

EUCLA–GAWLER DEEP CRUSTAL SEISMIC AND MAGNETOTELLURIC TRANSECT

INTRODUCTION

The Eucla–Gawler line is an 870 kilometre long seismic reflection (13GA-EG1) and magnetotelluric (MT) data transect acquired along the Trans-Australian Railway corridor, crossing the Nullarbor Plain. The data has provided an excellent view of the crust and upper mantle underlying cover rocks of the Eucla, Bight, Denman and Officer Basins, as well as depth and details of the basins themselves. The transect links to the 12GA-AF3 seismic line that crossed the Albany–Fraser Orogen (GSWA Record 2014/6) and traverses the Madura and Coompana Provinces and the western Gawler Craton in South Australia, from Hagg to Tancoopa. The interpretation of the western Gawler Craton portion of the line was released as a series of extended abstracts in Geological Survey of South Australia Report Book 2015/25, available at <https://anbigbass.pir.sa.gov.au/WebSite/View/Summary/1/1/image/DDD/RB20150025.pdf>

Here we present the interpretations of the Madura and Coompana Provinces, which lie between the Albany–Fraser Orogen and the Gawler Craton. Interpretation of the seismic and MT data is a collaborative project between GSWA, the Geological Survey of South Australia (GSSA), and Geoscience Australia (GA). New interpretation methodology was tested, in particular the use of digital onscreen 2D and 3D visualization and annotation, so that interpretation workshops focussed mainly on discussing the geological significance of the identified features. Unlike seismic data imaging basins, two-dimensional (deep crustal seismic) data of hidden crystalline basement

and upper mantle are difficult to interpret due to geological ambiguity and structural complexity, as well as the lack of continuity of features and reflectors, out of plane reflectors, apparent dip, inability to image steeply dipping or vertical reflectors, and determining the significance of areas of non-reflectivity, including if they represent data gaps. Working digitally provides direct links to interpreted bedrock geology maps, drill core information, magnetic and gravity images, and the ability to overlay and interrogate MT models. However, full size plots of the seismic data were also utilized for visualization and discussions.

The group discussions and the mix of expertise, ranging from challenging issues associated with data processing to making sense of completely hidden basement geology, proved very effective. The interpretations were presented at the Australian Earth Sciences Convention (June 2016; see <http://www.dmp.wa.gov.au/Geological-Survey/Eucla-Gawler-Deep-Crustal-1456.aspx>) and have just been released as a non-series map, which is included in this poster.

Final, uninterpreted migrated 1D images of the seismic sections are available on the webpage as zip files, as well as supporting data. Alternative formats are available from Geoscience Australia: <http://www.ga.gov.au/metadata-gateway/metadata/record/89637>

MADURA PROVINCE INTERPRETATIONS

Rodona Shear Zone

The Madura Province is separated from the Albany–Fraser Orogen by the Rodona Shear Zone. To complete a seamless interpretation across this major crustal boundary the overlapping ends of seismic lines 12GA-AF3 and 13GA-EG1 were merged (Fig. 1). Merging two seismic datasets that were acquired under different conditions was challenging, particularly with regard to migration. The seismic data clearly show the easterly dip of the Rodona Shear Zone, which corresponds to significant north-northeasterly trending structures visible in aeromagnetic and gravity data (Fig. 2), and distinct geochronological, geochemical and isotopic differences (e.g. GSWA Reports 133, 150; GSWA Record 2015/10). The Rodona Shear Zone is interpreted as a complex series of west-vergent thrusts, overprinted by sinistral shear zone movement. Deformed Esperance Supersuite intrusions (c. 1170 Ma metamorphic) occur within and adjacent to the shear zone, indicating that at least some of its history post-dates these intrusions.

Rocks in the hanging wall of the Rodona Shear Zone have been intersected by numerous drillholes (Fig. 2) and include mafic schist of the 1389 Ma Pinto Basalt (MAD002), metamorphosed gabbro to ultramafic rocks and plagiogranites of the 1415–1389 Ma Hagg Cave Supersuite (Loongana, Hagg, Serpent, and MAD002), and interlayered metabasalt and Fe- and Mn-rich sedimentary schist of the Sleeper Camp Formation (Burkin prospect). Together, these rocks define the oceanic and oceanic-arc character of the Madura Province, and are considered to be part of an ophiolite complex (the Knabiddy Ophiolite Complex). In the MT model there is a large gap in conductivity coinciding with these ophiolite rocks and the Rodona Shear Zone itself, consistent with the interpretation of a major crustal boundary and its easterly dip.

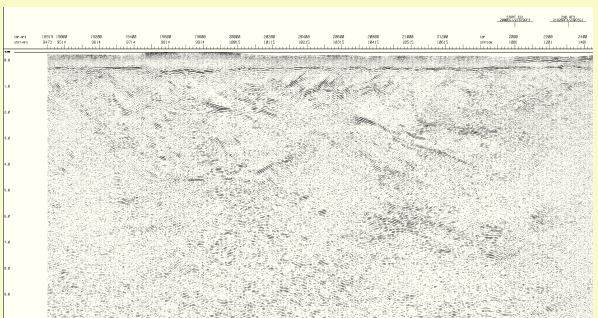


Figure 1. Western end of the seismic section showing merged, uninterpreted, migrated data. The strong, east-dipping reflectors define a series of shear zones collectively termed the Rodona Shear Zone.

Central area

This area encompasses the region between the Serpent and Gauge Shear Zones, and is dominated by complex intersections of structures in the potential field data, and a large non-reflective area in the seismic data. The seismic data shows interpreted extensional shear zones dipping either side of a large domal area (Family Dam, Kybo, Gauge, Vincent, and Carriage Shear Zones). The domal area includes a large non-reflective area interpreted to be dominated by c. 1200–1120 Ma Moodini Supersuite intrusions. Reflective zones appear to be truncated by non-reflective zones, consistent with this interpretation. The western side of the domal area coincides with a strongly conductive zone in the MT model. The subvertical Serpent Shear Zone cuts the extensional shear zones, and probably relates to a phase of strike-slip movement, although there are no clear shear sense indicators along this structure.

Mundrabilla Shear Zone

The Mundrabilla Shear Zone represents a major crustal boundary separating the Madura and Coompana Provinces. In aeromagnetic data it is a very distinctive, northerly trending structure and its long length and linearity suggests it is a subvertical, strike-slip shear zone. A broad zone of strong magnetic response is drawn into the western side of the shear zone, indicating sinistral shear sense. The Mundrabilla Shear Zone provides an opportunity to examine a large subvertical structure in seismic reflection data, and to make comparisons to the MT data.

In the seismic data the Mundrabilla Shear Zone is imaged as a stair-stepped, weakly to non-reflective zone interpreted to extend to the base of the crust (Fig. 3). Areas of reflective crust are truncated by the weakly to non-reflective zone, and these truncations were interpreted to mark the edges of the shear zone. Subhorizontal offsets suggest subhorizontal sliding (into and out of the plane) of portions of the shear zone during sinistral shear. In the MT model, the Mundrabilla Shear Zone is not apparent, although an area of very strong conductivity in the lower crust is confined to the western side of the shear zone.

West of the Mundrabilla Shear Zone is another domal region, similar to that described in the central area but containing rafts of reflective crust. The domal region is flanked by the Lynch and Laundry Shear Zones, interpreted as extensional shear zones. GSWA stratigraphic drillhole MAD011 penetrated the top of this domal area, and intersected c. 1445 Ma monzogabbro belonging to the Moodini Supersuite. This occurs within an elongate anomaly of strong magnetic and gravity response that is part of a large zone of similar geophysical response drawn into the Mundrabilla Shear Zone with sinistral shear sense. Moodini Supersuite metamorphosed granite with a subhorizontal L-S tectonic fabric was intersected in drillcores from within the shear zone (Fig. 4; Moodini prospect, near the Eyre Highway), and has a magnetic age of c. 1130 Ma (see geochronology records for GSWA 1126/5 and 1126/6). This is interpreted to indicate shear zone movement either during or after this time. Given the prolonged magnetic history in the region, it is feasible that movement along the Mundrabilla Shear Zone was facilitated by magnetism and associated fluid migration, perhaps during sinistral transtension. This could fit with the apparent coincidence of Moodini Supersuite magnetism and conductivity in the MT model in both domal areas. However, the Mundrabilla Shear Zone itself is not obvious in the MT model.

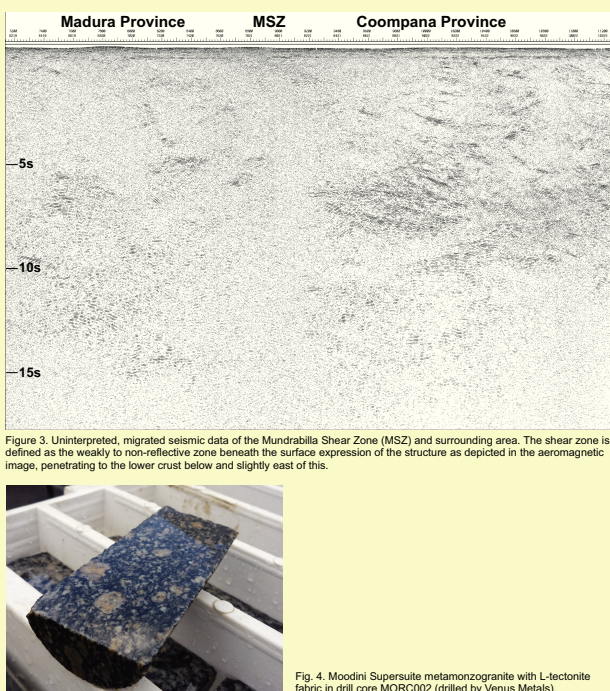
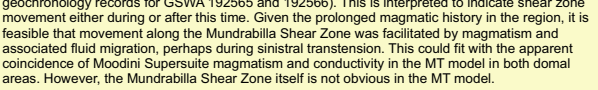


Figure 2. Combined gravity (colour) and reduced to pole, first vertical derivative (greyscale) aeromagnetic image showing the Rodona Shear Zone, structural interpretations, drill hole locations and prospect names, and location of seismic lines.

Figure 4. Moodini Supersuite metamorphosed granite with L-S tectonic fabric in drill core MORC002 (drilled by Venus Metals).



Typical track and vista on the Nullarbor Plain.

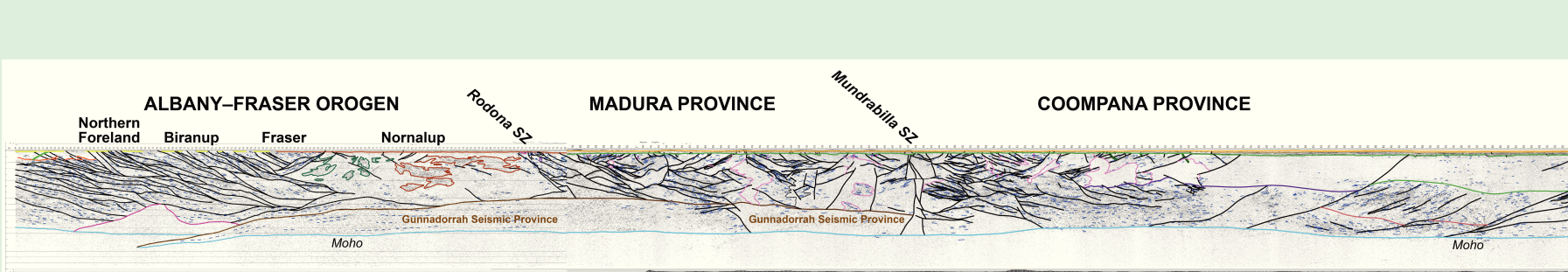
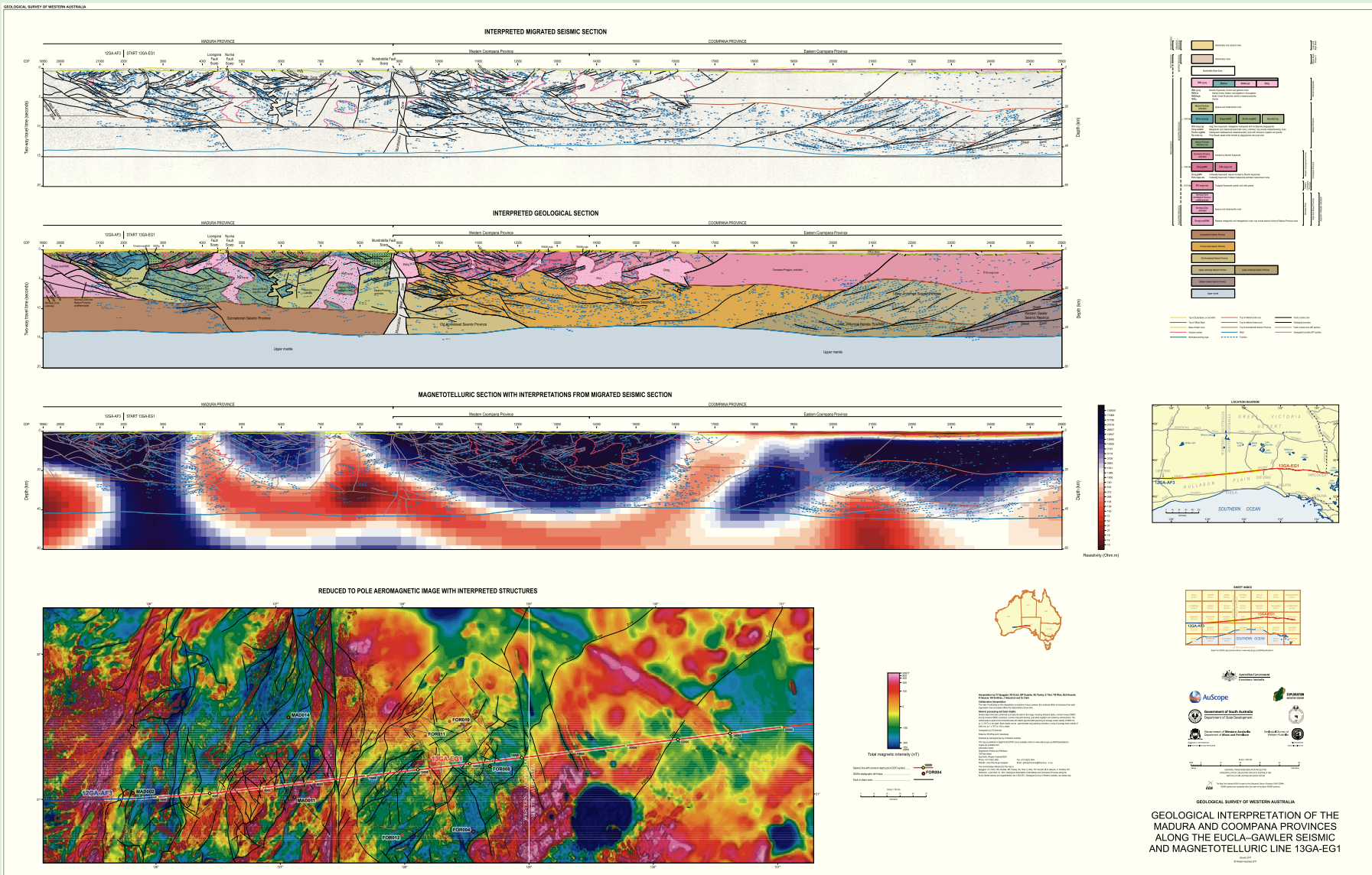


Figure 5. Overlapping image of seismic lines 12GA-AF3 (GSWA Record 2014/6) and 13GA-EG1 showing interpreted lines.

SUMMARY OF INTERPRETATIONS

The Moho

The Moho is defined by non-reflective upper mantle. Several features of crustal thickness are highlighted:

- The Moho is imaged at approximately 14s TWT (two-way-travel time, approximately 42 km depth) at the Albany–Fraser Orogen margin, and is gently undulating at about this depth across the Madura Province
- The crust thickens slightly to approximately 15s TWT (45 km) in the vicinity of the Mundrabilla Shear Zone
- The crust thins in the western Coompana Province to approximately 13s TWT (approximately 39 km), but thickens again to approximately 15s TWT (45 km) in the eastern Coompana Province
- There is a degree of overlap in these features with the MT model, and also between the seismic provinces and the inferred effects of the Maralinga Event (Moodini Supersuite intrusions)

Madura Province and the link to the Albany–Fraser Orogen:

- A clear (inverted) thrust-dominated architecture is evident in the Albany–Fraser Orogen, particularly its western part (Fig. 5)
- Less coherent, less continuous structures are evident in the Albany–Fraser Orogen east of the Fraser Zone and in much of the Madura Province, corresponding to the intrusion-dominated architecture
- The Rodona Shear Zone is clearly defined as a broad system of southeasterly dipping coherent reflectors, and is coincident with the suture zone between the Albany–Fraser Orogen and the Madura Province
- Ophiolite rocks occur in the hanging wall of the Rodona Shear Zone
- The Gunnadarrah Seismic Province is interpreted to be common to both, suggesting it is related to Moodini Supersuite magnetism and/or earlier extension related to the formation of the ocean-continent transition (GSWA Report 133). To the west the Gunnadarrah Seismic Province stops short of less to non-reworked Yilgarn Craton crust
- Domal features in the Madura Province relate to extension and voluminous Moodini Supersuite intrusions during the Maralinga Event
- The Mundrabilla Shear Zone is a subvertical, crustal-scale, sinistral transtensional shear zone probably linked to Moodini Supersuite magnetism

Coompana Province:

- Contains evidence for both Proterozoic subduction-related and rift-related magmatism within an oceanic setting (Fig. 7)
- Several crustal-scale structures identified, some coincident with conductivity identified in the MT data
- The Cook Domain adjacent to the western Gawler Craton may represent an ocean-continent transition, or the reworked margin of the Gawler Craton
- MT data appear to record the effects of voluminous magmatism associated with the Maralinga Event, particularly the strongly magnetic, northeasterly trending linear belt of plutons that occur southeast of the Border Shear Zone

The c. 1220–1120 Ma Maralinga Event:

- Defined as the massive magmatic event that produced the Moodini, Esperance, and Pijanjara Supersuites (Fig. 7)
- Locus in the Musgrave Province, extends into the edge of the West Australian Craton
- Variable deformation – extension and inversion (thrusting) in the Albany–Fraser Orogen (Albany–Fraser Orogeny Stage I), dominantly extension in the Madura and Coompana Provinces
- Extensive and diverse, mafic, intermediate and felsic intrusions whose compositions reflect new juvenile input and the crust they intrude. Forms a large component of the geophysical expression of the present-day crust, but preserves remnants of older oceanic and oceanic-arc crust in the Madura and Coompana Provinces



The Trans-Australian Railway and access track, along which seismic line 13GA-EG1 and the MT data were acquired.



Collapsed limestone at Old Homestead Cave, approximately 35 km south of Forrest.

COOMPANA PROVINCE INTERPRETATIONS

Western boundary – Mundrabilla Shear Zone

There is a distinct geophysical change between the Madura and western Coompana Provinces across the Mundrabilla Shear Zone. The western Coompana Province shows overall higher reflectivity in the seismic data, lower densities in the gravity data, and completely different structures and features in the aeromagnetic data – none of which can be traced across as displacement markers. In addition, the subhorizontal reflectors that define the Gunnadarrah Seismic Province in the Madura Province are lacking, and the lower crust appears as a weakly-reflective, gently east-dipping wedge truncated by the Mundrabilla Shear Zone. This wedge is defined as the Old Homestead Seismic Province, and is somewhat mirrored by conductive crust in the MT model, although the conductive feature continues into the domal area west of the Mundrabilla Shear Zone in the Madura Province. However, a domain of very high conductivity in the lower crust is restricted to the Madura Province side of the shear zone.

The Forrest Lakes Seismic Province, defined as strongly reflective, subhorizontal lower crust in the MT model, also contains strong reflectors that define an upright antiform, flanked by the Approach East Shear Zone (Fig. 6a). This is coincident with a small but strong magnetic and gravity anomaly northeast of Forrest (Fig. 6b). The Tank Shear Zone was likely to be extensional, perhaps facilitated by Moodini Supersuite intrusions.

Western Coompana Province

This corresponds to the region between the Mundrabilla and the Mulyawara Shear Zones, separating dominantly Undawidgi Supersuite (c. 1490–1500 Ma, mostly intermediate to felsic metavolcanic and intrusive oceanic rift-related rocks) to the west from dominantly Toigana Supersuite (c. 1610 Ma, mostly intermediate to felsic, primitive oceanic-arc rocks) to the east, although the two are not mutually exclusive (see GSWA Record 2015/10). Initially, the tectonic subdivisions of Shaw et al. (1996) were followed where the Forest Zone was defined as a separate entity, but recent drillcore analysis and this work have shown that subdivision to be unnecessary. The Mulyawara Shear Zone is interpreted as a major northwest-dipping structure that continues into South Australia to the northeast, and was utilized by the northerly trending, west-dipping Tank Shear Zone, which cuts easterly dipping shear zones in its hanging wall. The hanging wall also contains strong reflectors that define an upright antiform, flanked by the Approach East Shear Zone (Fig. 6a). This is coincident with a small but strong magnetic and gravity anomaly northeast of Forrest (Fig. 6b). The Tank Shear Zone was likely to be extensional, perhaps facilitated by Moodini Supersuite intrusions.

This region, as far east as the Border Shear Zone, has a bowl-shaped geometry in the seismic section, which appears to be mirrored in the MT model. Bland, weakly to non-reflective areas are interpreted as dominated by Moodini Supersuite intrusions. Some of these intrusions appear to have utilized or cross-cut various shear zones, suggesting synchronous or post-deformation magmatism.

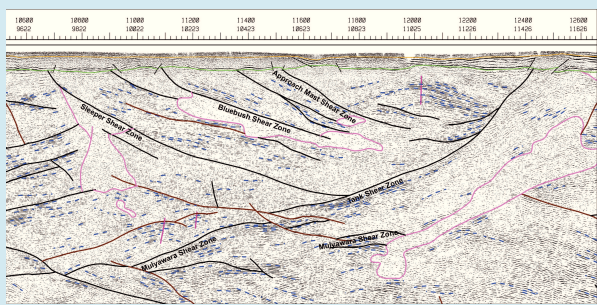


Figure 6a. Interpreted antiform feature near Forrest, top right figure, that coincides with a strong magnetic and gravity anomaly shown in Figure 6b. Brown lines are extensional shear zones, other colours as per legend on map.

Eastern Coompana Province

This corresponds to the region between the Mulyawara and Jindargna Shear Zones. The Jindargna Shear Zone dips moderately to the west, separating the underlying edge of the western Gawler Craton from the overlying eastern Coompana Province. East of the Palinar Shear Zone (defined as the Cook Domain in South Australia) the crust is three-layered comprising a remarkably bland, weakly to non-reflective upper crust, a strongly reflective, moderately west-dipping mid-crust (Upper Jindargna Seismic Province), and a strongly reflective, subhorizontal to east-dipping lower crust (Lower Jindargna Seismic Province). The upper crust in this region is unknown, and is possibly either Toigana Supersuite-dominated, or part of the western Gawler Craton.

West of the Palinar Shear Zone the crust is two-layered, comprising the continuation of remarkably bland, weakly to non-reflective upper crust, and strongly reflective, subhorizontal lower crust defined as the Forrest Lakes Seismic Province. The latter continues west beneath the western Coompana Province, changing to a gentle to moderate east dip below the Mulyawara Shear Zone. The weakly to non-reflective upper crust extends west to the Border Shear Zone, which separates it from gently west-dipping reflective crust dominated by the Toigana Supersuite. This section of upper crust, which is between 4 to 6s (12 to 18 km) thick, coincides with a distinct linear belt of northeasterly trending, magnetic intrusive rocks interpreted to be dominantly granitic rocks of the Moodini Supersuite (represented by the Eucla 1 drill hole, see geochronology record for GSWA 194773). Non-reflective seismic data in the lower part of the footwall of the Border Shear Zone supports this interpretation, as does a distinct west-dipping conductive zone in the MT model, although the latter also crosses the Forrest Lakes Seismic Province.

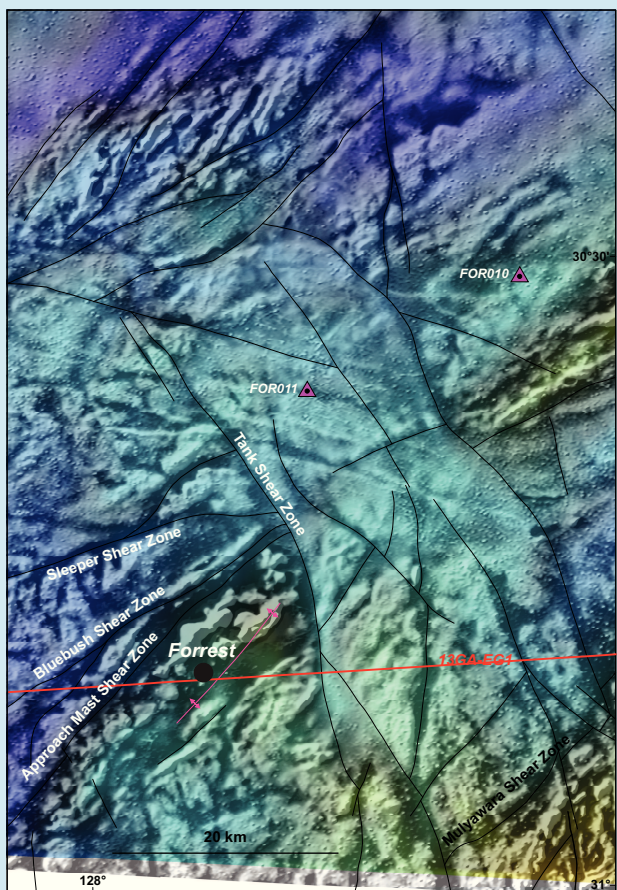


Figure 6b. Combined gravity (colour) and reduced to pole, first vertical derivative (greyscale) aeromagnetic image showing interpreted structures and the northeasterly trending antiform near Forrest.

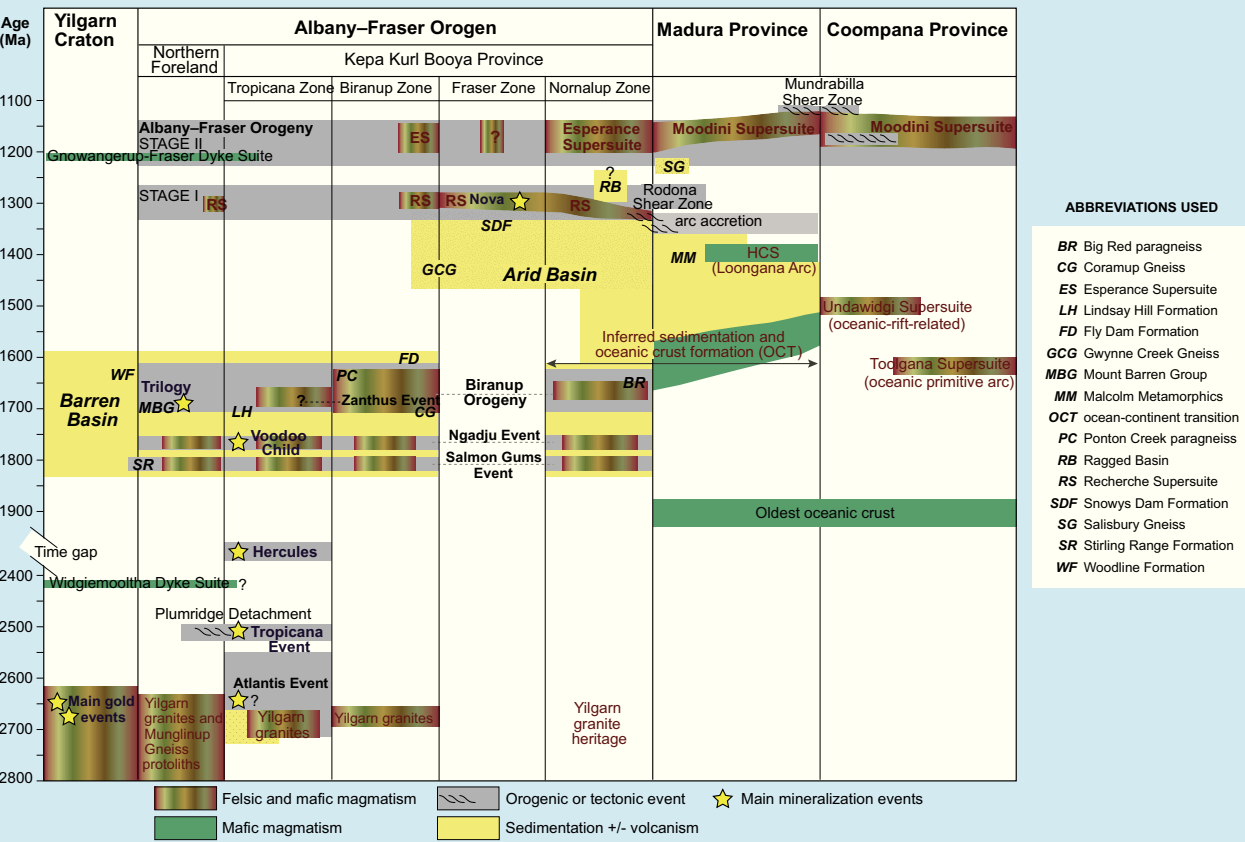


Figure 7. Time-space diagram showing major tectono-thermal events, sedimentation and basin evolution, and main mineralisation events. The diagram is organised from approximately west to east (GSWA Reports 133, 150, Record 2015/10).

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