Seismic line 10GA-YU2

(Youanmi Terrane, Yilgarn Craton)

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Location

Maps: Kirkalocka (SG 50-3), Youanmi (SH 50-4), Sandstone (SG 50-16), Leonora (SH 51-5), Sir Samuel (SG 51-13)

Zone: MGA Zones 50 and 51

End coordinates: 628891E 6871551N to 878026E 6909320N

Length: 273 km

Type of modelling: 2D forward modelling of gravity and magnetics, 2D inversions of joint gravity and magnetics, and 3D magnetotelluric (MT) inversion of a profile.

This is a west to east section that crosses the Murchison and Southern Cross Domains of the Youanmi Terrane within the Yilgarn Craton. It terminates across the Ida Fault in the Eastern Goldfields Superterrane (Fig. 1).

Tectonic units

The Windimurra Igneous Complex is a large, relatively complete, mafic–ultramafic intrusion in the Murchison Domain with economic vanadium deposits (Ivanic et al., 2010). The profile crosses a series of Murchison granites. Thereafter, it crosses into the Southern Cross Domain, which consists mainly of granites with some greenstone belts, such as the Sandstone greenstone belt (Chen, 2005) and the tip of the Booylgoo Range greenstone belt. Finally, the profile crosses the Agnew greenstone belt, which is exploited for gold (Stewart, 2001; Duuring et al., 2012).

Structure

The main structures in this section are the Youanmi Fault, which defines the boundary between the Murchison and Southern Cross Domains and the Ida Fault. The Ida Fault is probably incorporated within the Waroonga Shear Zone and constitutes the boundary between the Youanmi Terrane and the Eastern Goldfields Superterrane.

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Geophysical data

A new gravity grid was created by combining data collected along the Youanmi seismic transect (at a 400 m station spacing) with existing gravity data from the Australian National Gravity Database (ANGD) (Wynn and Bacchin, 2009). The new grid created from this process was used in the forward and inverse modelling in the area (Gessner et al., 2014). Topographic data were taken from the Australian Height Datum (AHD). Sample points were extracted at the locations of the Common Depth Points (CDP) of the seismic profile (Costelloe and Jones, 2014).

Magnetic data were extracted from the Geological Survey of Western Australia (GSWA) State gridded data (GSWA, 2013).

Magnetotelluric (MT) data were also collected at 5 km spacing along this profile for broadband instruments and 15 km spacing for long-period instruments (Milligan et al., 2014).

Physical property values were taken from tabular data in Emerson (1990), Telford et al. (1990), and Rudnick and Fountain (1995). Values used in this modelling are found in Table 1.

Forward modelling

Geoscience Australia, in collaboration with GSWA, conducted the Youanmi Deep Crustal Seismic Reflection Survey (10GA-YU2) in 2011 (Korsch et al., 2014). The purpose of this survey was to image deep crustal structures and the crust–mantle boundary. Data was recorded to 20 s of two-way travel time (~60 km deep, assuming an average crustal velocity of 6000 m/s).

A crucial part of the seismic interpretation process is to test the interpretation against other data. In this case, the seismic interpretation was tested against gravity data through 2D forward modelling using ModelVision v.11.0 software. 2.5D modelling was performed by extending the polygons 100 km to each side, perpendicular to the profile. Only gravity modelling was performed as the magnetic profile is dominated by short-wavelength anomalies. They relate to near-surface features and therefore were not included in this regional-scale modelling study.

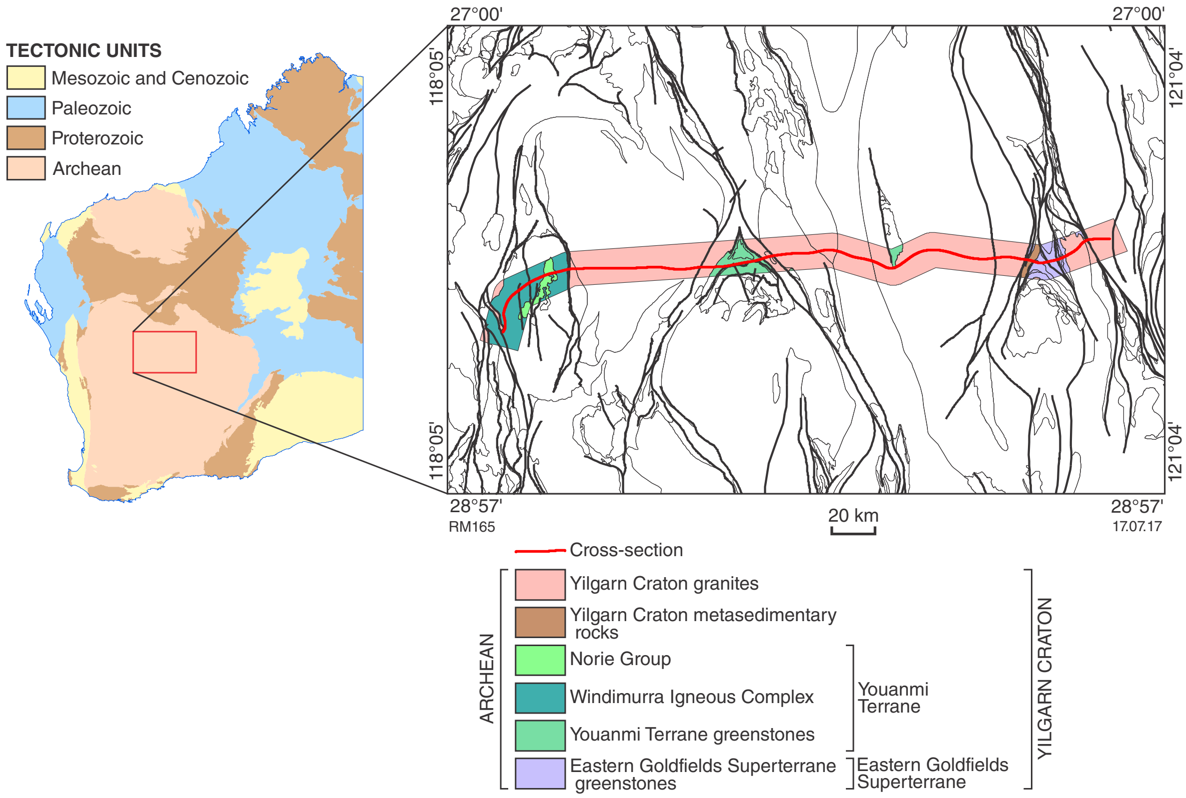

Figure 1. Murchison region 1:500 000 simplified interpreted bedrock geology map showing location of the seismic line 10GA-YU2 (in red) along which the section was modelled

Forward modelling results

The 10GA-YU2 seismic section was forward modelled down to a depth of 60 km (Gessner et al., 2014). The model was the interpretation from data of the 10GA-YU2 seismic line (Fig. 2a; Korsch et al., 2014) and the densities were modified to achieve a fit with the observed data.

In the west, the Windimurra Igneous Complex is interpreted to cause a high-amplitude gravity peak of 60 mgal which, in the gravity profile, matches poorly with the observed data. The model was restricted by the geometries interpreted from the seismic section. In this case, a better fit may have been achieved by the subdivision of the Windimurra Igneous Complex into smaller bodies.

The Sandstone greenstone belt is modelled as a V-shaped, high-density body. The Agnew greenstone belt also produces a gravity high of 30 mgal, but at lower amplitude than the others as it is interpreted to be underlain by the Lawlers Tonalite, which is modelled with a slightly lower density (2.67 g/cm^3) than the rest of the upper crust (2.67 – 2.76 g/cm^3). This body is suggested by Blewett et al. (2010) to explain the synextensional volcanism in the area, but the inclusion of this body adds a steep gravity gradient into the model, which is not seen in the observed data (Fig. 2b).

The granites of the Eastern Goldfields have been modelled with higher density than those of the Youanmi Terrane (Fig. 2c).

The Yarraquin Seismic Province has been modelled with relatively high densities of 2.83 – 2.89 g/cm^3 and is overlain by the low reflectivity Youanmi granites. This upper and lower crustal division is not seen in the Eastern Goldfields, with the crustal granites being continuous from the upper through to the lower crust, although the profile does not extend far into the Eastern Goldfields.

Inversions

Joint magnetic and gravity inversions

Joint inversions of the gravity and magnetic data were performed to search for multiple geophysical models that are structurally matching and fit multiple datasets. Cross-products of the density and magnetization distributions are calculated for the upper 18 km using the method of Gallardo (2007) as applied by Gallardo and Thebaud (2012) and Gallardo et al. (2012). To cope with the effect of a crooked geometry of the line, the magnetic data were reduced to pole, using the average parameters for that area for 1998, viz.: inclination –61.43°, declination +0.3°, and intensity 56 184 nT. No correction was made for possible areas of magnetic remanence. A constant value of 80 mgal was added from the gravity data.

MT inversions

MT data were processed in the frequency domain using the Bounded Influence Remote Reference Processing

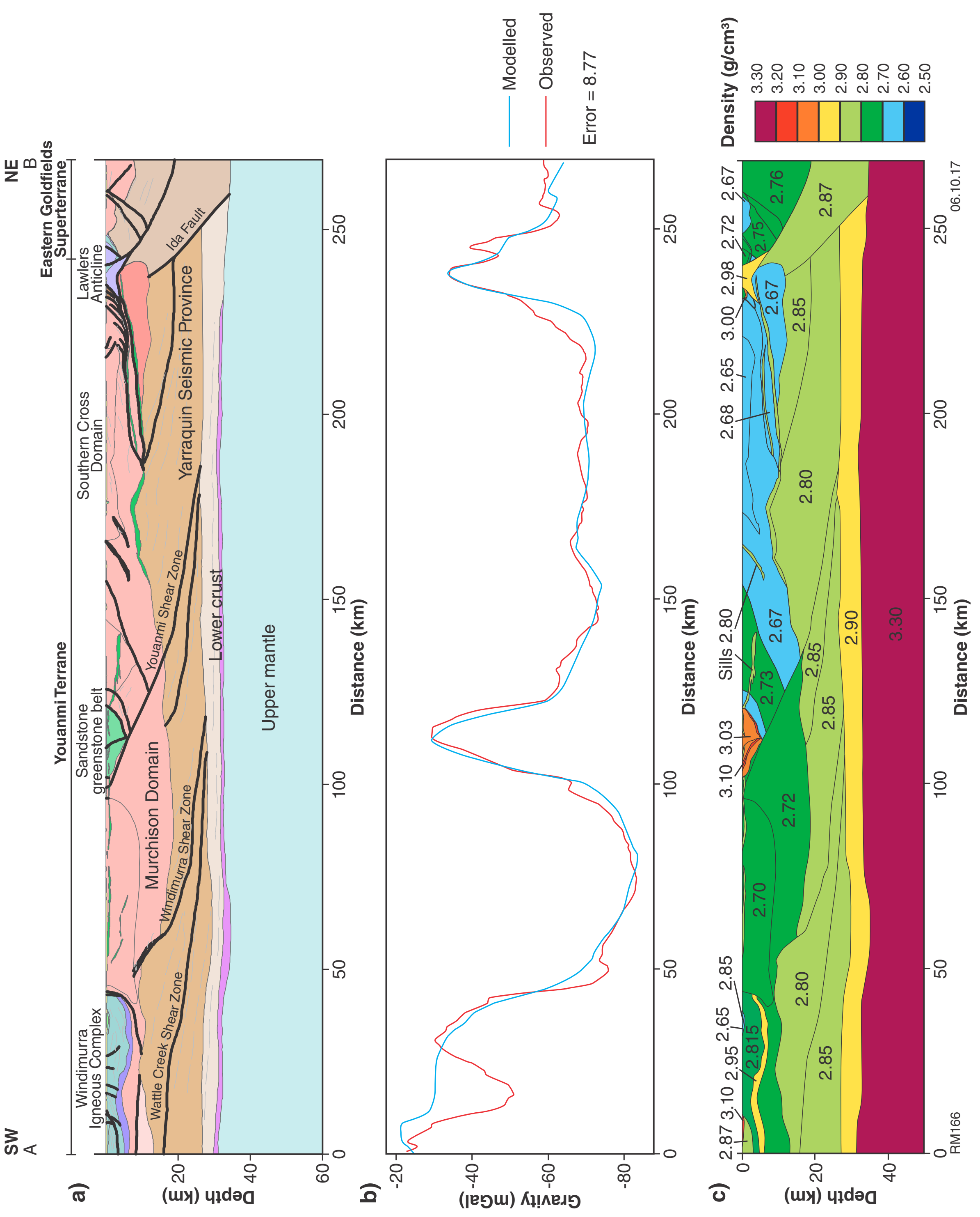

Figure 2. **Forward modelling of the 10GA-YU2 seismic line: a) lithological interpretation of the 10GA-YU2 seismic line from Zibra et al. (2014); b) observed and calculated gravity anomaly profile from Gessner et al. (2014); c) profile of density in g/cm³ per lithology**

Table 1. Summary of the physical properties used in the gravity model of the seismic line 10GA-YU2. The colour column refers to colours used in Figure 2a

Colour	Lithological unit	Map code	Rock type	Density (g/cm³)
	Proterozoic sills	P_-WK-od	Dolerite	2.800
	Windimurra Igneous Complex			
	Mafic rocks	A-AN-xmg-o	Selection of mafic rocks	2.815
	Ultramafic rocks	A-ANwu-xmad-oa	Ultramafic rocks	2.950
	Norie Group	A-Nom-mb	Mafic rocks	2.85
	Youanmi Terrane upper mid-crustal granites including low reflectivity crust	A-SDB-mg, A-TU-mg, A-BRG-gm, A-JU-mg	Granitic rocks	2.650 – 2.730
	Eastern Goldfields Superterrane upper crustal granites	A-g-Y, A-mgs-Y	Granitic rocks	2.720 – 2.760
	Lawlers Tonalite		Granitic rocks	2.670
	Eastern Goldfields Superterrane greenstones	A-b-YEG, A-f-YEG, A-o-YEG, A-u-YEG	Various greenstone rocks	2.720 – 3.000
	Eastern Goldfields Superterrane mid-crust		Mid-crustal rocks	2.870
	Youanmi Terrane Greenstone belts	A-mb-YEG, A-mu-YYO	Various greenstone rocks	2.98–3.1
	Yarraquin Seismic Province		Mid-crustal rocks	2.830 – 2.890
	Lower crust		Lower crustal rocks	2.900
	Moho transition zone		Moho transition zone	2.900
	Upper mantle		Mantle	3.300

(Chave et al., 1987; Chave and Thomson, 2004) and then modelled in 3D using the ModEM code of Egbert and Kelbert (2012).

Inversion results

Joint inversion results

The gravity and magnetic profiles (Fig. 3b) show short-amplitude anomalies in the vicinity of the Windimurra Igneous Complex and Lawlers Anticline. Within the Windimurra Igneous Complex, broad peaks of high gravity coincide with a pattern of shorter wavelength magnetic anomalies.

There is a pronounced magnetic trough and gravity high between CDP 9000 and CDP 10 000 near the Sandstone greenstone belt.

A gravity low is coincident with a magnetic low amplitude between the Windimurra Igneous Complex and the Sandstone greenstone belt and again between the Sandstone greenstone belt and the Lawlers Anticline.

In general, features with common physical property gradients (Fig. 3c) alternate at longer wavelengths in 10GA-YU2, compared to 10GA-YU1, probably because fewer greenstone belts are intersected.

Similarly to 10GA-YU1, the topography of relatively magnetic and moderately dense lower crust imaged in this section correlates well with the topography of the Yarraquin Seismic Province. The Yarraquin Seismic Province in section 10GA-YU2 has a similar shape to the response seen in the MT profile.

MT results

The conductivity features seen in the MT profile (Fig. 3d) are interpreted to be related to coincident features that are seen in the seismic interpretation (Fig. 3a; Milligan et al., 2014; Zibra et al., 2014). The upper crustal layers and granitic plutons are interpreted to be more resistive as indicated in the deepening of the upper crust around CDPs 8000–11 000 and a corresponding resistive anomaly. This may represent the heart of the Archean Craton (Milligan, 2012; Milligan et al., 2014). The Windimurra Igneous Complex on this line is shown by a thinning of the upper crust. The mafic dykes and sills are seen at CDP 14 800 at a depth of about 8 km. Granites are known to be low-conductivity structures (i.e. highly resistive). It is therefore interpreted that the low conductivity at 10 km depth between CDP 15 300 and CDP 16 200 is the Lawlers Tonalite. Outcropping mafic rocks of the Lawlers Anticline have high conductivities and the crust of the Eastern Goldfields is generally more conductive.

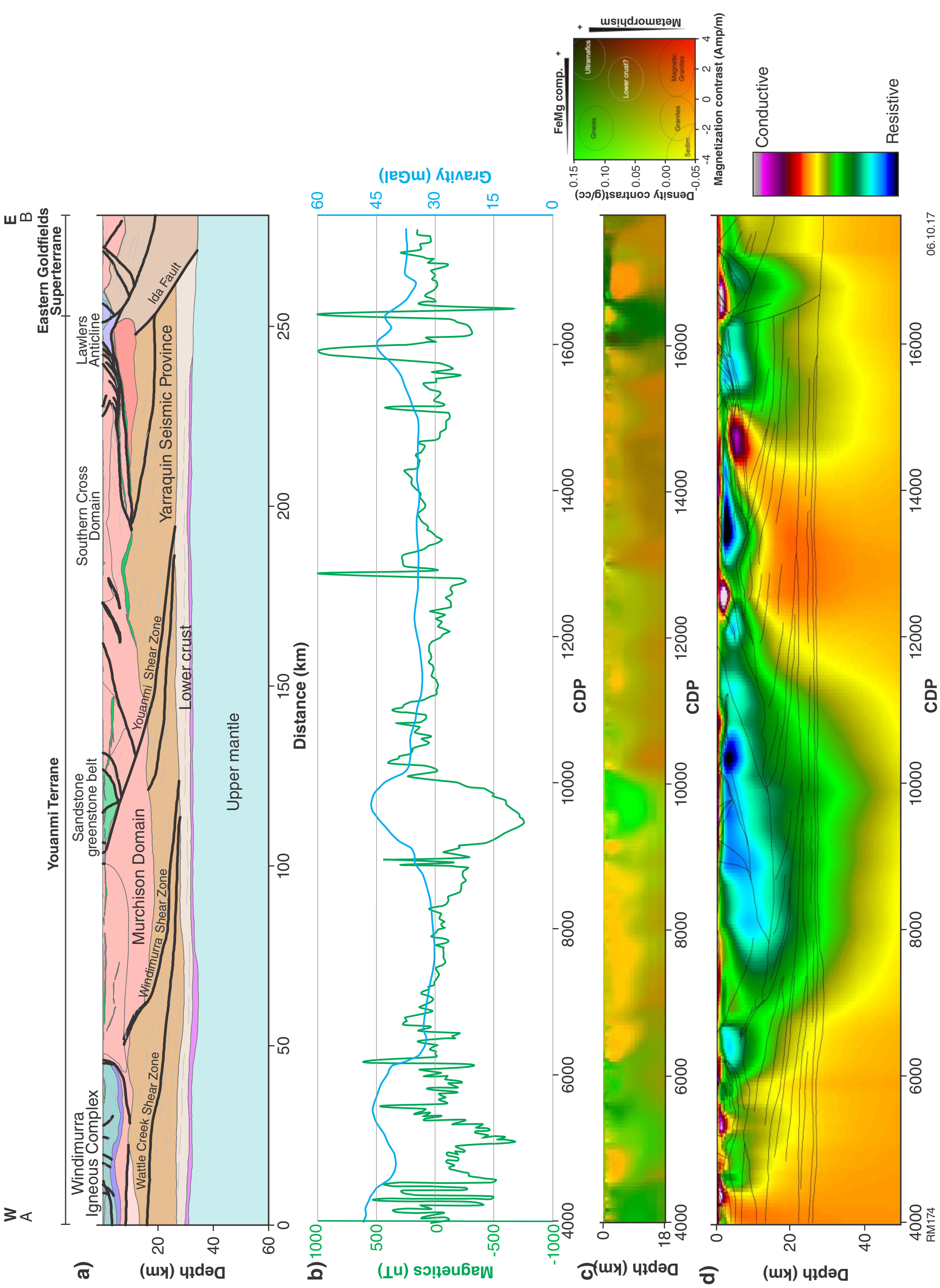

Figure 3. Inversion results of the seismic line 10GA-YU2: a) lithological interpretation of the 10GA-YU2 seismic line from Zibra et al. (2014); b) gravity and magnetic profiles used in the joint inversion; c) joint magnetic and gravity inversion geospectral image with a colour legend on the side; d) MT profile from Milligan et al. (2014) overlain with line work from the seismic interpretation of Ivanic (2014)

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