Geological and Geodynamic implications of the western Gawler Craton section of Seismic line 13GA-EG1


What lies beneath the western Gawler Craton?
Seismic and Magnetotelluric workshop, Adelaide, 2015

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Introduction

13GA-EG1E

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 was processed first.

The remainder of the line is currently being processed and will be released in 2016.
Outline

In this presentation we present the preliminary geological and geodynamic interpretations from the 13GA-EG1E seismic section

- Briefly re-visit the main features of the seismic line
- Outline the process used and some of the challenges faced
- Present an event history for the geological development of the western Gawler Craton derived from the seismic section and geology
- Present a few brief comments on implications for exploration
- Where to next for the west of SA

All of these presentations, the associated Abstract Volume, the SEG-Y data and the poster plate of the interpretations is available from the minerals website: minerals.statedevelopment.sa.gov.au
Domains

- Gawler Craton divided into a number of different domains based on geology and potential fields
- We have interpreted a number of seismic domains in the seismic section
Structure

- Western Gawler displays a complex structural architecture
- Numerous anastomosing shear zones
- Many of which are interpreted to be crustal scale
- Major domain bounding structures:
  - Coorabie SZ
  - Karari SZ
  - Jindarnga SZ
Interpretation Process

This presentation presents an attempt to integrate the existing data from the western Gawler Craton with the new insights gained from the seismic section and the supporting Magnetotelluric modelling and potential field inversions and forward modelling.

Existing datasets include:

- Known lithostratigraphy from mapping and drill holes
- Regional geochronology and thermochronology
- Metamorphic constraints
- Geochemical and Isotopic constraints
Challenges

- Poor data, often in places of greatest complexity
- Challenge of interpreting data with multiple overprinting events
- Many events strike-slip dominated, so significant out of plane movement. Potential for apparent offsets not reflecting in-plane movements
- Lack of existing geological data to constrain interpretations
- Because of uncertainties, often present more than one interpretation
Event history

Through the seismic interpretation process and integration of existing geological knowledge we have recognised 10 individual events (E) affecting the western Gawler Craton

- E1 – Pre Mulgathing Complex structure
- E2 – Deposition of Mulgathing Complex
- E3 – Sleafordian Orogeny
- E4 – Nawa and Fowler Deposition
- E5 – Kimban Orogeny
- E6 – St Peter/Coompana magmatism
- E7 – Kararan Orogeny/Hiltaba Event
- E8 – Coorabie Orogeny
- E9 – Officer Basin
- E10 – Eucla Basin
E1-Pre Mulgathing Complex

Distinguished 2 different Seismic Provinces; Central Gawler Seismic Province (CGSP) and Western Gawler Seismic Province (WGSP)
E1-Pre Mulgathing Complex

Central Gawler Seismic Province
- Contains a number of west dipping anastomosing and sigmoidal shear zones that roughly parallel the Bulga Shear Zone
- Reflective middle to lower-crust located at the eastern end of the line beneath the Wilgena Domain
- One possibility is that this province represents the continuation of the reflective lower-crust in the WGSP, but has a different fabric inventory or fabric orientations related to structural thickening
- A second possibility is that the different seismic character of the CGSP compared to the WGSP may indicate that the seismic provinces are two different geological entities
- A third alternative is the different seismic character of the CGSP is a result of younger tectonic processes that have modified the seismic character of the lower crust of the CGSP to make it distinct from the character of the WGSP
E1-Pre Mulgathing Complex

Western Gawler Seismic Province

- Occurs beneath the western Wilgena, Christie, Nawa and Coompana domains
- Dominated by listric, west dipping structures, many of which continue through the upper-crustal Mulgathing Complex to the surface
- This province contains two layers of different seismic character; a strongly reflective lower-crust, and domains of relatively unreflective middle-crust
- The thickness of the seismic province varies along the line, including two ‘bulges’ of thickened crust beneath the eastern Christie Domain, and the Nawa Domain
E1-Pre Mulgathcing Complex

The earliest potential structural and tectonic events recorded in 13GA-EG1E is a pre-Mulgathcing shortening event, reflected in

- a possible ‘suture’ at the Bulga Shear Zone between the Neoarchean or older middle- to lower-crustal seismic provinces, the CGSP and WGSP
- an early shortening event within the WGSP producing the apparent lower crustal ramp structures. The timing of this event, and even its existence, is speculative.
- There are other potential explanations for these structures
  - reflective zones represent unmodified lower-crust and the non-reflective zones between them are in fact an alteration or overprint which has destroyed the reflectivity in these regions – not supported by other data sets
  - reflect later shortening events
The oldest event that can be confidently recognised is extension associated with the deposition of the Mulgathing Complex protoliths.

- Extension was accommodated along a series of east and west dipping crustal scale faults and shear zones that penetrate through the WGSP and likely represent reactivation of earlier structures in this Neoarchean or older basement.
- Of note is a highly magnetic region modelled in the magnetic inversions.

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**E2-Mulgathing Complex**

![Diagram of geological structures](image-url)
E2-Mulgathing Complex

• Of note is a highly magnetic region modelled in the magnetic inversions and mirrored by a conductor modeled in the magnetotelluric data
• This magnetic conductor may indicate a large proportion of iron formations in this part of the Mulgathing Complex
• Or may represent altered komatiites at the base of the Wilgena Domain
E3-Sleafordian Orogeny

Mafic and felsic magmatism in the Mulgathing ‘rift basin’ was accompanied by HT-LP high geothermal gradient metamorphism during the c. 2465 – 2410 Ma Sleafordian Orogeny

- Effected Christie and Wilgena domains
- This apparently long lived, hot metamorphic event was likely associated with ongoing extension punctuated by compressive deformation producing large wavelength regional folding within the upper-crust
- The upper crust was largely decoupled from a hot and highly ductile middle to lower-crust, which potentially responded by lateral flow to these punctuated shortening events
- This event was followed by slow cooling and slow exhumation
E3-Sleafordian Orogeny

- Sleafordian aged metamorphism is highest grade in central Christie Domain
- Decreases east and west
- Appears to be structurally controlled exhumation
- Thermochronology indicates slow cooling and erosive exhumation followed by more exhumation during subsequent events
Extension along the margins of the proto-Gawler Craton (Mulgathing Complex) led to the deposition of the Paleoproterozoic metasediments of the Nawa and Fowler domains between c.1750 and 1720 Ma.

- Fowler Domain not imaged in section
- Nawa Domain metasediments = Moondrah Gneiss
- Deposition of these sediments was predominantly accommodated by the crustal scale structures, including the Karari Shear Zone and the Wirinijinna Shear Zone
- Interpreted intra-continental setting
The basement to the Moondrah Gneiss within the Nawa Domain has been separated into two seismic subdomains based on different reflective character:

- Karari Seismic Subdomain to the east contains a reflective upper unit and a weakly reflective lower unit while the Wirinijinna Seismic Subdomain to the west only consists of a weakly reflective unit.
- Geochronological evidence from drill holes in the Nawa Domain indicate three possible ages for a pre-1750 Ma basement: c.2526, c.1914 Ma or c. 1775 – 1750 Ma.
- We suggest that the upper reflective package in the Karari Seismic Subdomain may be a correlative of the Mulgathing Complex, which is overlying weakly reflective middle crust of the Western Gawler Seismic Province (WGSP).
- This reflective upper crust is missing from the Wirinijinna Seismic Subdomain, suggesting that the Wirinijinna Shear Zone marks the western extent of the Mulgathing Complex.
E5-Kimban Orogeny

Sedimentary deposition in the Nawa and Fowler domains was terminated by deformation associated with the near craton-wide 1730 – 1690 Ma Kimban Orogeny
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- In the Nawa Domain, early HT-LP granulite facies metamorphism was followed by an increase in pressure to produce an apparent anti-clockwise P-T path.

- Little evidence of pervasive deformation or metamorphism of this age within the Mulgathing Complex.

- Instead, it is likely that this event was strongly partitioned into predominantly strike-slip deformation and reactivation of the major shear zones in the Christie and Wilgena domains.
**E5-Kimban Orogeny**

- The onset of Kimban-aged metamorphism during deposition of the Nawa Domain sediments and the interpreted metamorphic P-T path suggests that, in the northern and western Gawler Craton at least, orogenesis occurred in a predominantly extensional setting, followed by compression in a probable transpressional setting with minimal exhumation.

- Significant syn- to post Kimban Orogeny magmatism is also recognised from across the province. In 13GA-EG1E this is recorded in the eastern Christie Domain by magnetic and non-magnetic intrusions of the syn- to post-Kimban granitoids and Tunkillia Suite.
The Tarcoola Formation was deposited into localised basins within the Wilgena Domain between c.1650 – 1600 Ma.

Between c.1640 – 1607 Ma significant calc-alkaline magmatism occurred in the south western Gawler Craton (St Peter Suite) and within the Coompana Province (Toolgana Supersuite).
Coompana Province contains evidence for 3 magmatic events

- c.1610 Ma (Kutjara 1, Toolgana SS)
- c. 1500 Ma (Mallabie 1, Undawidgi SS)
- 1192–1140 Ma (Mulyawara 1, Moodini SS)

- All isotopically juvenile
- Younger ages not seen on Gawler Craton
- Isotopically juvenile crust probably NOT built on evolved Gawler Craton basement
E7-Kararan Orogeny/Hiltaba event

Between c. 1600 – 1580 Ma the western Gawler Craton underwent a major phase of deformation (Kararan Orogeny) and significant magmatism associated with the Gawler Range Volcanics and Hiltaba Suite granites.

- Seems to be the major structural event recorded in the 13GA-EG1E section
High-grade Kararan metamorphism is constrained to regions of Palaeoproterozoic units

- In the northern Gawler, HT-HP granulites were exhumed over HT-LP to UHT-LP granulites during south vergent thrusting
- The timing of HT-HP granulite facies overprinting in the Moondrah Gneiss is poorly constrained, may be late Kimban, or early Kararan
E7-Kararan Orogeny/Hiltaba event

Structural evolution

- East-vergent thick-skinned thrusting led to the juxtaposition of the Coompana Domain over the western Nawa Domain and Gawler Craton along the Jindarnga SZ
- Tectonic stacking produced a significantly thickened crust beneath the Nawa Domain and exhumed the HT-MP Kimban-aged granulites of the Moondrah Gneiss.
E7-Kararan Orogeny/Hiltaba event

Structural evolution

- Reactivation of major west-dipping structures in the Christie Domain led to crustal thickening and further exhumation of Sleafordian-aged granulites in the eastern Christie Domain and unroofing of syn-Kimban and Tunkillia Suite granites.
- Exhumation of this block between the Tallacootra and Coorabie shear zones, together with the ‘out of plane loading’ due to shortening of the Fowler Domain can account for the observed crustal thickening beneath the eastern Christie Domain.
- The eastern ‘ramp’ structure may terminate at the base of the Mulgathing Complex beneath the Wilgena Domain, or alternatively may form an apparent duplex truncated against the Bulga Shear Zone.
E7-Kararan Orogeny/Hiltaba event

Magmatic evolution

- Significant Hiltaba-aged magmatism is confined to the eastern part of the Wilgena Domain overlying the CGSP.
- The apparent easterly rise of the Moho and highly reflective character of the CGSP may be a result of a mantle plume or lithospheric delamination generating the significant felsic crustal melts that produced the Hiltaba Suite and Gawler Range Volcanics.
E8-Coorabie Orogeny

At c.1450 Ma, the major structures in the western Gawler Craton underwent low-temperature reactivation during the Coorabie Orogeny, in a predominantly strike-slip regime.
E9-Officer Basin

Renewed extension during the Neoproterozoic to Cambrian associated with the development of the Centralian Superbasin and the Adelaide Geosyncline reactivated existing basement structures in the Nawa and Coompana domains to accommodate the deposition of sediments of the Officer Basin.

• Underlying mafic volcanics are c. 860 Ma, synchronous with Gairdner Dolerite and Amata Dolerite

• Highly evolved Nd isotopic composition ($\varepsilon_{Nd}^{860\text{Ma}}$ between -9.9 and -12.7) suggests possible contamination by evolved crust
E10-Eucla Basin

Regional down warping and marine transgression during the Cenozoic led to the deposition of the sediments of the Eucla Basin and the paleostrandlines of the Ooldea and Barton ranges.
Major crustal structures

Comparison to GOMA section
Major crustal structures

Economic implications

- Major crustal boundaries and crustal-scale structures can act as conduits for the passage of magma and associated fluids from the deep crust or mantle into the upper crust.
- The deep seismic reflection section 13GA-EG1E provides evidence for a number of major crustal discontinuities and structures, with several of these structures, including the Karari and Coorabie shear zones, also being imaged in the MT data.
Major crustal structures

Economic implications
Major crustal structures

Economic implications

Comparison between 13GA-EG1E section and Fowler traverse
Structures and intrusions

Economic implications

- Significant volumes of Hiltaba-aged magmatism in the eastern Wilgena Domain confirms this region as highly prospective for potential IOCG, or Au only type mineralisation.
- Recognition of middle-crustal scale east dipping shear zones, which acted as conduits for Hiltaba-aged magmatism, further enhances the potential for lode-gold mineralisation.
- Low-metamorphic grade Tarcoola Formation to these structures and associated Hiltaba Suite intrusions has potential for skarn related mineralisation.
Where next for western SA

Coompana airborne Magnetic and Radiometric survey – due soon
Where next for western SA

Continue 13GA-EG1 seismic interpretation – release at AESC 2016 Adelaide

Eucla - Gawler
Disclaimer

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