Seismic line 10GA-YU3

(Murchison Domain, Yilgarn Craton)

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Location

Maps: Kirkalocka (SG 50-3), Youanmi (SH 50-4)

Zone: MGA Zone 50

End coordinates: 566437E 6897822N to 667047E 6869956N

Length: 105 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 Mount Magnet greenstone belt and Windimurra Igneous Complex of the Murchison Domain of the Yilgarn Craton (Fig. 1). It joins the 10GA-YU1 and 10GA-YU2 seismic lines and gravity profiles.

Tectonic units

The Mount Magnet greenstone belt is part of a corridor of greenstones between Meekatharra and Mount Magnet (Archibald, 1982) and hosts several gold-producing mines. The Windimurra Igneous Complex is a large, relatively intact, mafic–ultramafic intrusion in the Murchison Domain with economic vanadium deposits (Ivanic et al., 2010). Autochthonous granites separate the mafic belts. Many of them lie along shear zones. Together with their corresponding seismic reflection data from the other two seismic lines, the true orientation of the features can be deduced.

Structure

The Wattle Creek Shear Zone is a major feature which is interpreted to penetrate to the lower crust. It bounds the western edge of the Mount Magnet greenstone belt and accommodates the emplacement of the Lakeside Granite to the west. The Cundimurra Shear Zone is seen as a set of east-dipping listric structures rooted beneath the Windimurra Igneous Complex. The Yarloo Shear Zone bounds the west side of the Windimurra Igneous Complex (Ivanic et al., 2014).

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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 along this profile at 5 km spacing for broadband instruments and 15 km spacing for long period instruments.

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-YU3) 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.

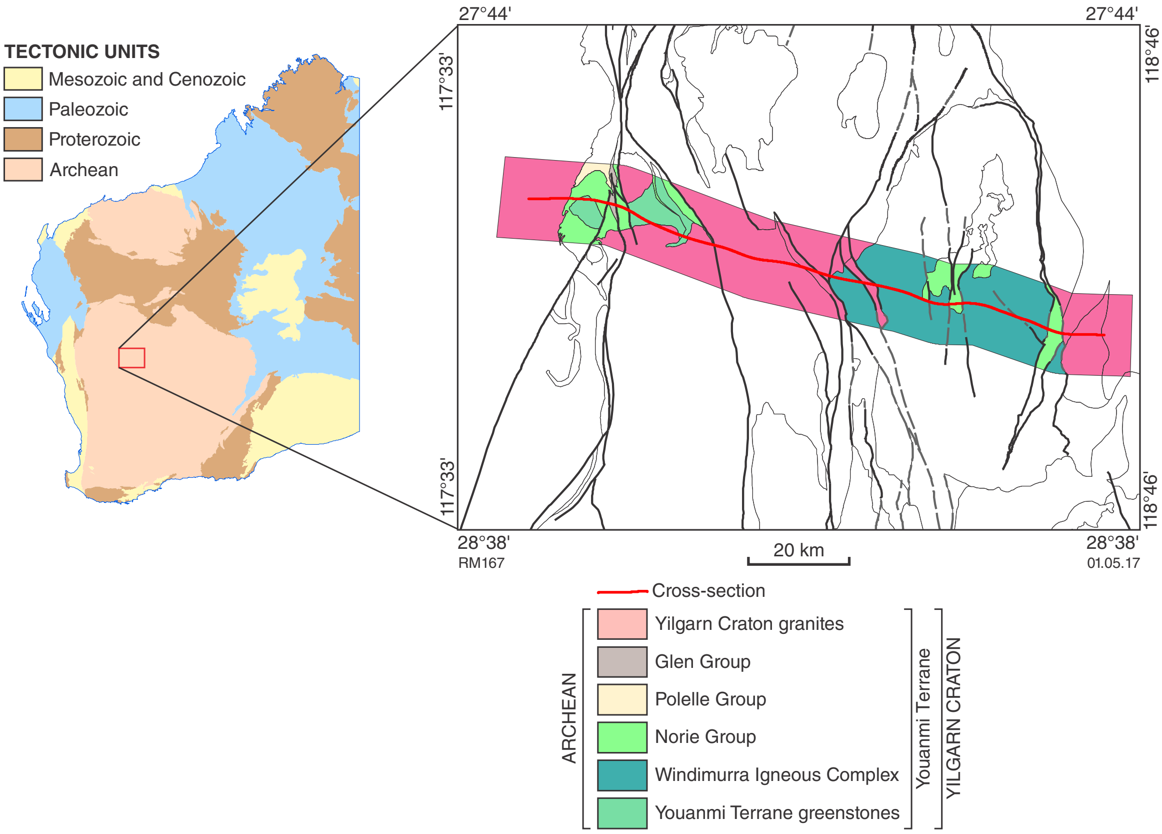

Figure 1. **Murchison region 1:500 000 interpreted bedrock geology map showing location of the seismic line 10GA-YU3 (in red) along which the section was modelled**

Forward modelling results

The section was modelled against gravity data down to a depth of 60 km (Gessner et al., 2014). The model geometry was the interpretation from data of the 10GA-YU3 seismic line (Fig. 2a; Korsch et al., 2014) and the densities were modified to achieve a fit with the observed data.

The regional trend of the gravity field (Fig. 2b) has been accommodated by a thickening lower crust from east to west. Two broad-wavelength peaks dominate the profile and are interpreted to correspond to the Mount Magnet greenstone belt and Windimurra Igneous Complex. Short-wavelength features within the Windimurra Igneous Complex are not accounted for by features in the seismic line and have not been added into the model. The Windimurra Igneous Complex is layered, with the lower layer being a high-density ultramafic zone (2.95 g/cm^3). Above this, the lower zone has a density associated with its pyroxenitic to anothositic composition of (2.815 g/cm^3) (Ivanic and Brett, 2015). The middle and upper zones have also been modelled individually and show layers dipping towards the centre (Fig. 2c).

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

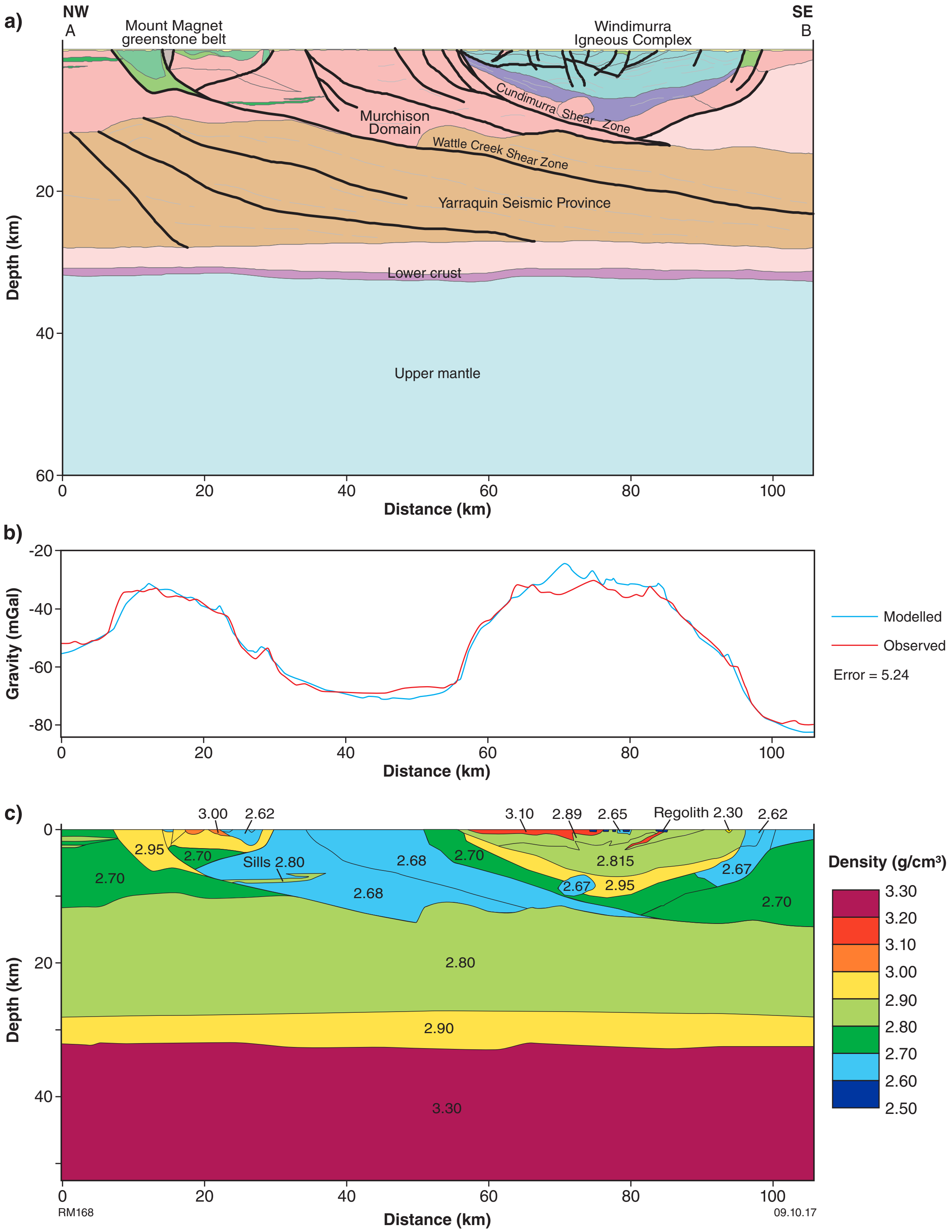

Figure 2. **Forward modelling of seismic line 10GA-YU3: a) lithological interpretation of the seismic line from Ivanic et al. (2014); b) observed and calculated gravity anomaly profile from Gessner et al. (2014); c) profile of density in g/cm³ per lithology**

Table 1. **Summary of the physical properties used in the gravity model of the seismic line 10GA-YU3. The colour column refers to colours used in Figure 2a**

Colour	*Modelled unit*	*Map code*	*Rock type*	*Density (g/cm³)*
	Regolith			2.300
	Kantie Murdana Volcanics Member*	A-ANK-jmg-md	Rhyolitic rocks	2.650
	Windimurra Igneous Complex			
	Upper Zone	A-ANK-jmg-md, A-ANwz-xoml-am	Norite and anorthosite	3.100
	Middle Zone	A-NNwm-xog-oml	Troctolitic rocks	2.890
	Lower Zone	A-NNwl-xol-oml	Olivine-rich gabbros	2.815
	Ultramafic Zone	A-ANwu-xmad-oa	Peridotites	2.950
	Murchison Domain granites	A-TU-mg, A-BR-g, A-SDBmg, A-JU-mg	Granitic rocks	2.680 – 2.700
	Mount Magnet greenstone belt	A-mu-YYO, A-NOm-mb, A-NOy-xf-cib, A-GLr-xs-b	Mixture of mafic, ultramafic rocks, and BIF	2.950 – 3.000
	Low reflectivity crust		Granitic rocks	2.700
	Yarraquin Seismic Province		Mid-crustal rocks	2.800
	Lower crust		Lower crustal rocks	2.900
	Moho transition zone		Moho transition zone	2.900
	Upper mantle		Mantle	3.300

NOTE: *Too small to be imaged on seismic section, but included in gravity modelling

Inversion results

Joint magnetic and gravity results

In the gravity and magnetic field profiles and the inversion model along 10GA-YU3 (Fig. 3b), broad peaks of high gravity (45 mGal) coincide with a pattern of shorter-wavelength magnetic anomalies within the region of the Windimurra Igneous Complex.

The Mount Magnet greenstone belt stands out as a prominent feature of high gravity (30 mGal) and relatively low magnetization in the upper crust, except for a spike interpreted to be related to banded iron-formations (BIF) at Mount Magnet. Even though the strongest magnetic signature of the greenstone belt can be easily interpreted only extend to depths of 8 km, some magnetization is still smeared down to depths of over 15 km (Fig. 3c). This is an artefact common in unconstrained inversions of large potential field anomalies, whether they are jointly or individually inverted. This artefact therefore needs to be considered during interpretation of these geospectral images, when assessing what is geologically plausible.

The area between the Mount Magnet greenstone belt and the Windimurra Igneous Complex (Fig. 3a) consists of the low-density and weakly to moderately magnetic Cundimurra Monzogranite. The Cundimurra Monzogranite is underlain by the Yarraquin Seismic Province, which is also seen in the inversion to extend below and east of the Windimurra Igneous Complex.

MT inversion results

The MT inversion model (Fig. 3d) shows high surface conductivities in the vicinity of the Windimurra Igneous Complex, which is interpreted to be related to the layered mafic upper zone (Milligan et al., 2014). High conductivities are also seen in the region of the Mount Magnet greenstone belt and also at depth in this region. The resistive nature of the upper crust is shown by the low conductivity area between CDP 7000 and CDP 8000, where the crust is suggested to mainly consist of granites.

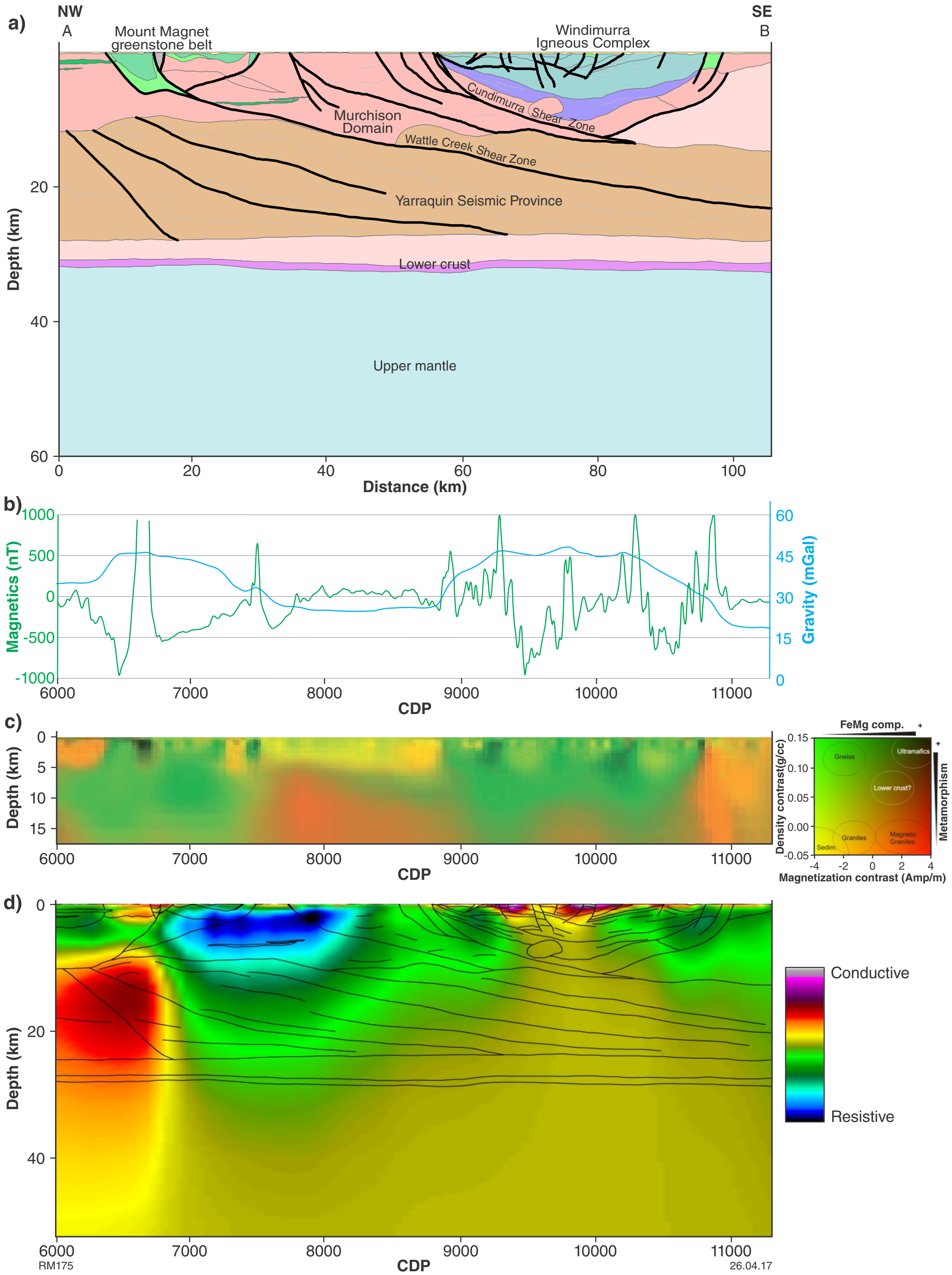

Figure 3. **Inversion results of the seismic line 10GA-YU3: a) lithological interpretation of the seismic line from Ivanic et al. (2014); b) gravity and magnetic profiles used in the joint inversion; c) joint magnetic and gravity inversion geospectral image with a colour legend on the side; d) MT profile from Milligan et al. (2014) with line work from the seismic interpretation of Ivanic et al. (2014) overlain**

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