

# What lies beneath the Nullarbor Plain?

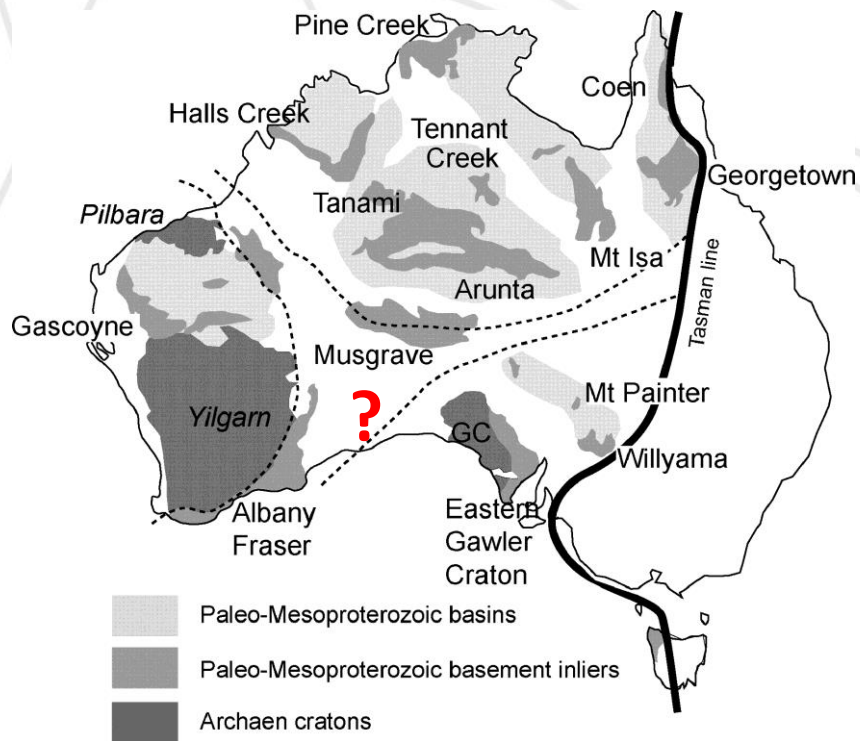
Insights into the geology of the Coompana Province  
from deep crustal seismic reflection profile 13GA-EG1

Rian Dutch, Catherine Spaggiari, Michael Doublier, Mark Pawley, Tom Wise, Brian Kennett, Klaus Gessner, Stephan Thiel, Dan Clark, and Josef Holzschuh

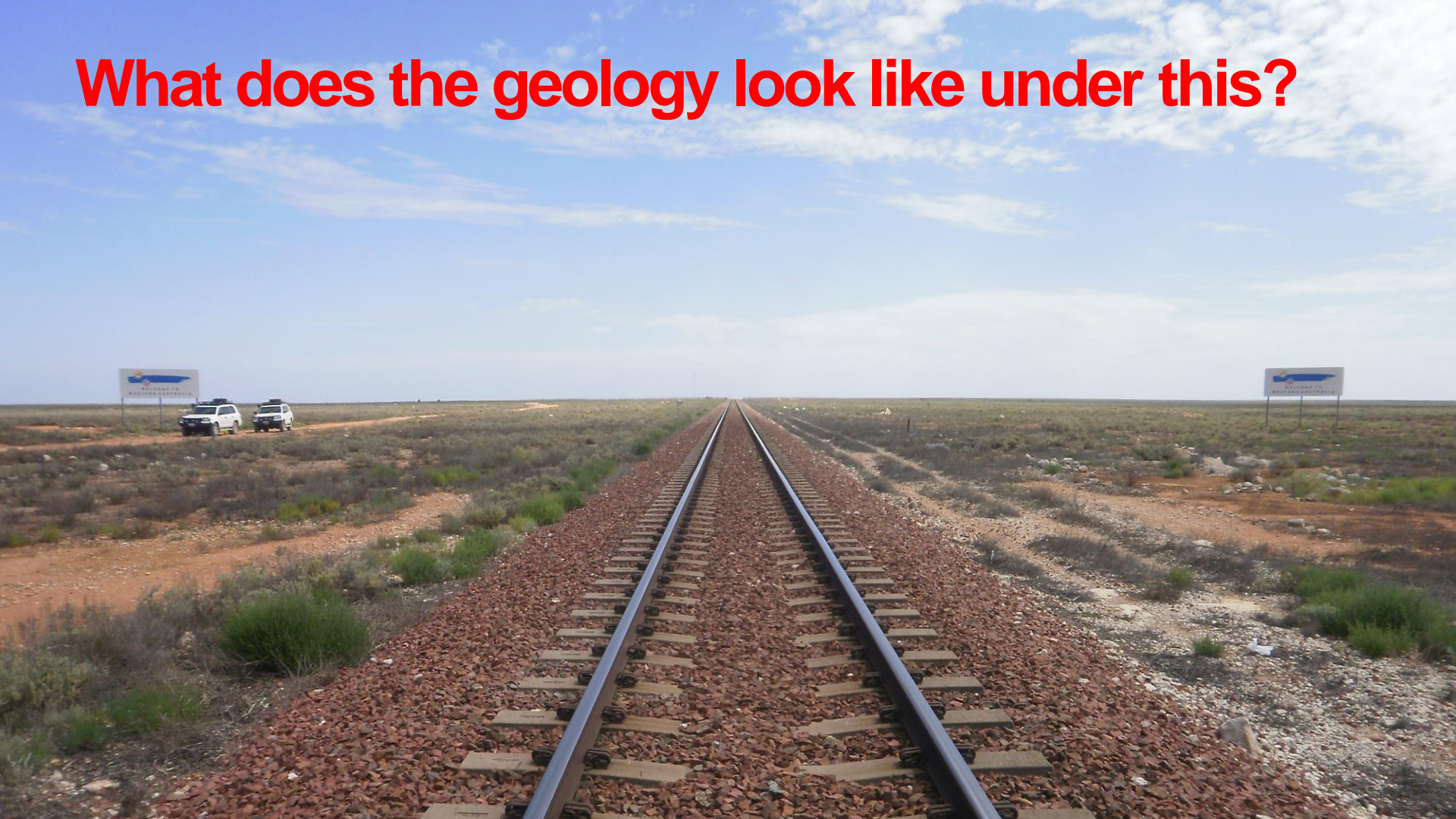
Australian Earth Sciences Convention, Adelaide, June 2016



# A key component in understanding the evolution of Proterozoic Australia



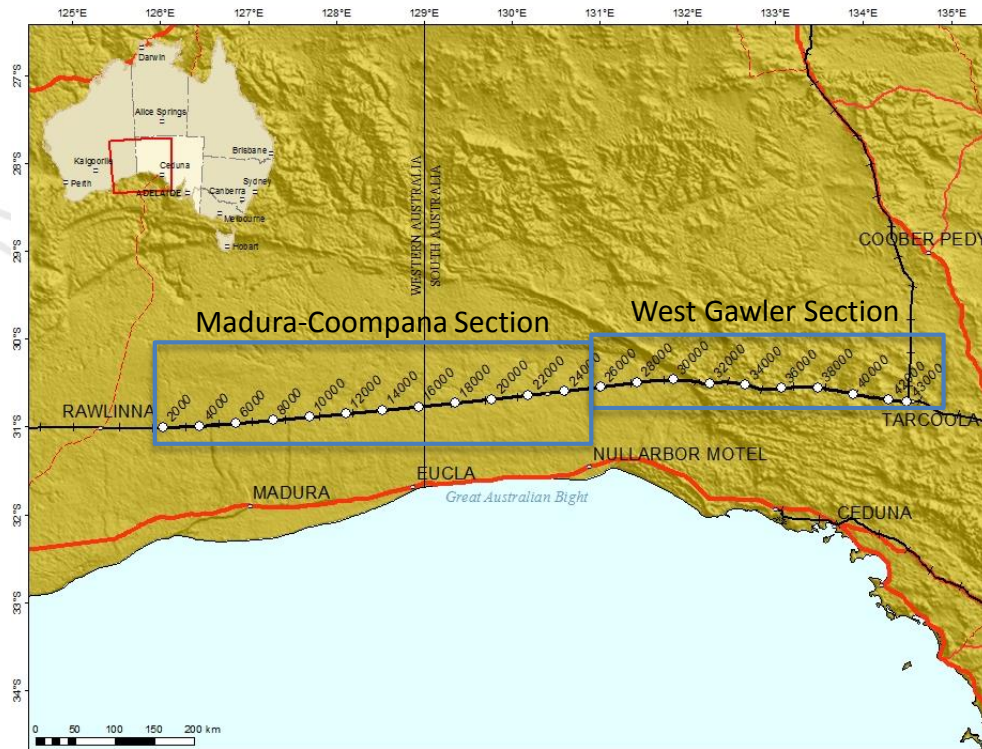
**What does the geology look like under this?**



# Introduction

## 13GA-EG1: Eucla Gawler seismic line

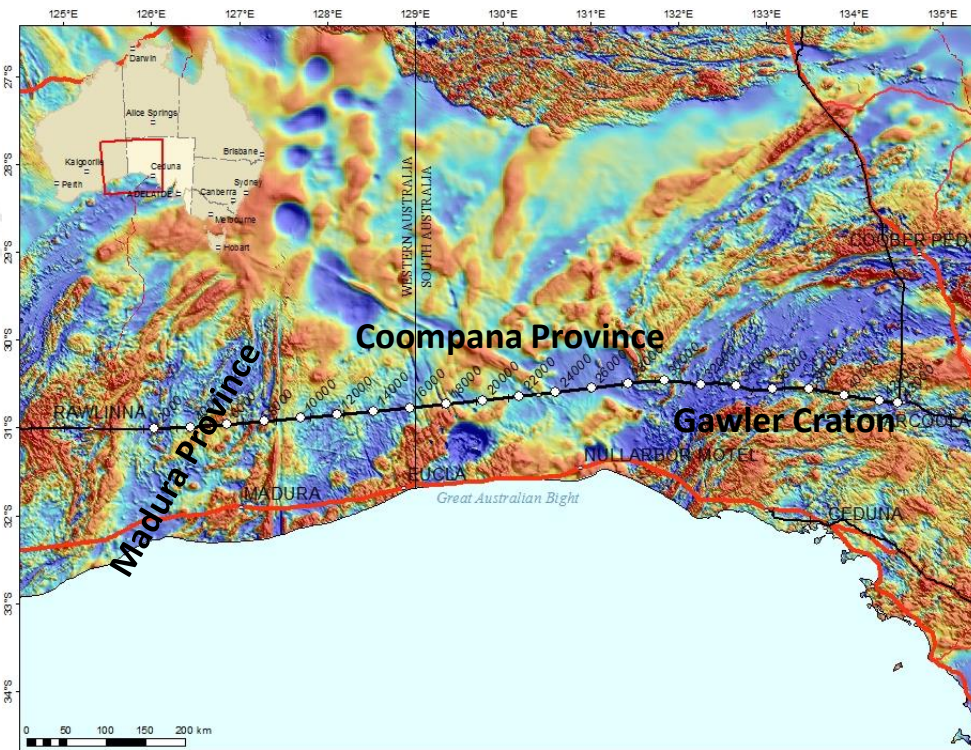
- In 2013, Geoscience Australia, in collaboration with the Geological Survey of South Australia, Geological Survey of Western Australia and AuScope, acquired 834 km of vibroseis-source, deep-seismic reflection data along the Trans-Continental Railway line from Haig in WA to Tarcoola in SA
- Due to the size and complexity of the data set, it was decided to break the line up into an eastern and western section
- The eastern section (13GA-EG1E, covering the western Gawler Craton) was processed first and released in December 2015





# Aims of 13GA-EG1

- Define Province boundaries
- Investigate the nature of the contacts between Provinces and the internal crustal architecture of the Provinces
- Image major faults and shear zones
- Image the overlying basins – provide thickness constraints on the cover
- Implications for mineral systems and prospectivity
- Investigate the covered contact between the West and South Australian Cratons – implications for the formation of Proterozoic Australia

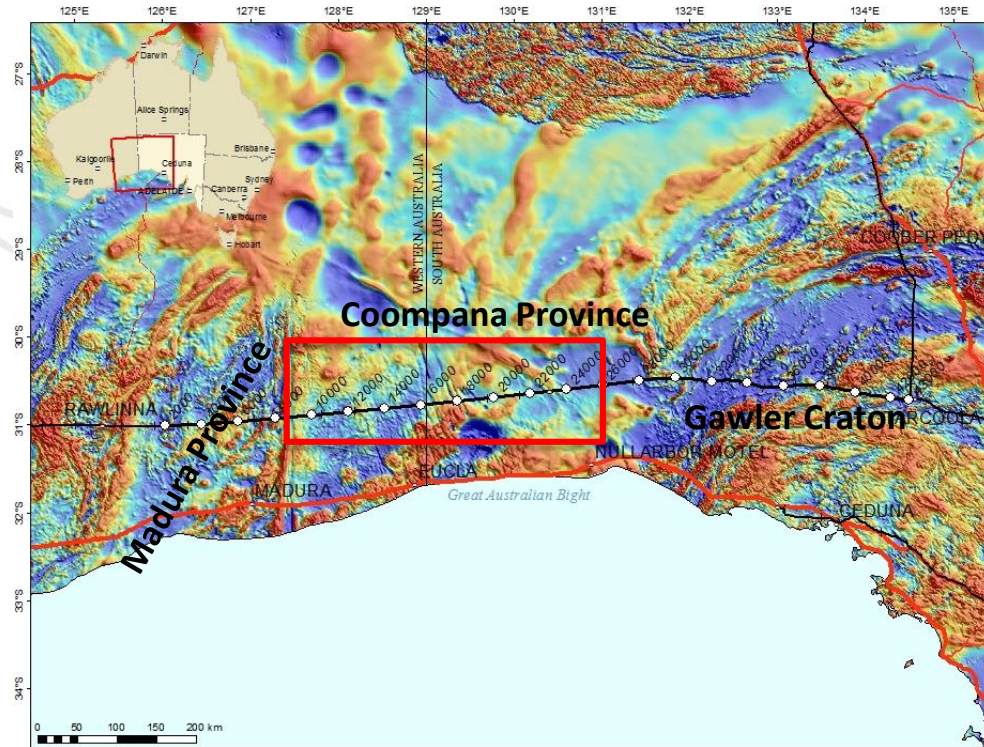


# Outline

In this presentation we will present the preliminary geological and geodynamic interpretations from the Coompana Province section of 13GA-EG1

This section covers CDP's from ~8000–26000, from the Mundrabilla SZ to the edge of the Gawler Craton

- Discuss the interpretation methodology and dataset
- Discuss some of the challenges in interpreting such a dataset
- Describe our interpretations
- Present some geological and geodynamic implications from the interpretation



# Interpretation methodology

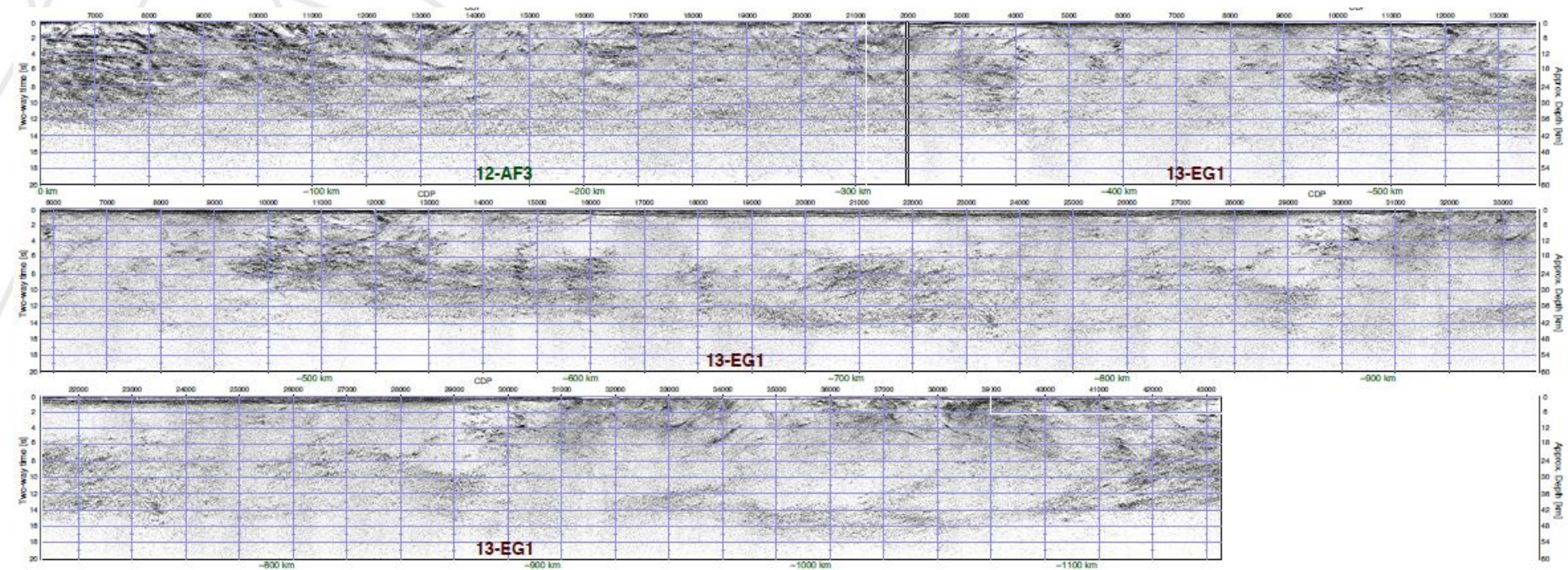
- Due to the cross border nature of this data set, interpretation required a collaborative approach between GA, GSWA, GSSA and additional researchers
- Interpretation was done using a combination of hardcopy printouts and digital interpretation using ArcGIS
- Digital interpretation provides a number of benefits
  - Easily working across scales. zooming in and out
  - digital linework allows for easy comparison between different interpretations and easy sharing between groups
  - during each stage linework can be visualized in 3D (e.g. GoCAD), or used for potential field modelling
  - overlay and compare different image types
  - It can be hard to find a table long enough to roll out a line of this length



# Interpretation methodology

- Previously, collaborative interpretation on Government seismic lines was conducted at a series of workshops on hardcopy images
- Generally the final compilation was done by a small group of people from the hardcopy linework
- This section has been a bit different
  - An initial workshop was held to discuss planning and begin discussions on interpreting the section
  - Each group then conducted their own interpretations digitally, sharing linework via the cloud and discussing over the phone
  - A second workshop was held to compile and begin merging the digital datasets and discuss the geological implications
  - Each group continued to refine their interpretations
  - The final interpretation dataset was then merged and edited for consistency and coherency across the section
- During this process constant feedback to Josef allowed for iterative improvements to the processing of the data

# The dataset



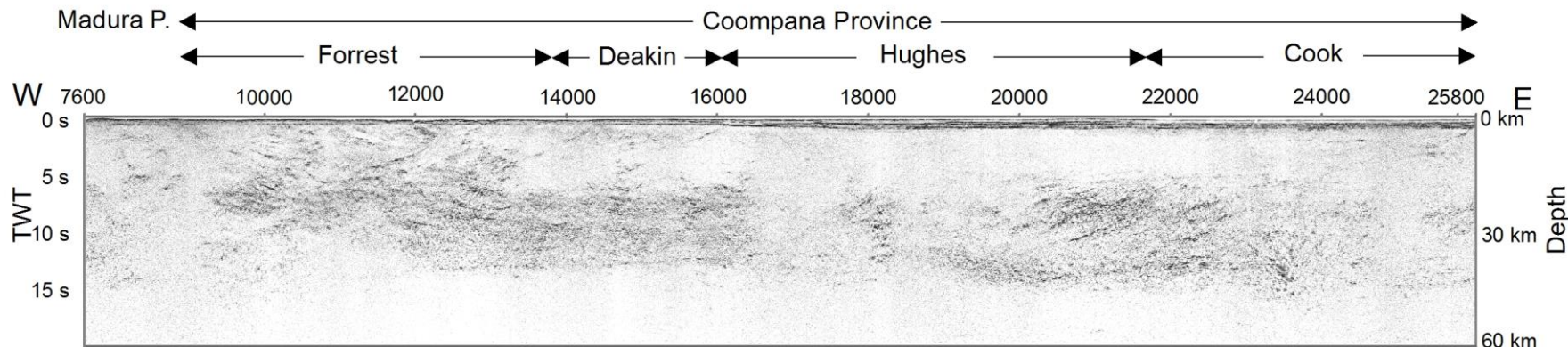
# Image types used in interpretation

- DMO stack
- Final migrated DMO stack with 20 m CDP spacing and 150 nominal fold
- Migrated and unmigrated NMO stack with 100m CDP spacing (nominal 700 fold) and 500 m CDP spacing (nominal 4000 fold) - improvement for imaging of the lower crust and areas with weak reflectors
- Image processed to increase contrast and enhance the distinction between regions of differing seismic character
- Image of the stack and migrated section processed by coherency enhancement processing and CDP trace equalisation

# Seismic image

## Final Migrated DMO stack

- Primary image used for interpretations and image available for download
- Quality of the seismic reflection data generally good
- There are some zones of limited or no reflectivity
- Some are real non-reflective zones, some are data gaps

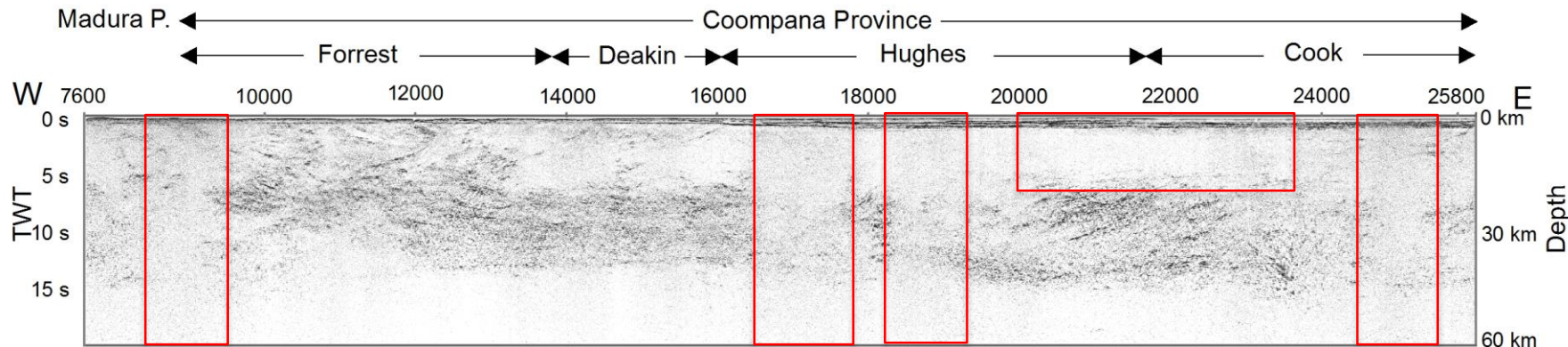


# Seismic image

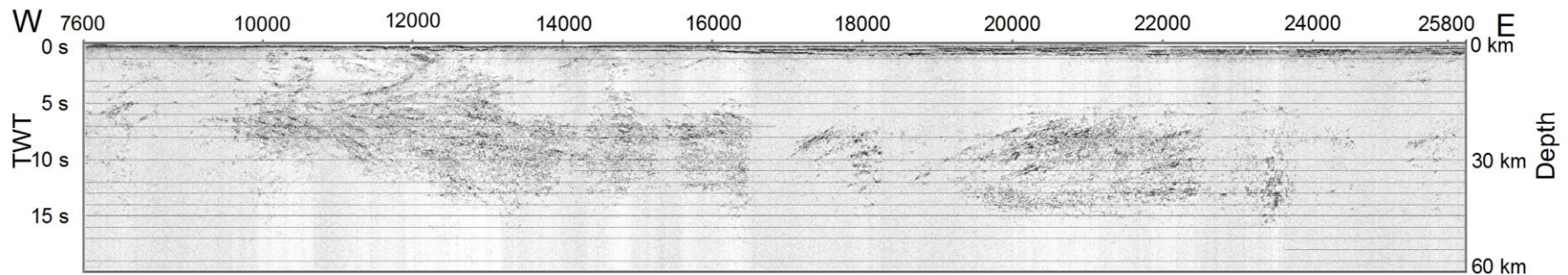
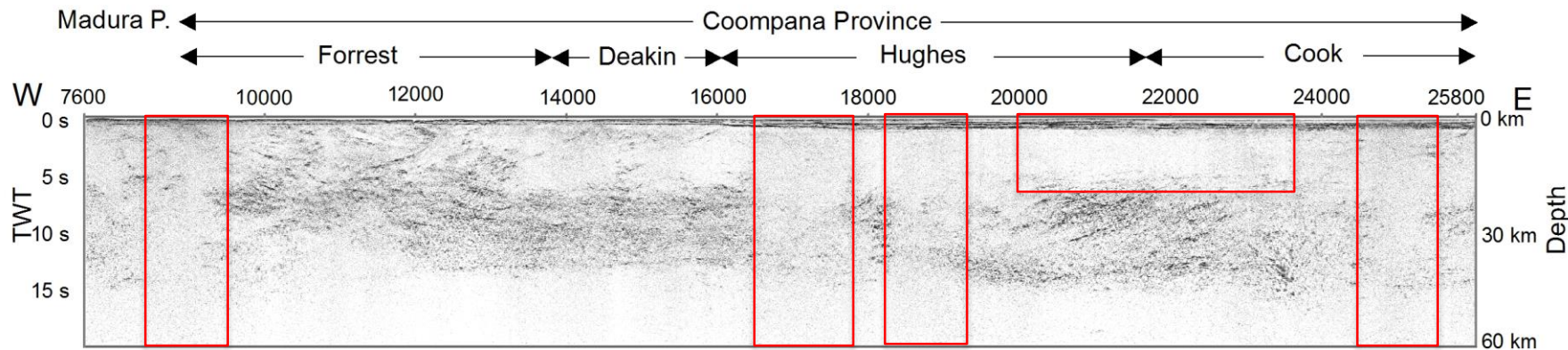
## Final Migrated DMO stack: low reflectivity zones

- Cook and Hughes upper crust
- Western lower crust
- Sections in Cook and Hughes domains

Reasons? Signal penetration through Nullarbor Limestone, signal attenuation at base of limestone, caves, weathering, vertical structure

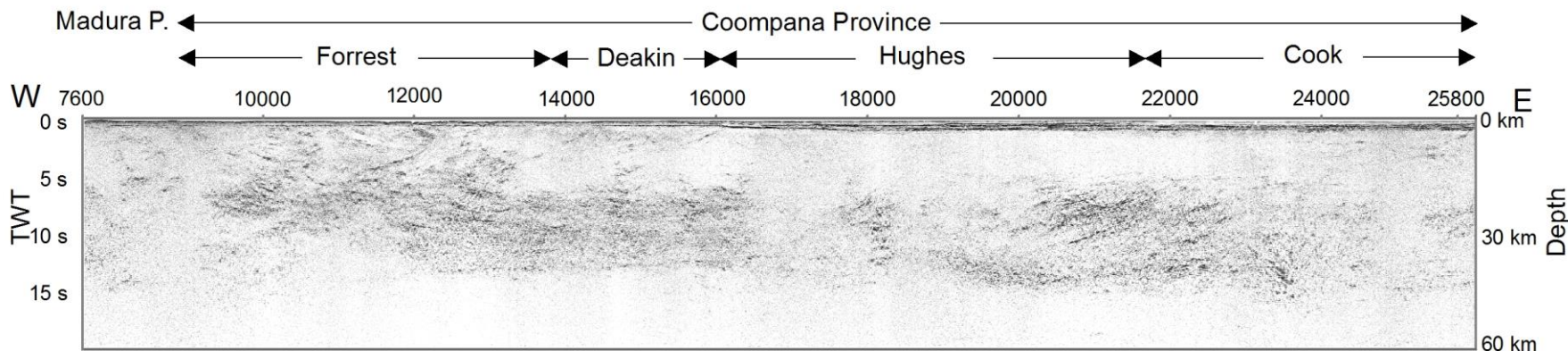
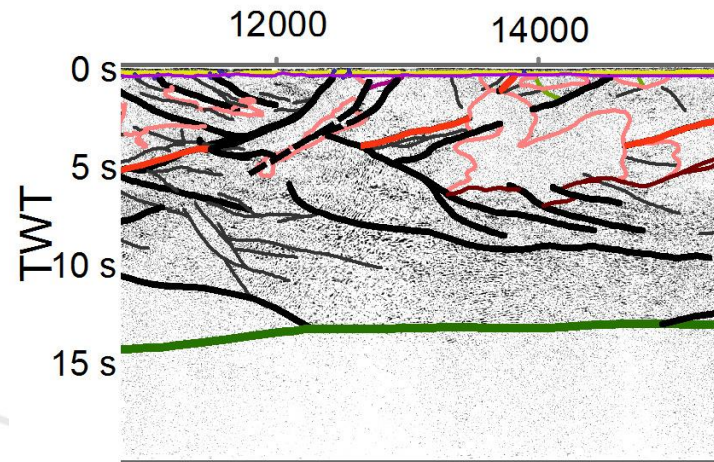


# Seismic image



# Challenges

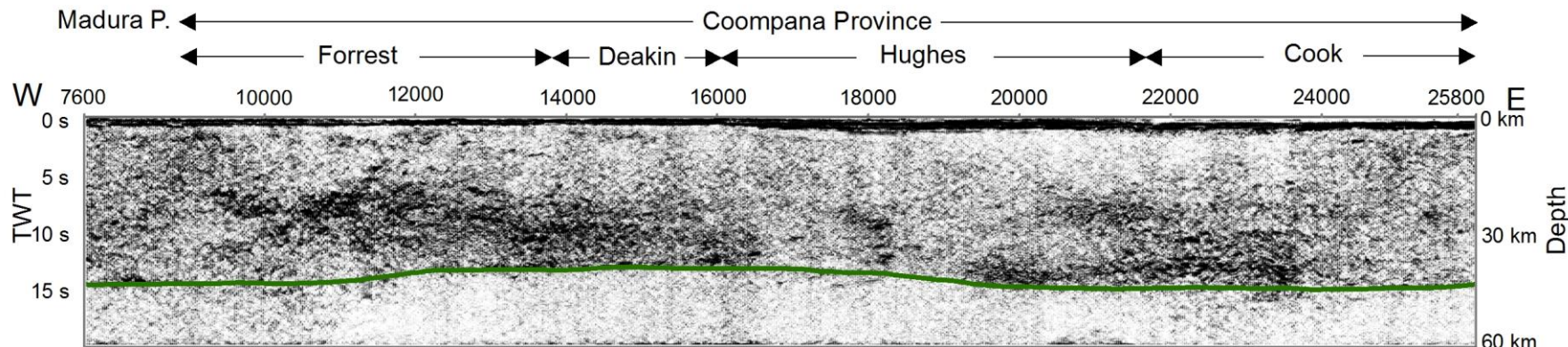
- Data gaps, often in places of greatest complexity
- Challenge of interpreting data with multiple overprinting events and progressive deformation
- Interpreting structure in a magmatically overprinted regime
- Potential strike-slip displacement on structures, so significant out of plane movement. Potential for apparent offsets not representative of in-plane movement
- Lack of existing geological data to constrain interpretations
- Because of uncertainties, often more than one interpretation is valid



# Interpretation - Moho

## Moho interpretation on High Fold data

- Moho is reasonably well imaged throughout the section
- General reflective discontinuity between reflective lower crust and non-reflective mantle
- Western end harder to pick because of un-reflective lower crust
- Moho generally between 14-15s TWT, ~42-45km depth
- Slight thinning of the crust in the western Coompana to 13s TWT, ~39km depth





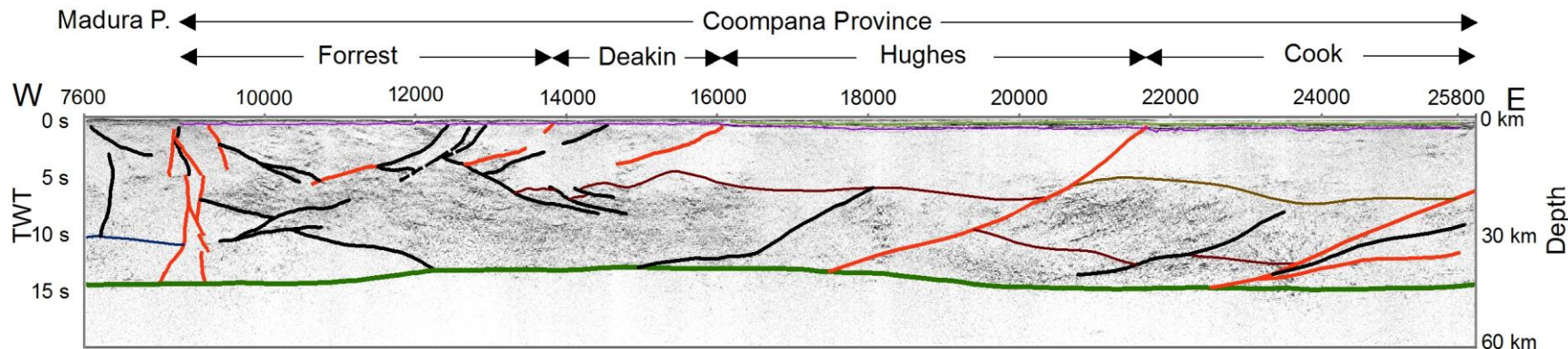
# Interpretation – Crustal architecture

Eastern Coompana section (Cook Domain) comprises a 3 layered crust

- Reflective flat lying lower crust
- Reflective inclined mid crust
- Un-reflective upper crust

The western part of the section comprises a 2 layered crust

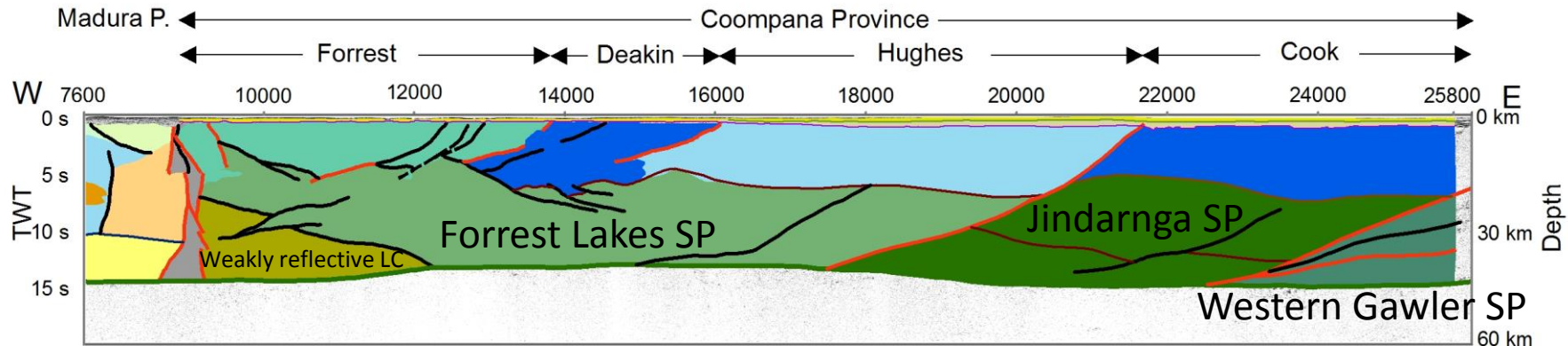
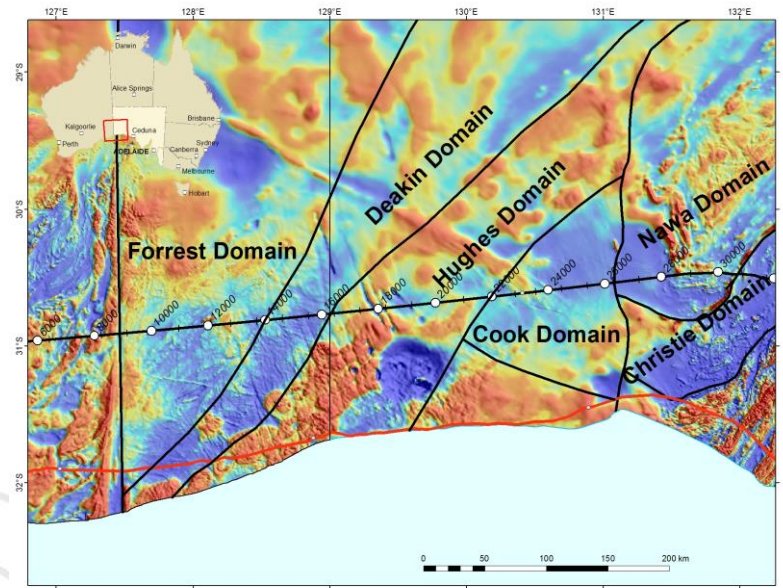
- East of 12500 CDP reflective lower crust and un-reflective upper crust
- West of CDP 12500 reflective upper crust and un-reflective lower crust



# Interpretation – Crustal architecture

Based on known geology, potential field data and seismic character a number of Domains and Seismic Provinces have been identified

- A 'seismic province': a discrete volume of middle-lower crust, which cannot be traced to the surface and whose seismic reflectivity is different from that of vertical or horizontally adjoining provinces (Korsch et al., 2010)

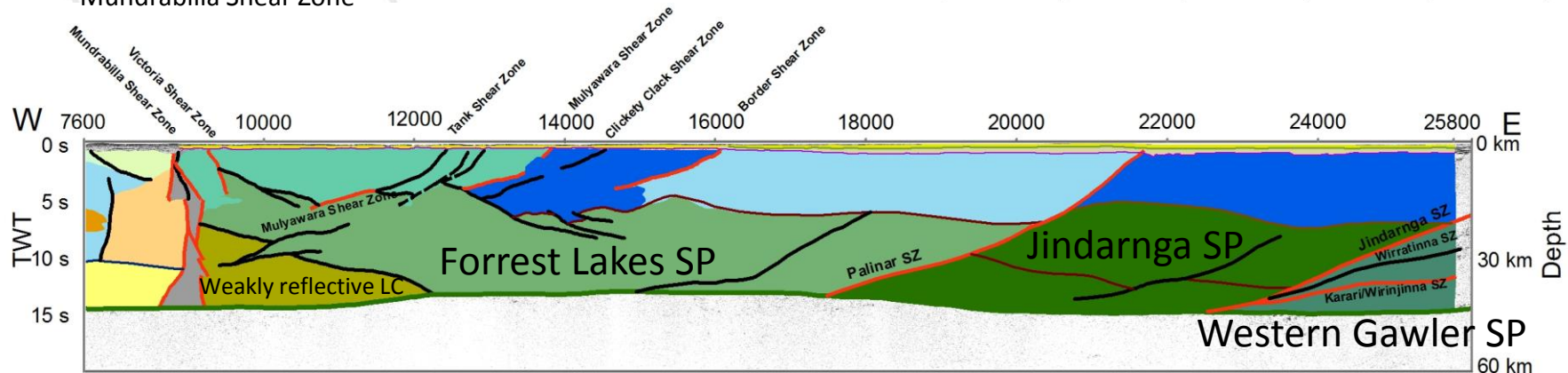
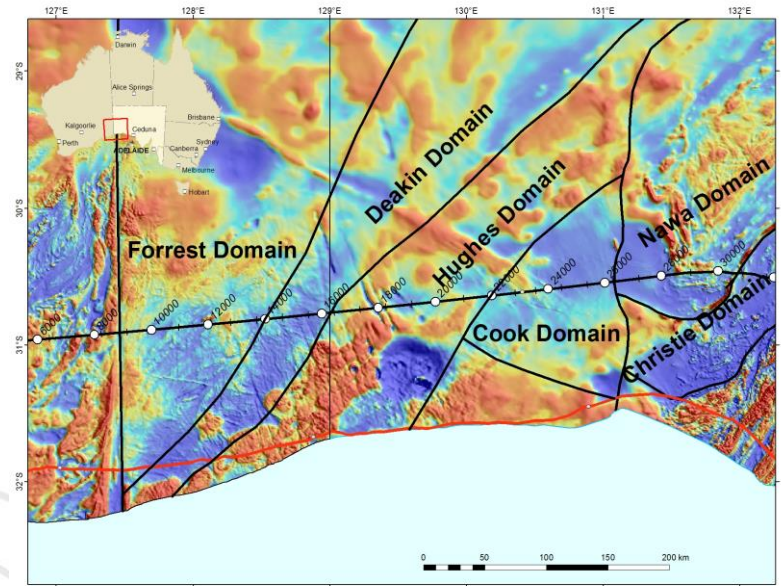


# Interpretation – Crustal architecture

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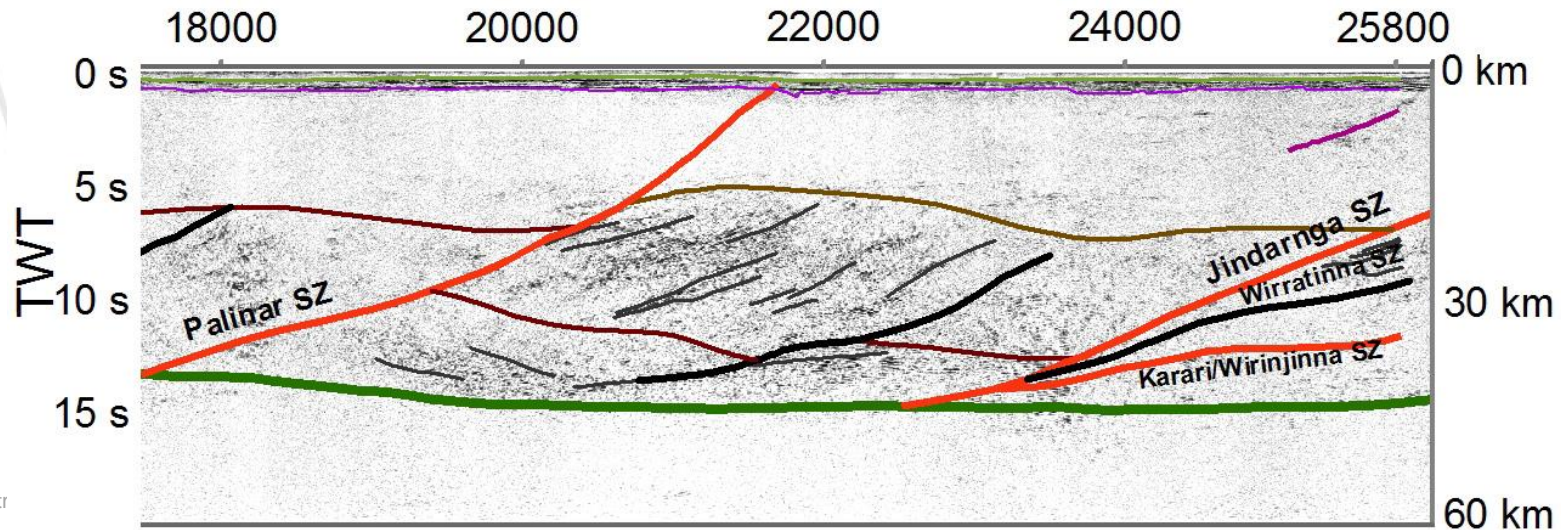
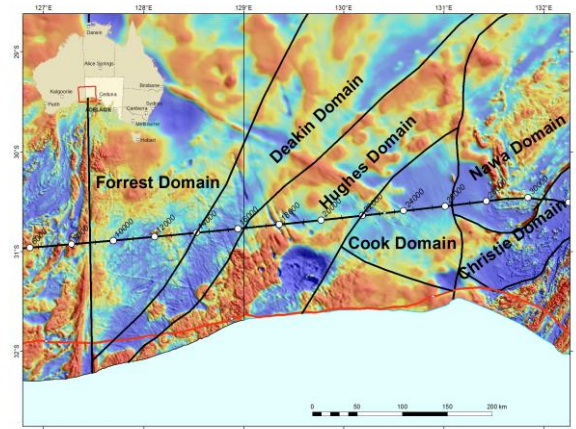
These domains are bound by a number of major shear zones

- Jindarnga Shear Zone
- Palinar Shear Zone
- Border Shear Zone
- Mulyawara Shear Zone
- Mundrabilla Shear Zone



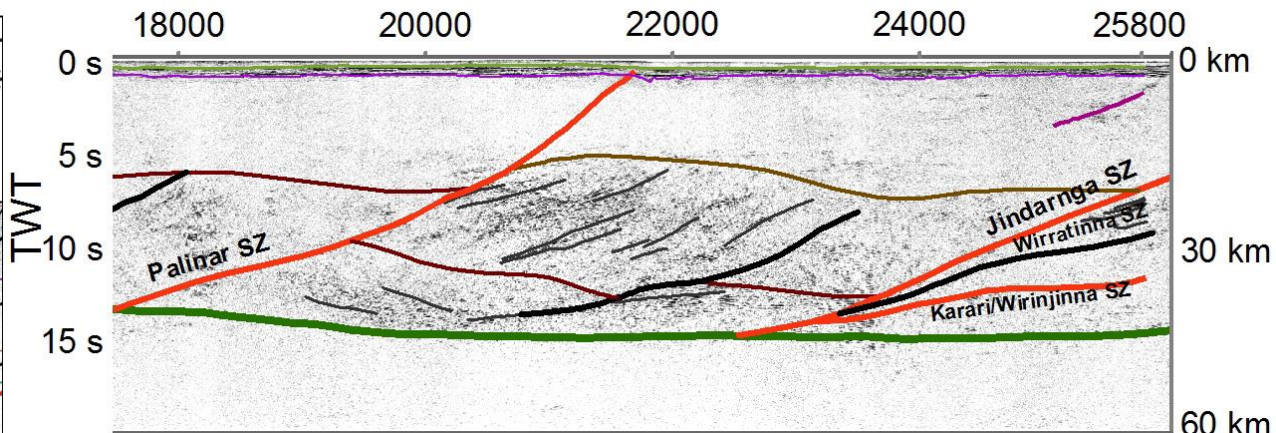
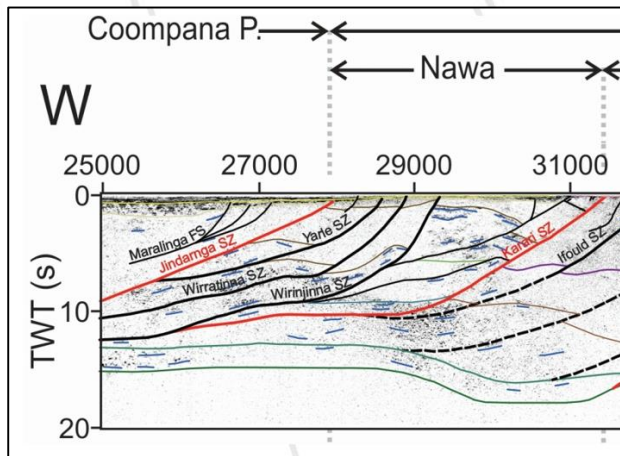
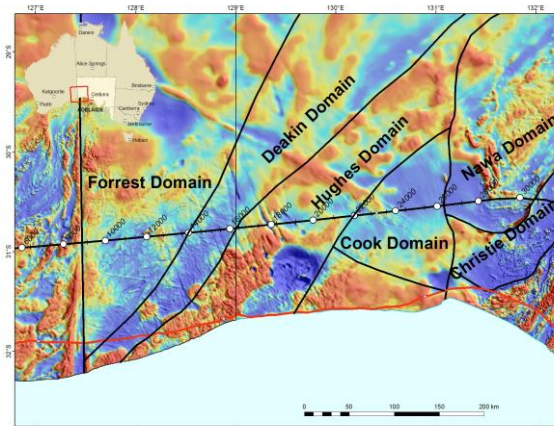
# Interpretation – Cook Domain

- Generally un-reflective but some patches of flat lying reflectors
- Sits in the hanging wall of the west dipping Jindarnga SZ – Previously interpreted as the contact between the Gawler and Coompana
- Bound to the west by the west dipping Palinar SZ
- Overlies the strongly reflective crust of the Jindarnga SP
- 6s (TWT) or ~18km at its thickest



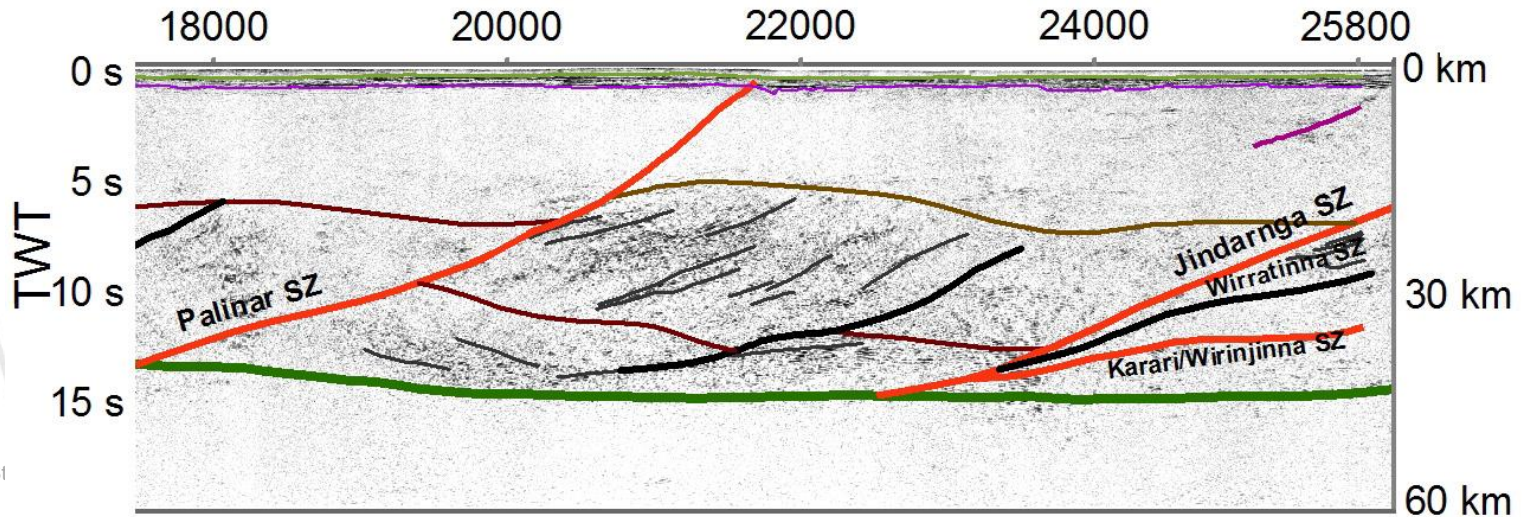
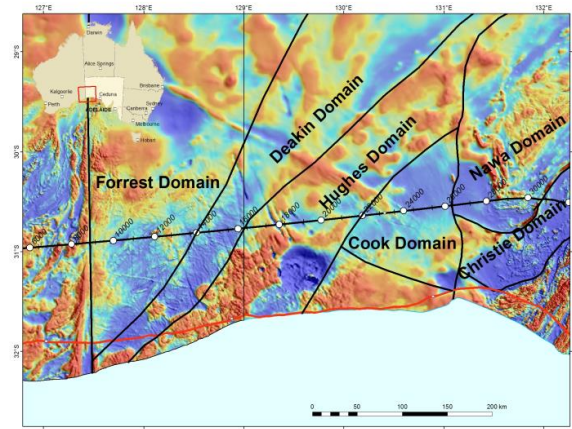
# Interpretation – Cook Domain

- No geological constraints on this crust
  - Potentially predominantly magmatic in nature?
  - The seismic character resembles the Wirinjinna SP
  - Based on location and geophysical character there are a couple of possibilities as to what the units here might be
1. Upper crust dominated by Toolgana Supersuite (Coompana)
  2. Palaeoproterozoic sediments and intrusives (Gawler Craton)



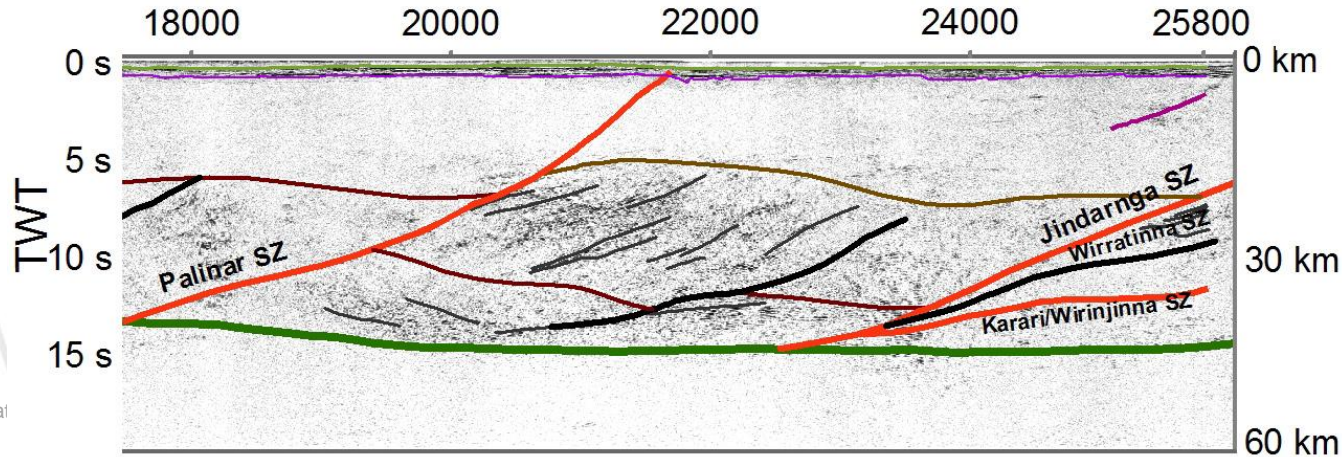
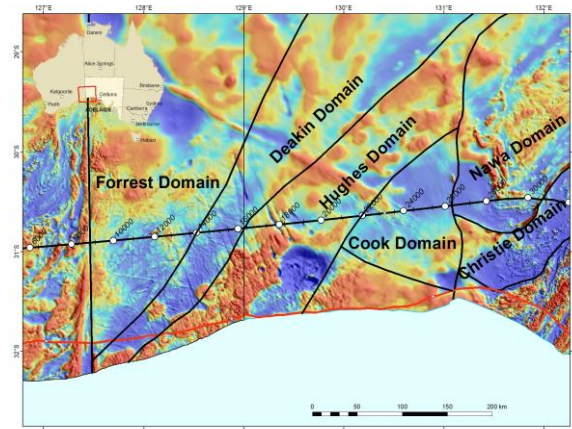
# Interpretation – Jindarnga Seismic Province

- No geological constraints on this crust
- Strongly reflective middle crust up to 9s (TWT) or ~27km thick
- Contains westerly dipping reflectors and small sigmoidal shear zones with generally extensional kinematics
- The lower crust is also strongly reflective and between 2-4s (6-12km) thick
- Reflectors here are generally flat lying and parallel the topography of the Moho



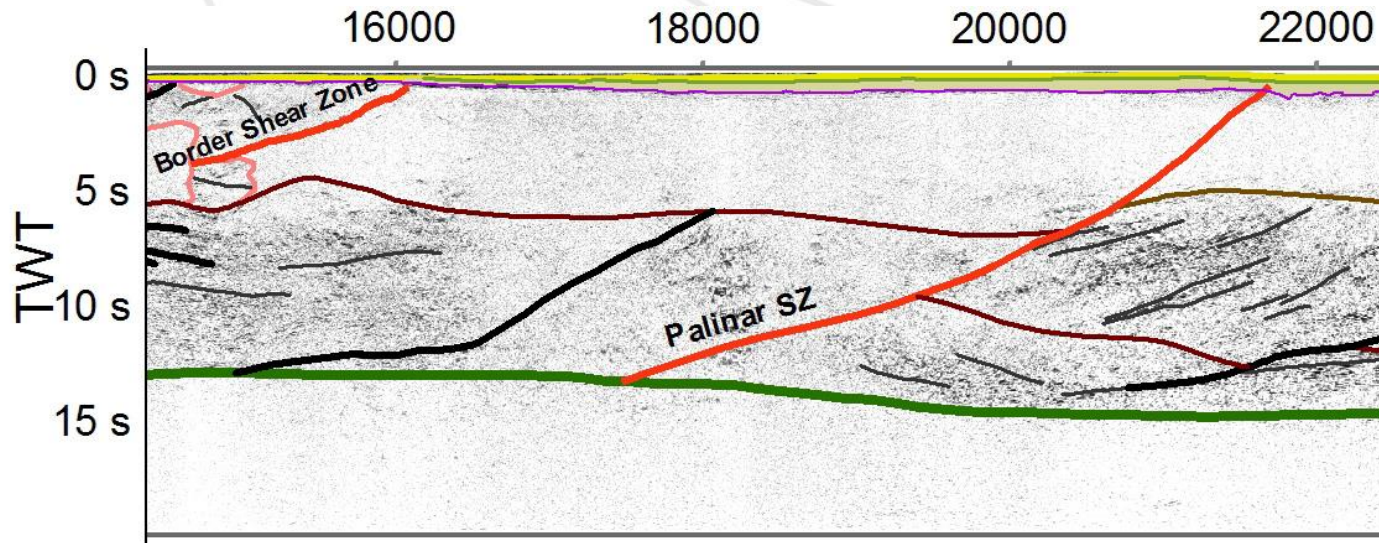
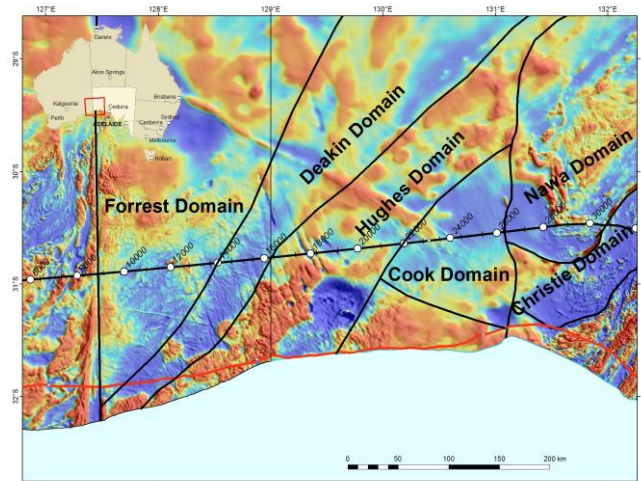
# Interpretation – Jindarnga Seismic Province

- The seismic character of this crustal package is quite different to either the Forrest Lakes SP to the west
  - Single layer, flat lying reflectorsor the Western Gawler SP to the east
  - Two layers, flat lying reflective lower crust, unreflective middle crust
- It is possible that the flat lying reflective lower crust is continuous across the Western Gawler and Jindarnga SP
  - That would suggest a contiguous Gawler Craton lower crust
- Or this block could be something completely different



# Interpretation – Hughes Domain

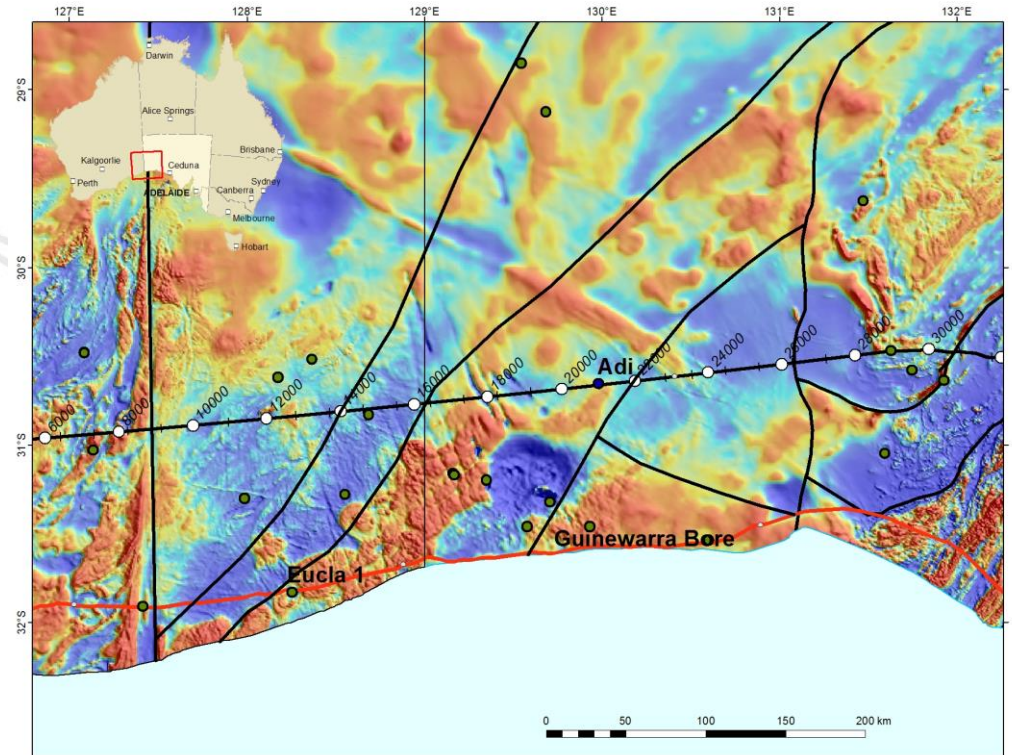
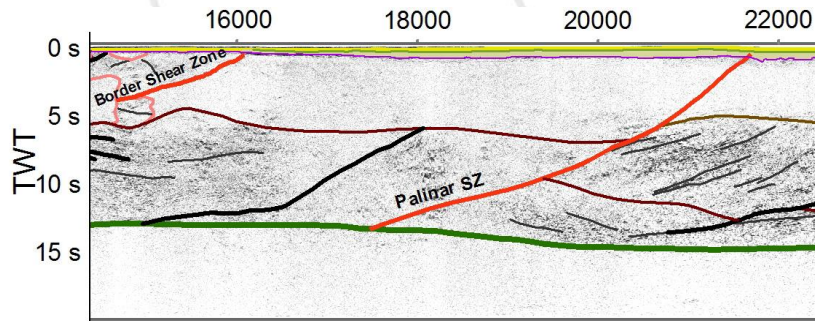
- The upper-crustal section bound by the Palinar SZ in the east and the Border SZ in the west
- Between 4-6s (12-18km) thick
- Appears completely non-reflective
- Coincides with a linear belt of magnetic intrusions





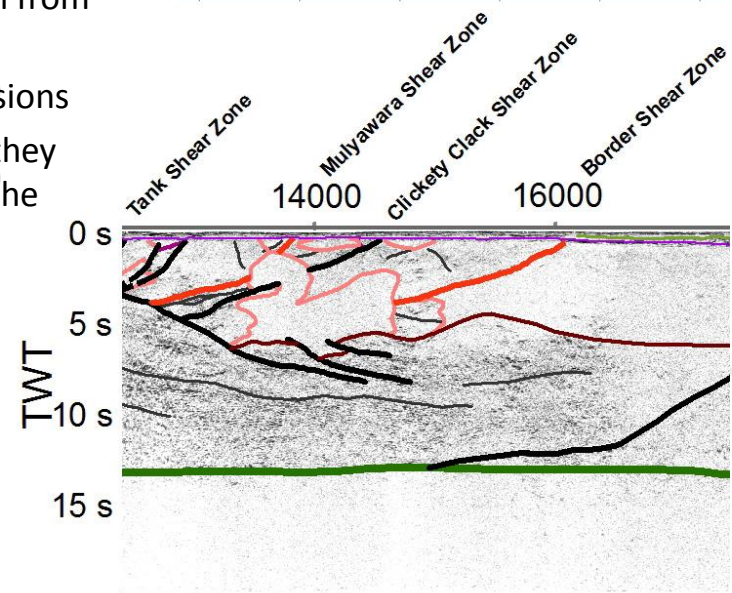
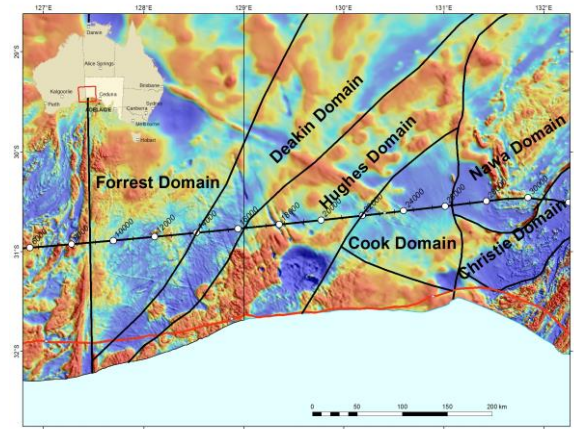
# Interpretation – Hughes Domain

- Eucla 1 = ~1140 Ma
- Guinewarra Bore = ~1160 Ma with 1640 Ma inheritance
- Seems likely that the belt of granites is Moodini Supersuite which has intruded Toolgana Supersuite aged crust



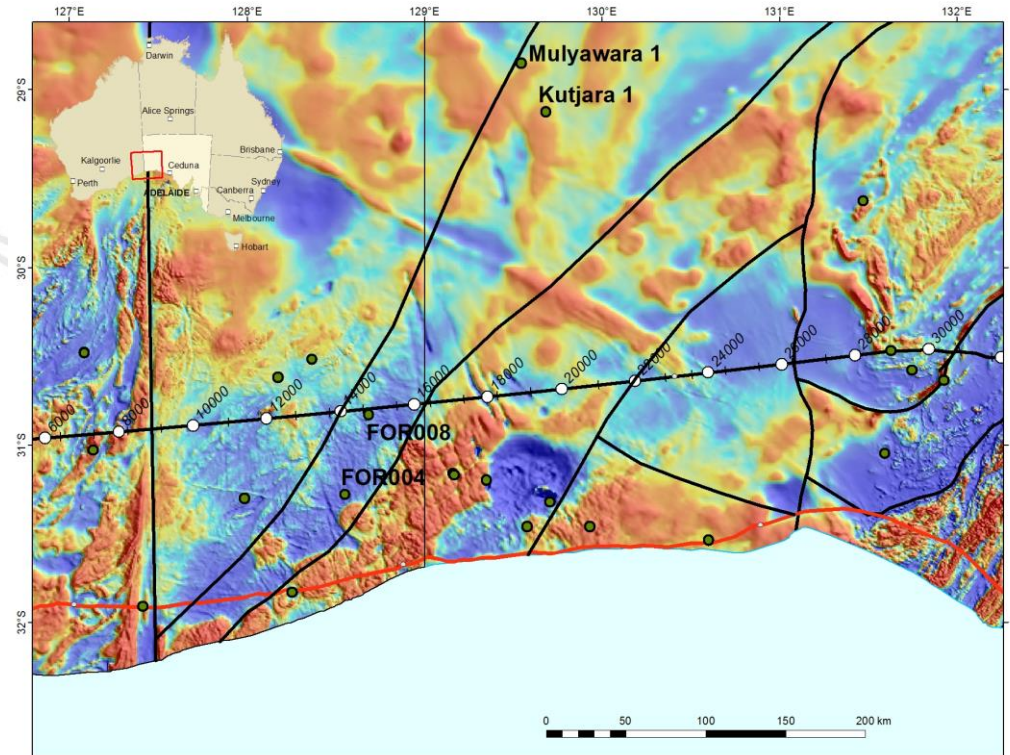
# Interpretation – Deakin Domain

- Small domain imaged between the west dipping Border SZ and the west dipping Mulyawara SZ
- Characterised by moderately reflective crust with generally west dipping reflectors parallel to the bounding shear zones
- West dipping shear zones and reflectors are truncated at the base by a series of east dipping structures separating the Deakin Domain from the Forest Lakes SP
- There are a number of large bland zones interpreted to be intrusions
- These intrusions utilise and cross-cut the structures suggesting they are syn-tectonic to late features - this also masks the extent of the structures



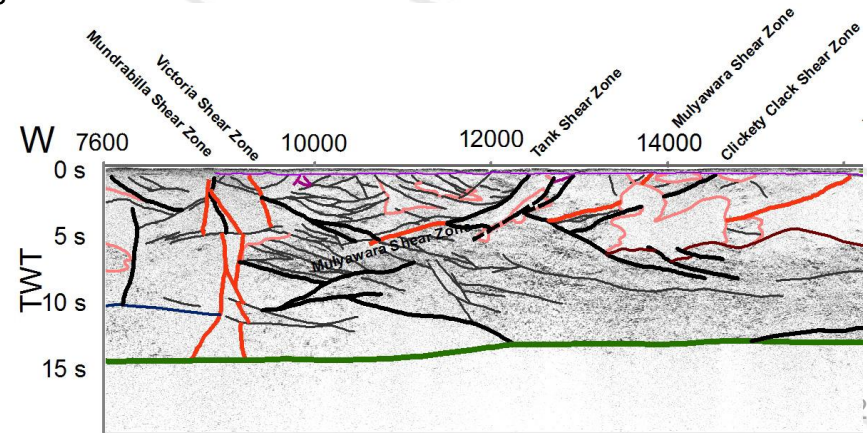
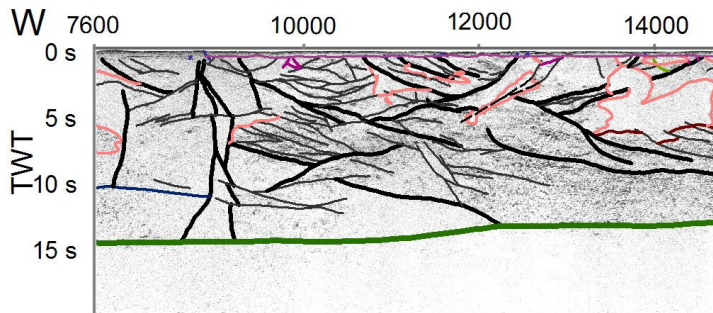
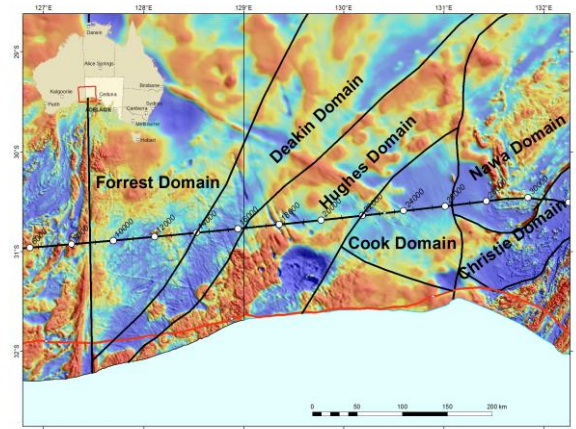
# Interpretation – Deakin Domain

- Mulyawara 1 =  $1168 \pm 6$  Ma
- Kutjara 1 =  $1591 \pm 11$  Ma with  $1167 \pm 7$  Ma metamorphic overgrowths
- FOR008 =  $1613 \pm 13$  Ma with  $1150 \pm 10$  Ma metamorphic overgrowths
- FOR004 =  $1613 \pm 4$  Ma with  $1179 \pm 10$  Ma metamorphic overgrowths
- Isotopically juvenile, geochemically subduction modified crust
- Predominantly Toolgana Supersuite crust
- Moodini Supersuite intrusions utilising and overprinting earlier structure



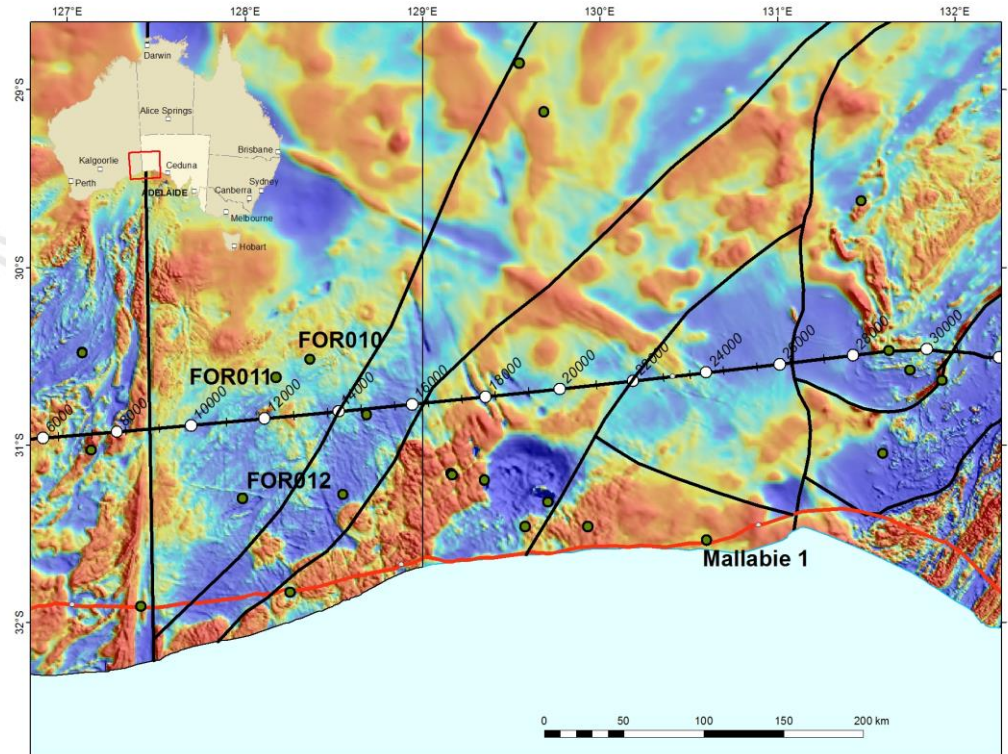
# Interpretation – Forrest Domain

- Forrest Domain is structurally complex
- Bound by the Mulyawara SZ to the east and Mundrabilla SZ to the west
- Underlain by the Forrest Lakes SP
- Intruded by numerous intrusions, some of which intrude the contact with the Forrest Lakes SP
- Eastern part relatively bland, intrusion dominated
- Western part contains abundant, shallow, predominantly east dipping shear zones
- Dominated by extensional kinematics on structures



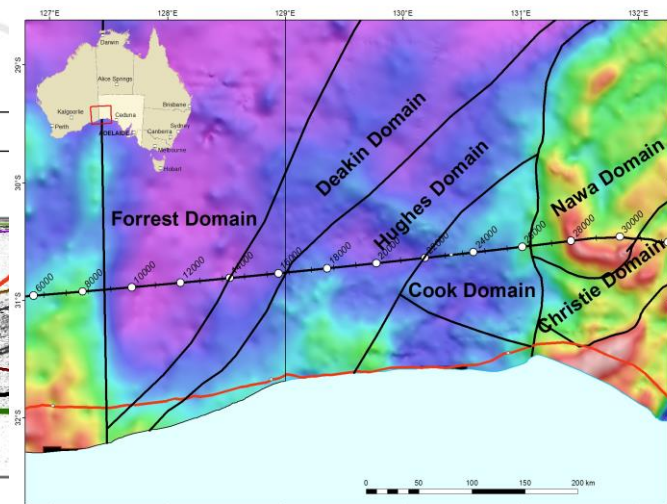
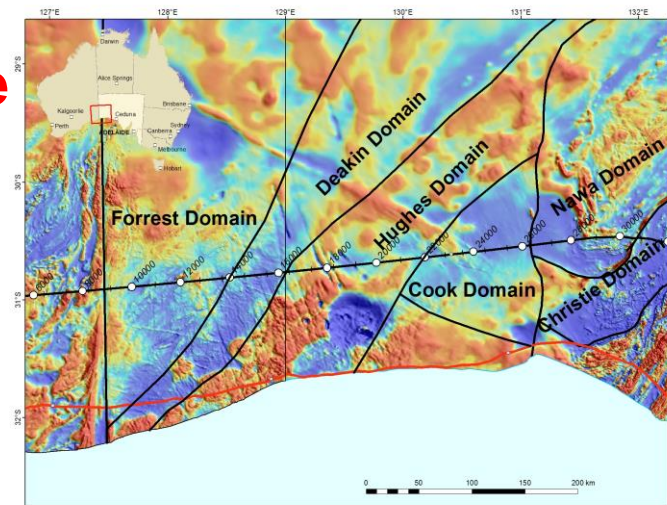
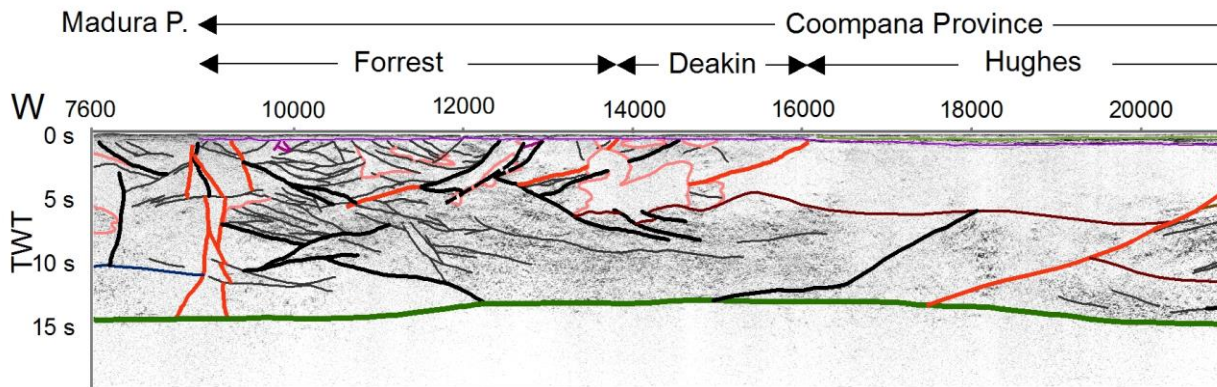
# Interpretation – Forrest Domain

- FOR010 =  $1492 \pm 9$  Ma
- FOR010 =  $1184 \pm 8$  Ma
- FOR011 =  $1688 \pm 4$  Ma with  $1174 \pm 12$  Ma metamorphic overgrowths
- FOR011 =  $1189 \pm 6$  Ma
- FOR012 =  $1505 \pm 8$  Ma
  
- Isotopically juvenile, reworking Toolgana-like crust
- Dominated by high-temperature rift related Undawidgi Supersuite
- Intruded by Moodini Supersuite and metamorphosed during Maralinga Event



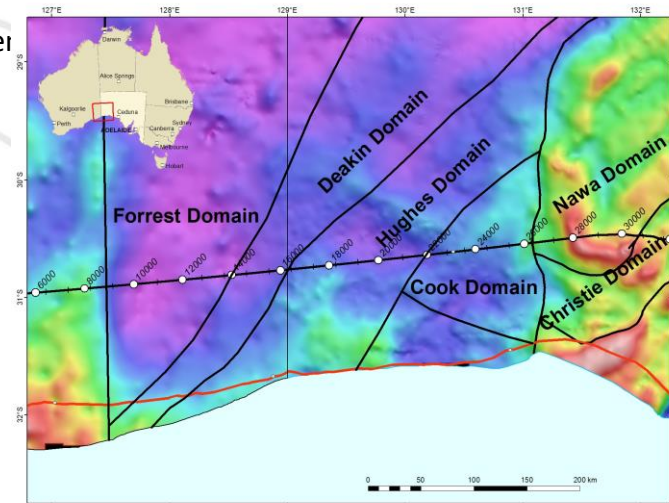
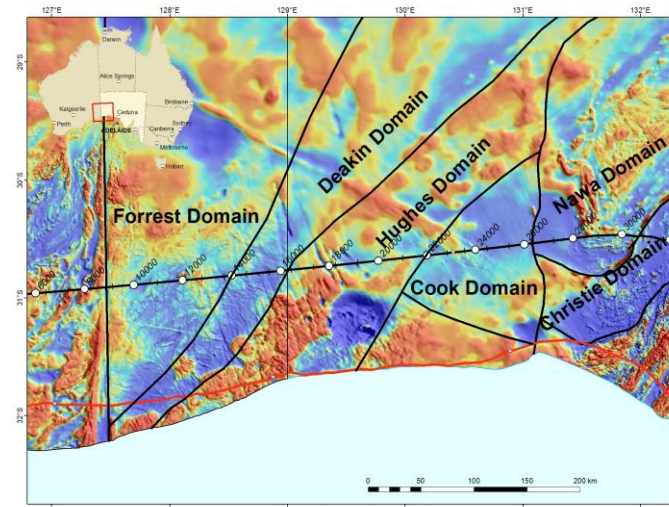
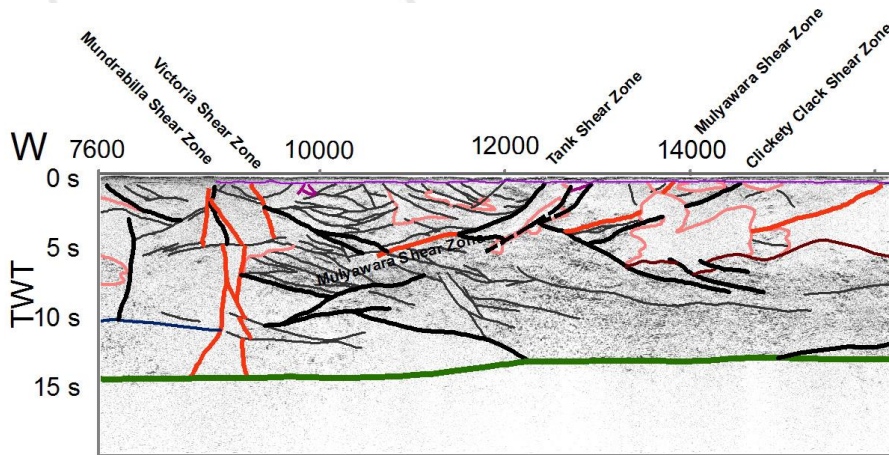
# Interpretation – Forrest Lakes Seismic Province

- Underlies the Hughes, Deakin and Forrest domains
- Sits in the hangingwall of the Palinar SZ and is truncated by the Mundrabilla SZ
- Varies from 4-9s (~12-27km) thick and rises to within 3s (~6km) of the surface near the Mundrabilla SZ
- Dominated by shallowly east dipping to flat lying reflectors and anastomosing shears with predominantly extensional kinematics
- Some evidence for west dipping structure but it is generally overprinted by the east dipping fabrics



# Interpretation – Weakly reflective lower crust

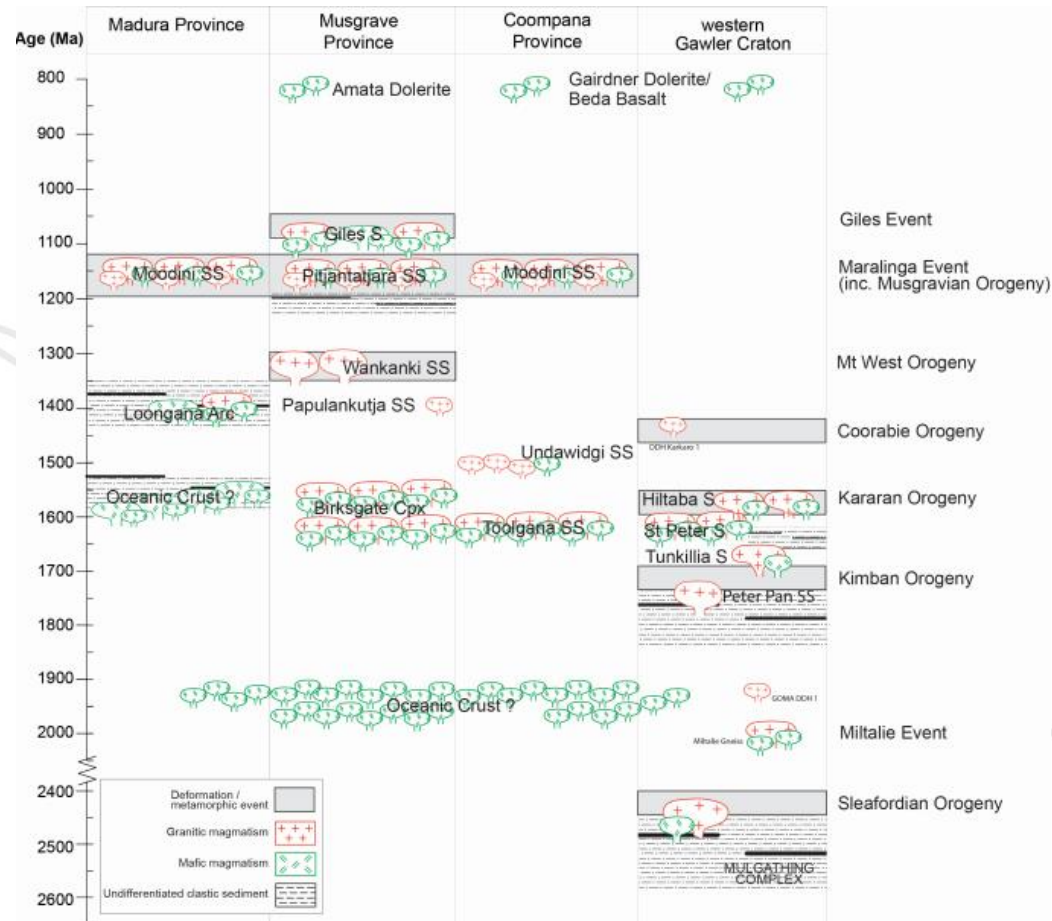
- Wedge of un-reflective lower-crust
- Not likely to be a continuation of the Gunnadorah SP across the Mundrabilla SZ based on density contrast
- Reflectors in overlying crust are parallel to boundary
- Shear bounded tongue of Forrest Lakes SP protrudes into the wedge
- Two possibilities for timing of this tongue development
  - Early, related to shortening along the subsequently reactivated Mulyawara SZ system
  - Late, related to a component of strike slip movement along Mulyawara SZ system



# Event chronology

Current available samples provide evidence for a number of events that have affected the region

- Western Gawler events
- Inferred oceanic crust development in the Coompana Province
- Magmatic-arc magmatism – Toolgana Supersuite
- Within plate magmatism - Undawidgi Supersuite (extension)
- A-type magmatism during the Maralinga Event – Moodini Supersuite

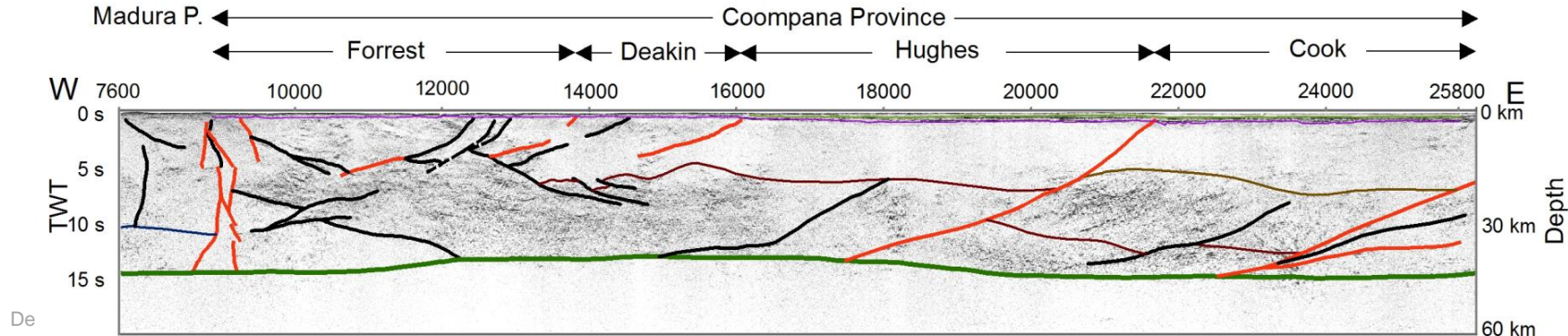




# Event chronology

## Cook Domain and Jindarnga SP?

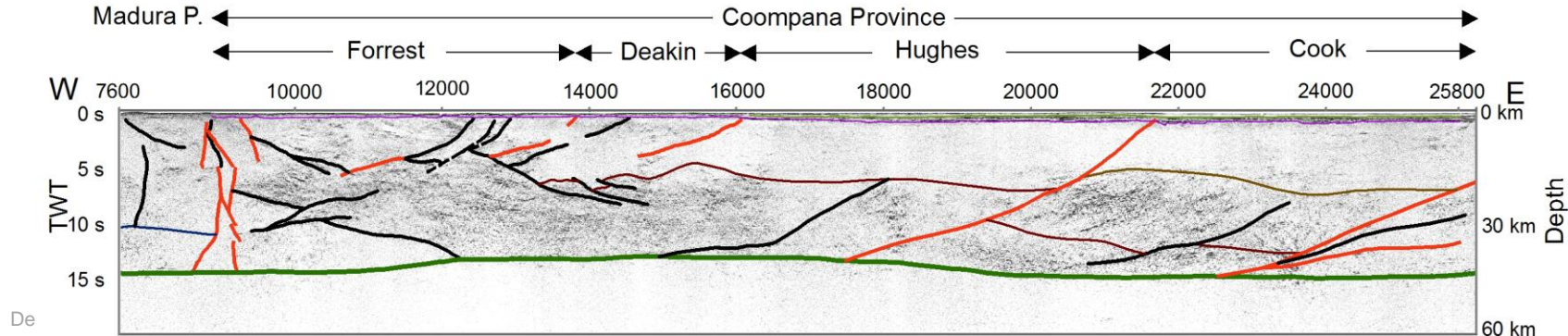
- No geological controls
- Multiple options for what this crustal column might represent
  - Could be Palaeoproterozoic Gawler Craton – Similar to Wirinjina SP
  - Could be Gawler Craton lower crust with Coompana Overprint (Toolgana, Undawidgi or Moodini)
  - Could be Coompana Province (juvenile oceanic crustal precursors)
  - Could be something completely different – micro continent?



# Event chronology

## Cook Domain and Jindarnga SP?

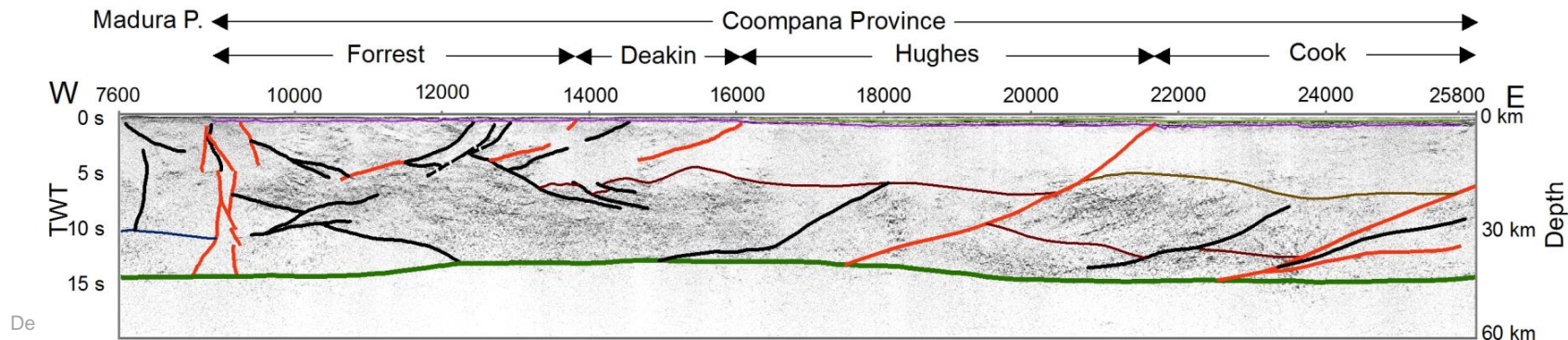
- In the Gawler seismic section, Jindarnga SZ displays reverse movement attributed to either the Kararan (~1600 Ma, preferred) or Coorabie (~1450 Ma) orogenies
- It is possible that the Palinar SZ was also active as a reverse SZ at this time
- Subsequent extensional reactivation along the Palinar SZ and minor shear zones within the Jindarnga SP likely relate to subsequent extensional events



# Event chronology

## Coompana Oceanic Crust Formation

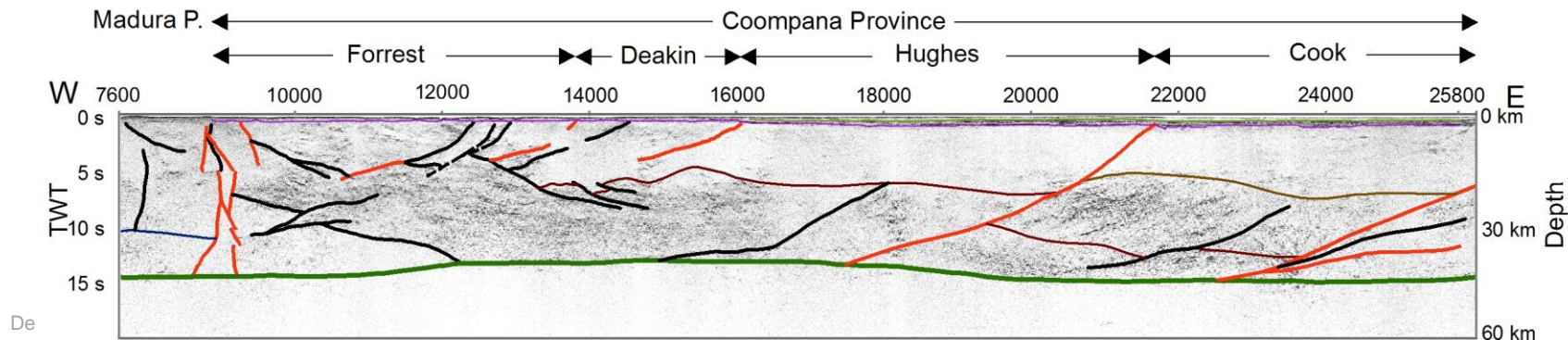
- Isotopic arguments suggest the Coompana Province crust is built on, and recycles, an oceanic crustal precursor formed between ~2000 – 1900 Ma
- OCT somewhere between the Central Hughes Domain and the Jindarnga SZ?



# Event chronology

## Toolgana Supersuite (~1620 – 1600 Ma)

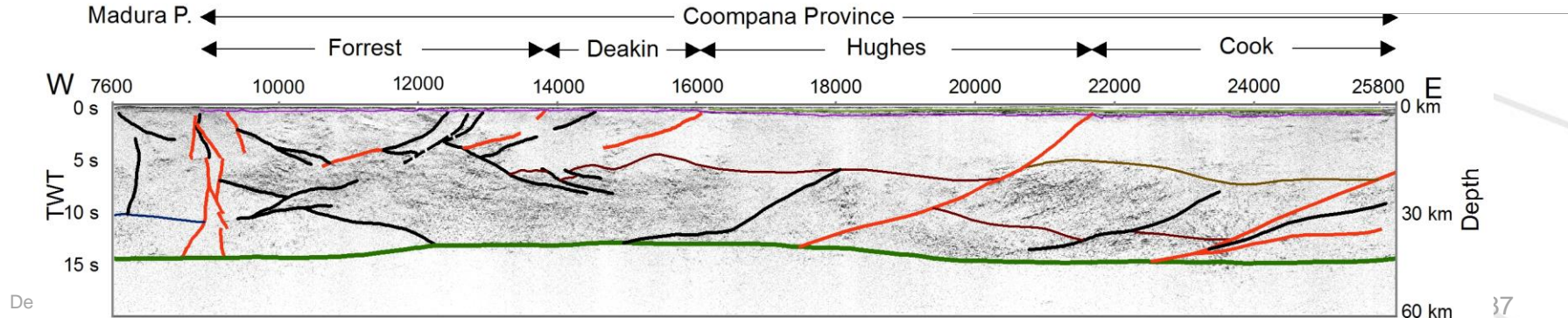
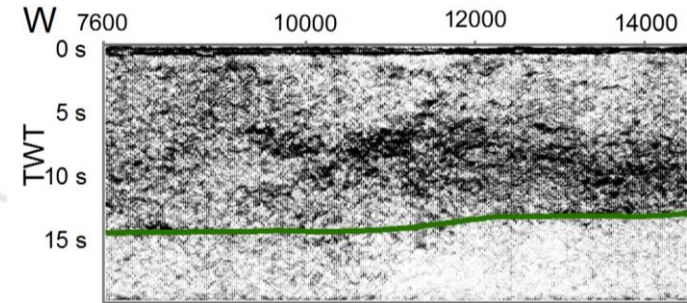
- Geochemical signature of subduction modified crust, magmatic-arc related intrusions
- Constrained by geochronology of magmatic rocks in the Deakin Domain
- Interpreted to be more widespread – inheritance, geochemical signature in Hughes and Forrest domains
- Correlated with similar units in the Eastern Musgrave Province and St Peter Suite



# Event chronology

## Major west dipping structure

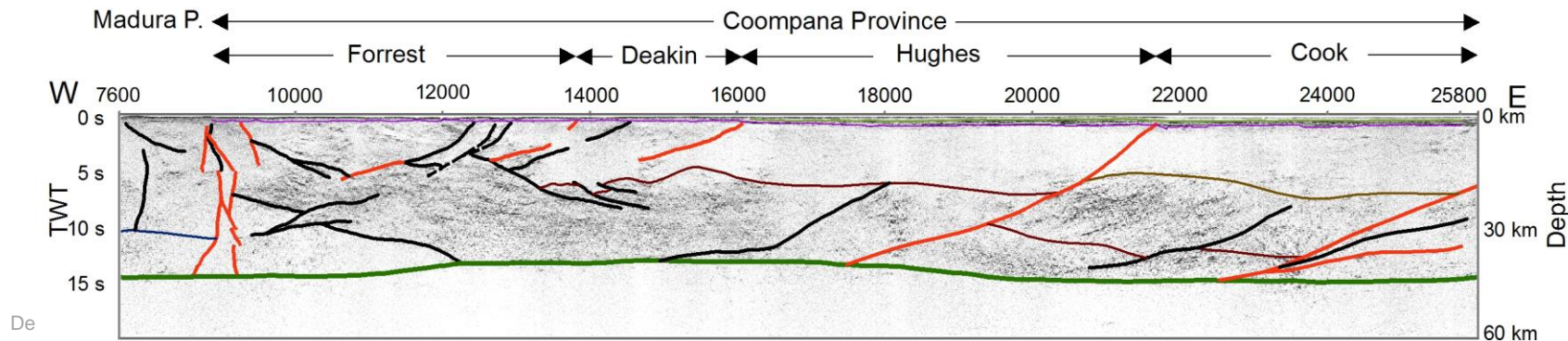
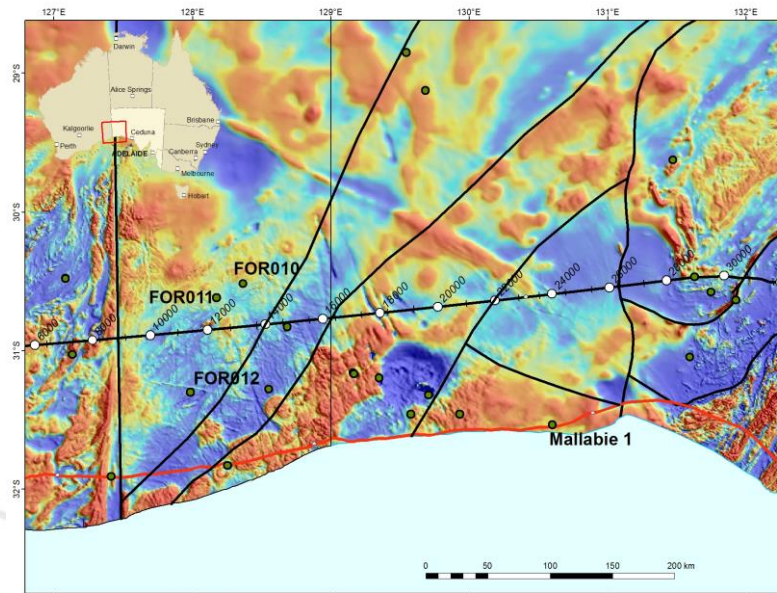
- There are a number of major west dipping structures
- These are apparent in the Hughes and Cook domains – Palinar SZ, Jingarnga SZ, WirinjinnaSZ, Karari SZ
- Less apparent in the west due to later extensional overprint
- Suggestion in the high-fold data for west dipping feature through mid-crust linking with tongue in lower crustal wedge – Mulyawara SZ System
- Potential reverse displacement preserved in the wedge –
- Kararan (~1600 Ma) aged compression?



# Event chronology

## Undawidgi Supersuite (~1500 Ma)

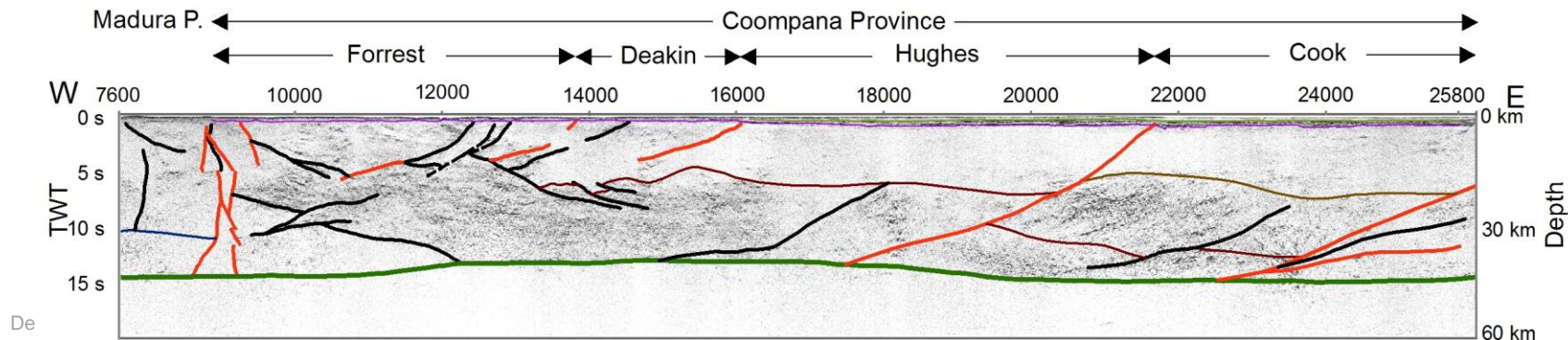
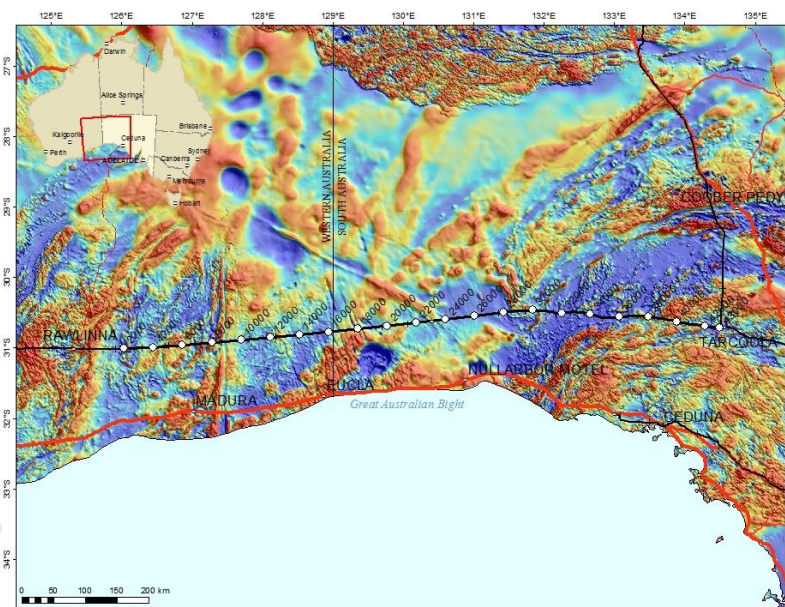
- Apparently constrained to the Forrest Domain and one occurrence in Mallabie 1 (Bruce Domain?)
- Geochemical characteristics of rift related magmatism
- Associated with extensional structures in the Forrest Domain



# Event chronology

## Maralinga Event ~1220-1120 Ma

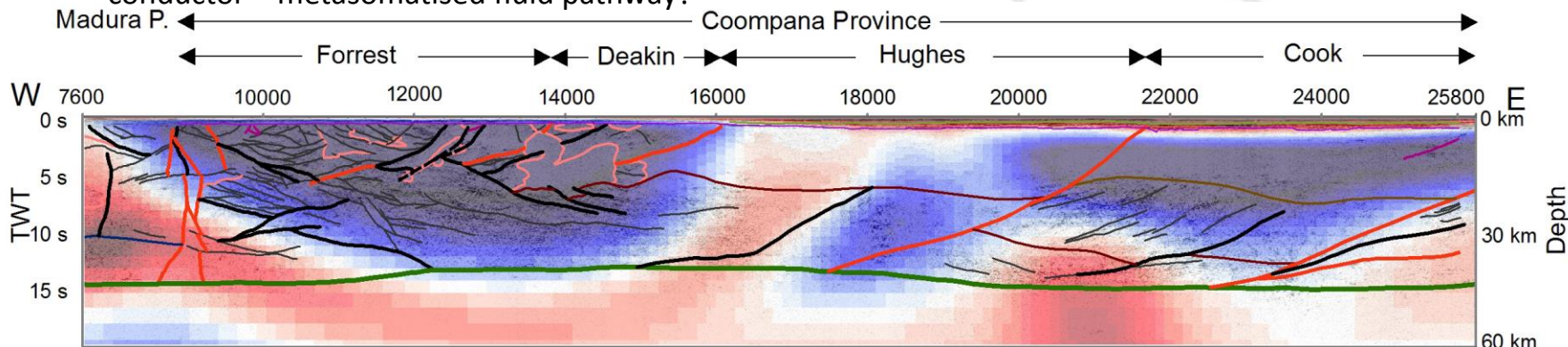
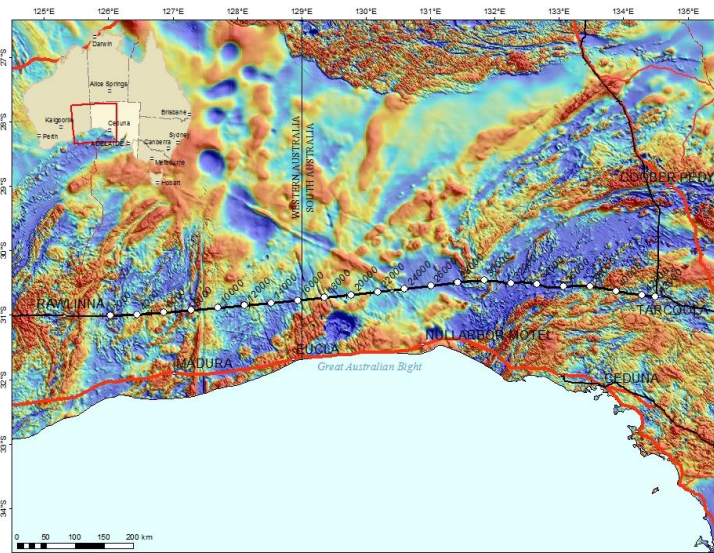
- Seems to be major event recorded throughout the region
- Associated with significant volumes of felsic magmatism throughout the region
- Moodini Supersuite magmatism is syn- to late deformation
- Associated with extensional fabric in the lower and mid crust which overprint earlier fabrics and crustal thinning



# Event chronology

## Maralinga Event ~1220-1120 Ma

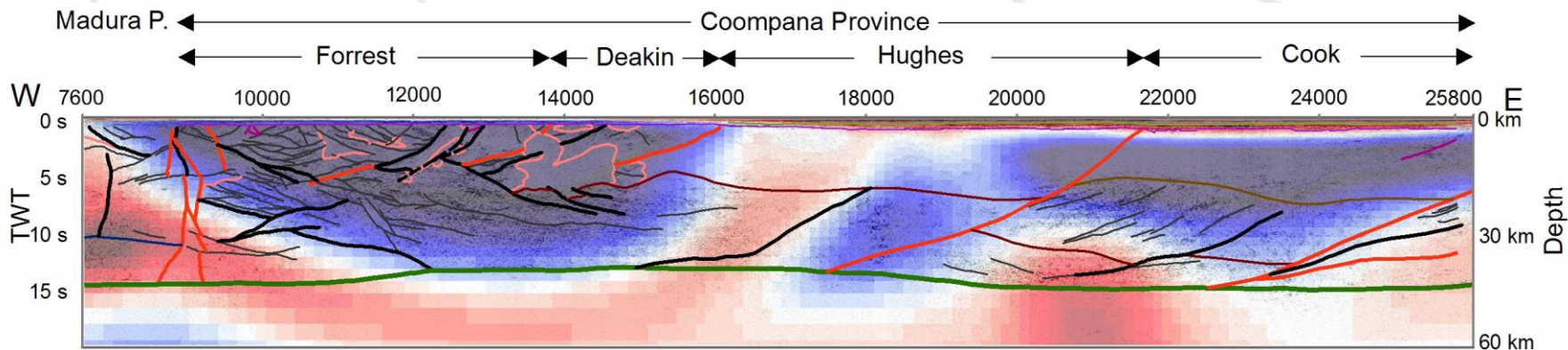
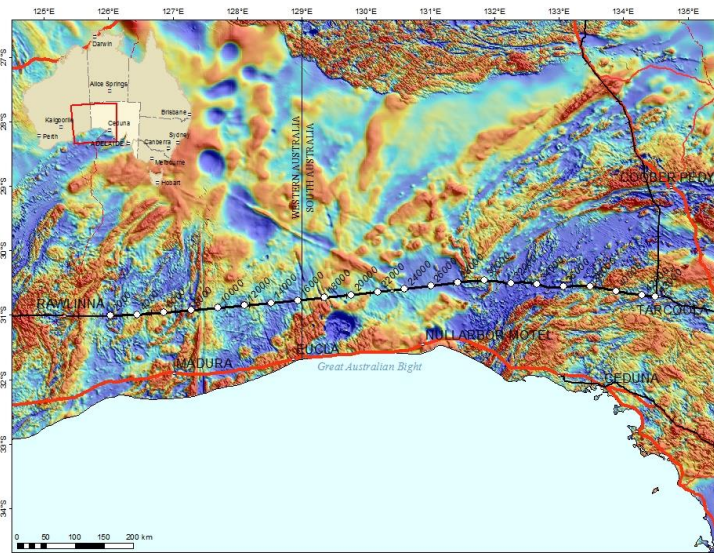
- Magnetotelluric data seems to record the late effects of the Maralinga Event and associated magmatism
- Large conductor in the Hughes Domain associated with line of late Moodini Supersuite intrusions (or maybe younger remnant magnetized bodies)
- Large conductor under the Cook Domain suggests it has seen Maralinga Event reworking – not seen in the Gawler Craton
- Weakly reflective lower crustal wedge coincides with MT conductor – metasomatised fluid pathway?





# Implications for exploration

- Geologically complex region
- Evidence for subduction related magmatism
- A number of crustal scale structures identified, some coincident with MT conductors
- Cook Domain may represent OCT zone or the reworked margin of the Gawler Craton



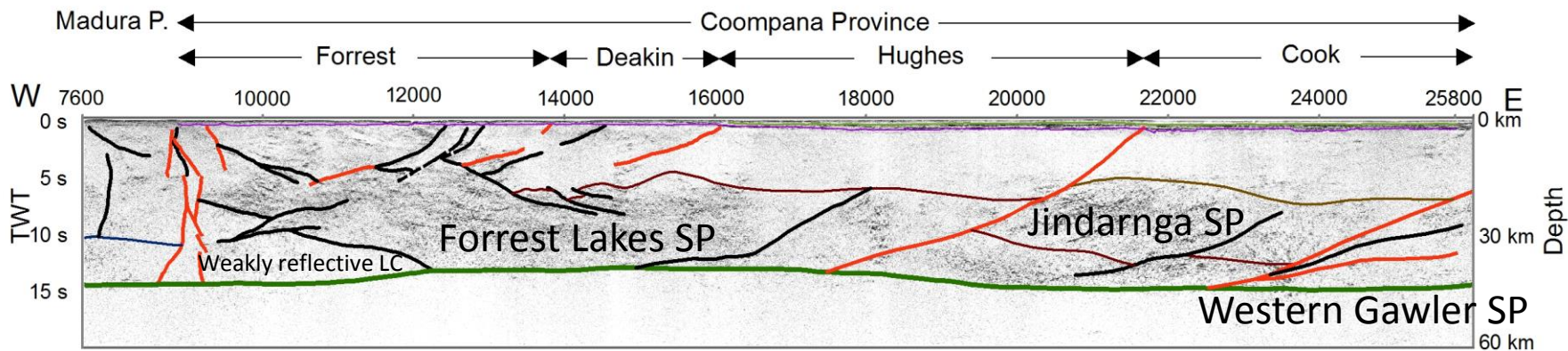
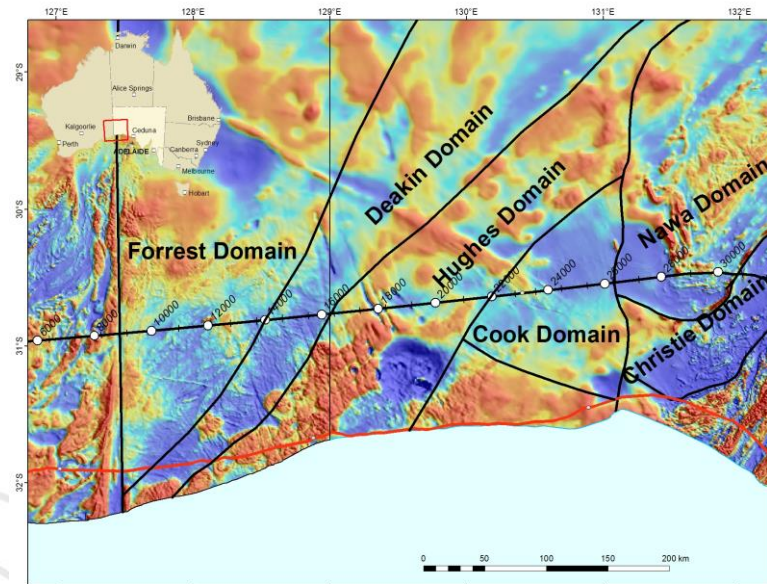
# Conclusions

This dataset sheds new light on what lies beneath the Nullarbor Plain

This was not an easy dataset to interpret and there are probably many valid opinions

This data, when combined with new potential field datasets and drilling, is revolutionising our understanding of Proterozoic Australia

The data is now available and provides a fantastic resource for future research



# Disclaimer

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