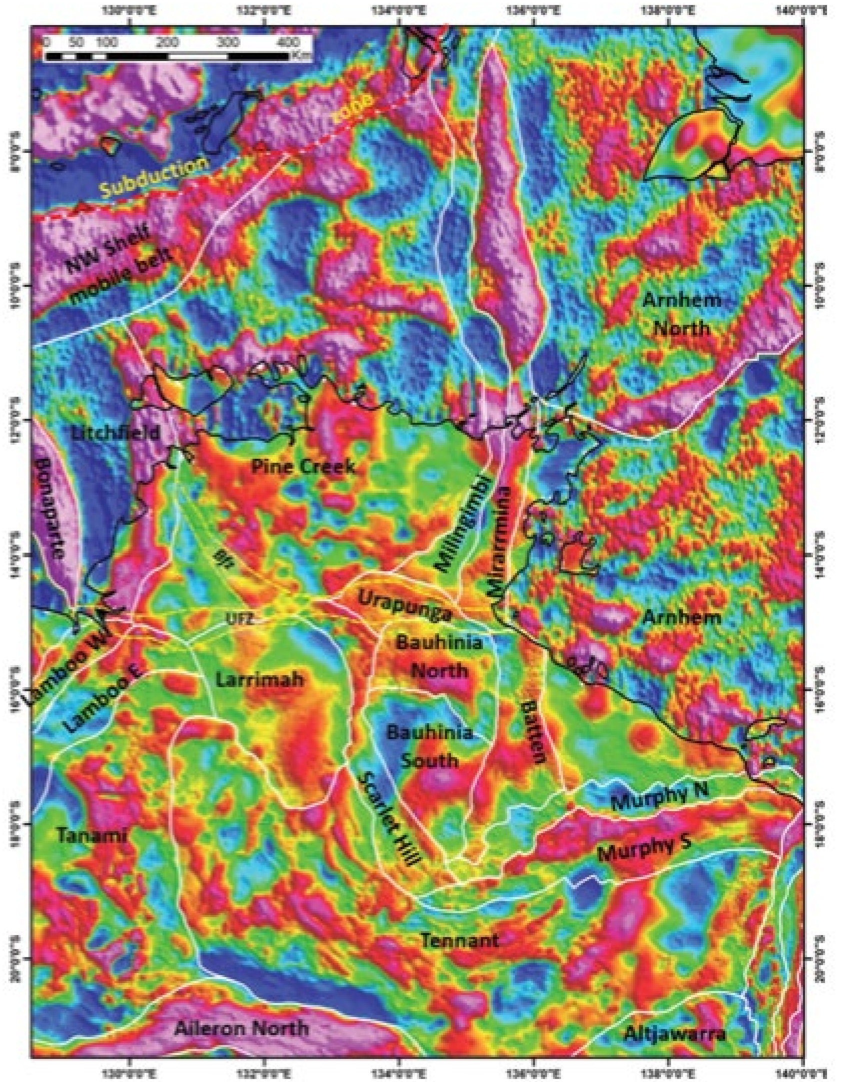
Fast velocity in the Gulf of Carpentaria





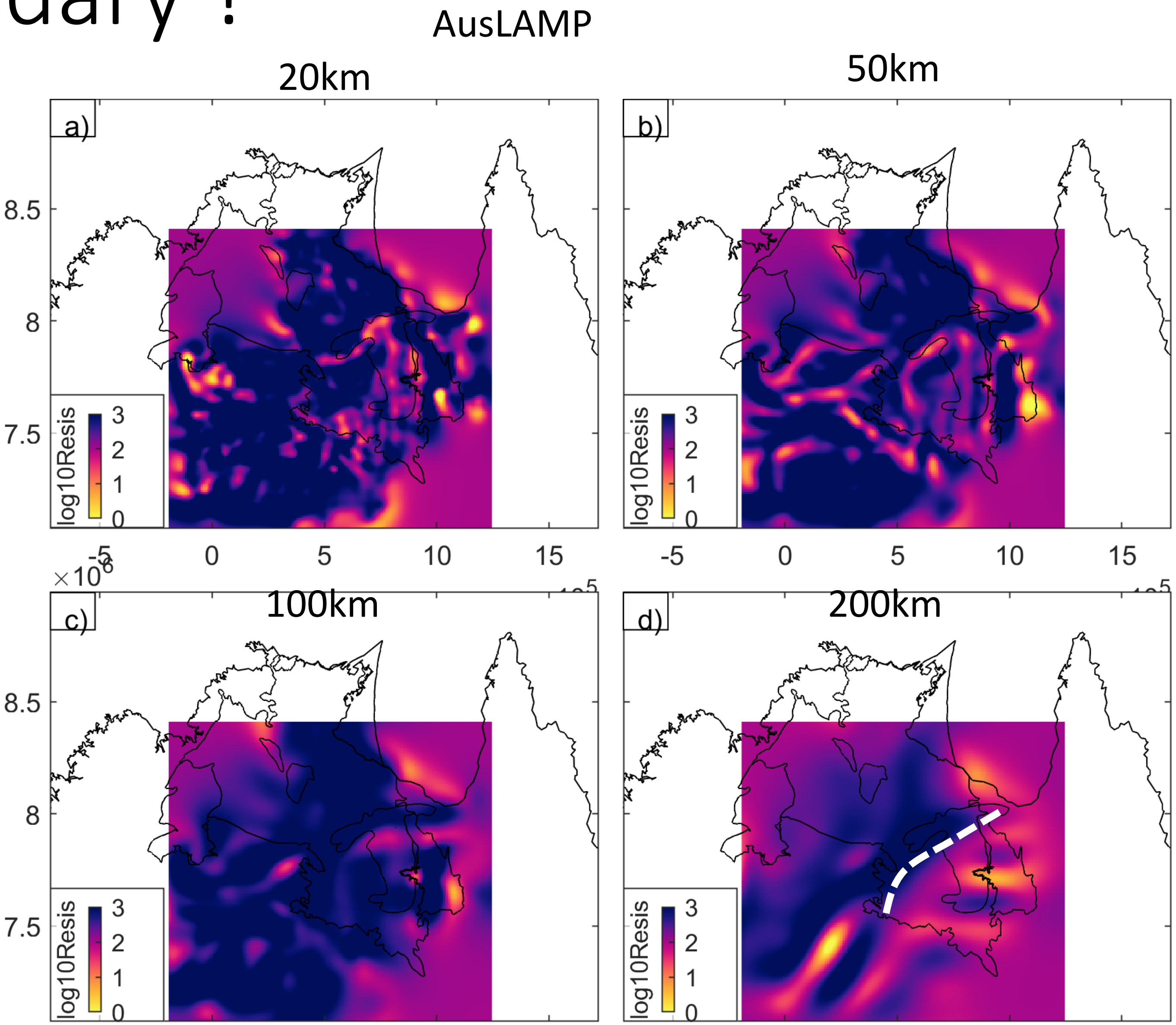


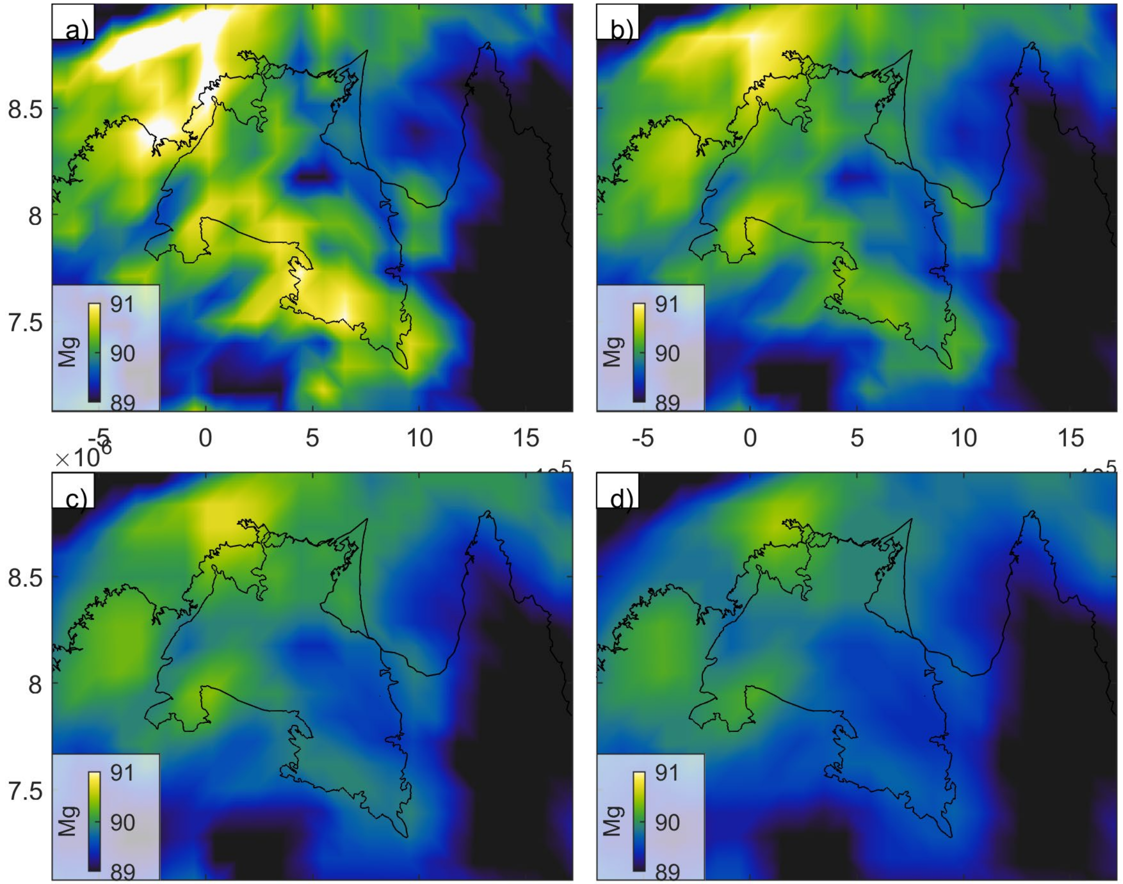




High pass 300 km Bouguer Gravity
(Connors and Pryer, 2018)

Domain boundary ?





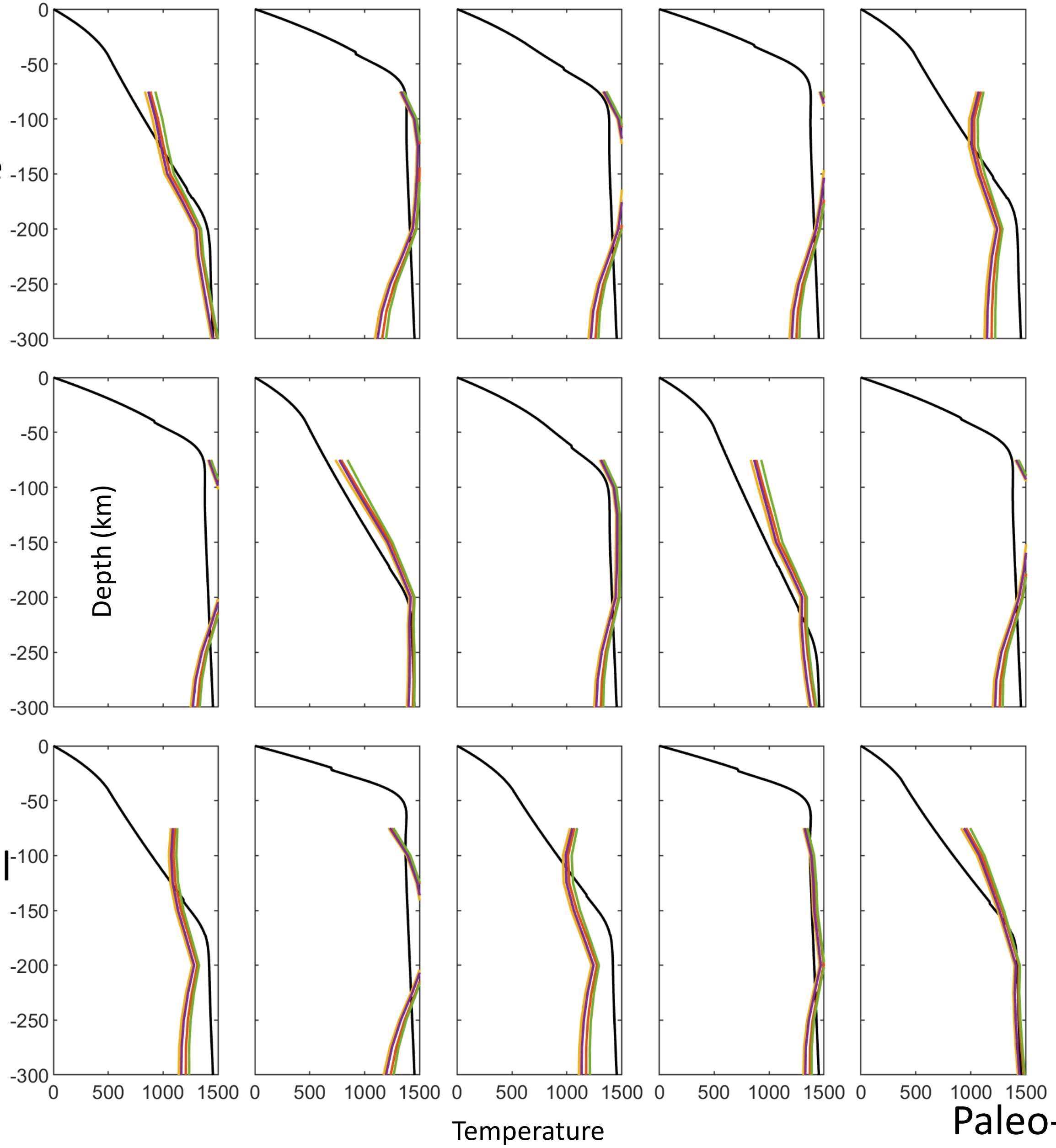
Tesauro et al., 2020

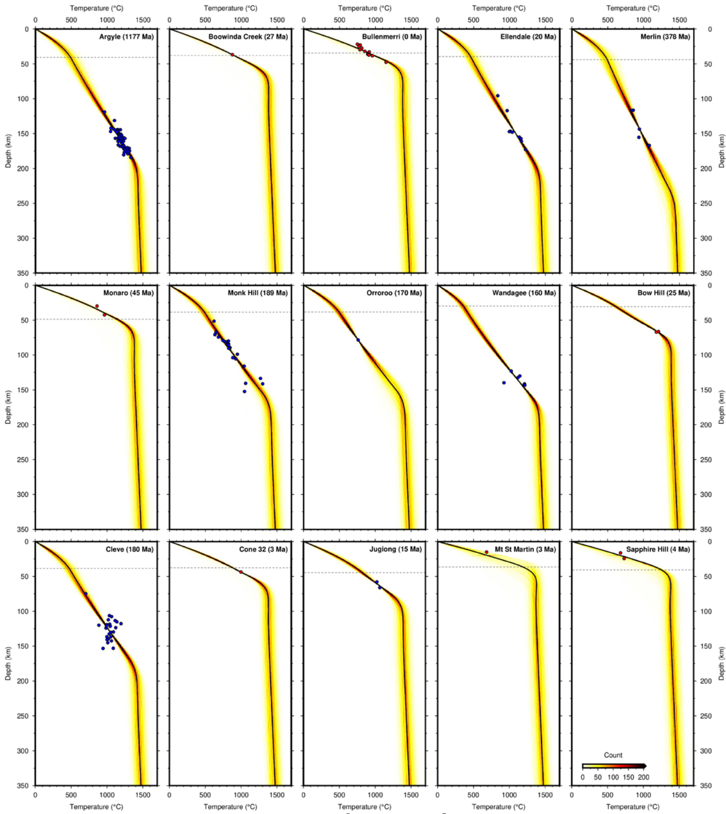
Issue for the mineral physics approach

Convert velocity to temperature with different mantle composition. But…

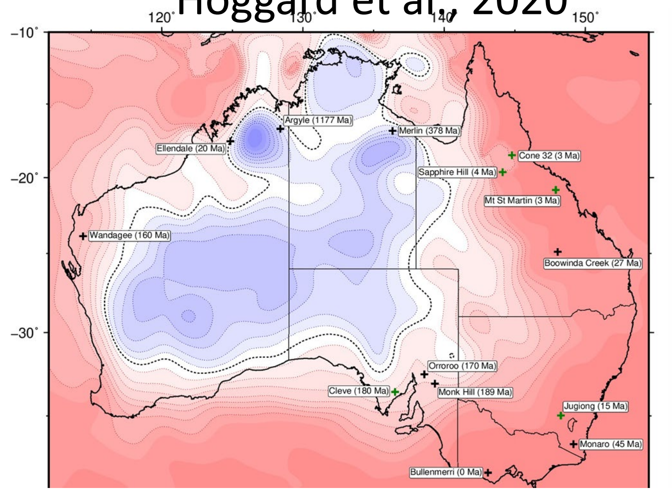
Incomparable with observation:

- Grain size difference
- Unknown attenuation
- Unknown composition
- Different regularization and reference model for generating tomography model





Hoggard et al., 2020



Paleo-geotherm from Xenolith/Xenocrystal