Resistivity structure of the Link East MT transect in the Southern Curnamona Province

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SUMMARY

We present results of 18 magnetotelluric (MT) stations from the Link East transect adjacent to the 03GA-CU1 Curnamona deep crustal seismic reflection line in the southern Curnamona Province, South Australia. The transect was designed to provide resistivity information on the crustal architecture to complement existing datasets and cross the Flinders Conductivity Anomaly (FCA), now known as separate conductors from AusLAMP 3D resistivity models. On the eastern third of the profile, the 10 km site spacing of the profile has allowed us to image two upper crustal conductors (1 Ωm) to the east and west of the Kalkaroo anticline. The eastern conductor (1-4 km depth) is situated in the southern limb of the Mooleulooloo syncline containing Bimba Formation and Strathearn Group sediments, while the western conductor (1-2 km depth) is situated in a small graben comprising Neoproterozoic sediments. On the eastern half, at mid-crustal depths (~15-30 km) a broad conductor (> 20 Ωm) is identified as the southern extension of the Curnamona Conductor with conductive fluid pathways connecting to the upper crustal conductors.

Key words: Magnetotellurics, Curnamona Province, lithosphere, electrical resistivity, seismic reflection

INTRODUCTION

As modern mineral exploration is increasingly looking for targets at greater depths and under cover there has been a paradigm shift to a conceptual targeting idea, that focuses on understanding the geological processes that control the distribution in Earth systems and predict where and how these processes might combine to form an ore deposit (McCuaig and Hronsky, 2017).

The fundamental caveat of the mineral systems approach is that ore deposits are part of a much larger system, evident at a variety of temporal and spatial scales (Hronsky and Groves, 2008; McCuaig and Hronsky, 2014). It is this scale dependency that is fundamentally important in exploration targeting, as the direct detection of ore deposits at the project scale is fraught with difficulties from its own chaotic manifestation, which itself is a product of a much more extensive system, but this more extensive system is inherently more easier to predict at larger scales (Hronsky and Groves, 2008).

From this evolution in mineral exploration targeting that takes a holistic view of the whole system in 4D, geophysical methods are ideal to explore the range of scales from the lithosphere up to the deposit (Jansen and Cristall, 2017). This change of focus in exploration, from the traditional direct targeting for deposits, to a staged process where geophysical approaches are instead used to first define the pathways in the Earth which carried mineralising fluids, to reducing scale and narrowing the search space (Witherly, 2014). The major advantage from thinking of the whole system are two-fold, in that the mineral system will present a larger exploration target, and will also result in greater knowledge of the whole mineral system which can improve prediction and vectoring towards economic deposits (Witherly, 2014)

Few geophysical techniques are capable of the required depth investigation required to view past the deposit and camp scale, these being methods that use the Earth's natural magnetic, gravity and electromagnetic (EM) fields and active and passive seismic (Jansen and Cristall, 2017). Out of all these methods, the use of natural field EM methods with their ability to map the resistivity of the lithosphere at varying scales from the surface to upper mantle depths and derive conductivity images from 3D modelling of the data is unique (Jones, 2017).

The Link East MT transect was designed as a continuation of the Curnamona-Gawler Link MT transect (Thiel et al., 2010) to provide resistivity information on the crustal architecture and complement existing datasets while providing greater insight into the Flinders Conductivity Anomaly (FCA), which was originally delineated from Geomagnetic Depth Soundings (GDS) in the 1970s. Though the FCA is now known to occur as separate anomalies within the Nackara Arc in the Flinders Ranges, and Curnamona Province from 3D resistivty models produced from long period MT data from the Australian Lithosphere Architecture Magnetotelluric Project (AusLAMP; Robertson et al., 2016).

METHOD AND RESULTS

The MT method is a passive electromagnetic technique utilising naturally occurring electromagnetic fields induced from solar terrestrial interactions at low frequencies and lightning traversing the globe within the ionosphere at frequencies >8 Hz. Source field variations are measured by two orthogonal magnetic induction coils, while the electrical field response is measured from an orthogonal pair of electrodes. A fifth component, the vertical magnetic field, can also be measured from a vertically orientated magnetic induction coil, or a fluxgate magnetometer which collects all three magnetic components simultaneously.

An 18 site MT survey was conducted along the 03GA-CU1 2003 Curnamona deep crustal seismic reflection line with average site spacing of 10 km (Figure 1). At each site separate broadband and long period data were collected. Data were acquired between 23rd April 2010 and 7th May 2010 for the Geological Survey of South Australia by the University of Adelaide with four components recorded at 500 Hz for the broadband, while the long period data recorded five components at 10 Hz. The time series data were converted into the frequency domain using the bounded influence remote reference processing (BIRRP) method utilising the robust algorithm (Chave et al., 2004) in the LEMIMT program. The processed data provided good impedances to a period range of ~0.001-100 s for all the broadband data and ~10-1000 s for 15 sites from the long period data. Figure 2 shows an example of the processed data.

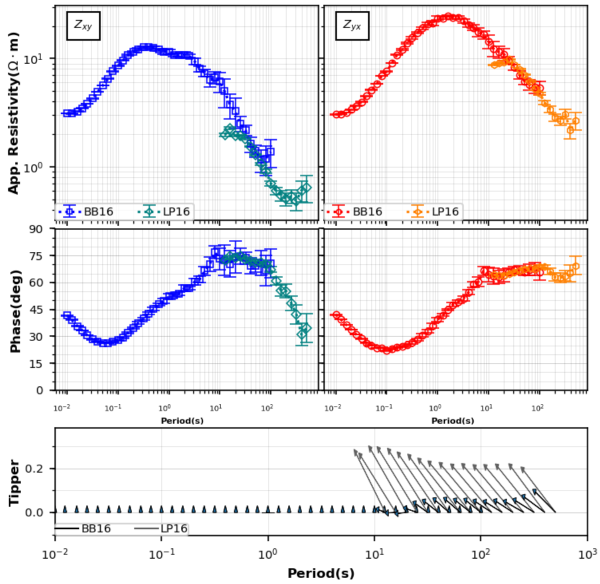

Figure 2. Example from site 16 broadband (BB16) and long period (LP16) data showing the apparent resistivity, phase, tipper (real = grey; imaginary = black).

The phase tensor approach of Caldwell et al. (2004) has been used to help determine the dimensionality and strike of the MT responses. The orientation of the ellipses major and minor axes shows the ideal current flow through the subsurface. Phase tensor ellipses have been calculated for the 18 MT sites for each period (Figure 3). The ellipses shown are coloured by the skew angle, and if this is greater ±5 degrees then the response for that period is the result from a 3D conductivity distribution.

The ellipses in the western half of the traverse along the Moorowie Sub-basin for short periods have a small skew angle and are essentially 1D, with conductivity decreasing with depth from the surface. A second obvious feature from the phase tensor ellipses is from the eastern half of the traverse and at higher periods. The ellipses decrease in size with depth, become more elliptical and the skew angle increases. Thus, the conductivity is more complex and 3D from these ellipses which makes 3D modelling of the MT data more appropriate then 2D.

Preliminary results of the 3D inversions using the ModEM algorithm of Egbert and Kelbert (2012) reveals the southern extension of the Curnamona Conductor (CC) at a depth range of 15-30 km along the central part of the East Link MT survey, with a possible break in the conductor situated along the boundary of the Olary and Mulyungarie geological domains (Figure 4). The resistivity values of the CC here are ~10 Ωm. Resistivities this low and at this depth in a relatively stable tectonic setting as the Curnamona Province only have a few known causes including interconnected sulphides and graphite at the grain boundary (Selway, 2018). Overall there is good agreement between the AusLAMP 3D resistivity models of Robertson et al. (2016) and the resistivities identified in this study for the mid crustal CC.

On the eastern third of the profile, the 10 km site spacing of the profile has imaged two broad upper crustal conductors with resistivities of ~1 Ωm. The first conductor is at station 13 with a depth of ~0.5-2 km located to the west of the Kalkaroo anticline situated in a small graben comprising of Neoproterozoic sediments. The second conductor is at station 15 with a depth of ~1-3 km and is situated in the southern limb of the Mooleulooloo syncline to the east of the Kalkaroo anticline containing Bimba Formation and Strathearn Group sediments. These high conductivities can possibly be interpreted as being caused from either the Bimba Formation which is a pyrite- or pyrrhotite-rich unit or from the Strathearn Group where the base is graphite-rich.

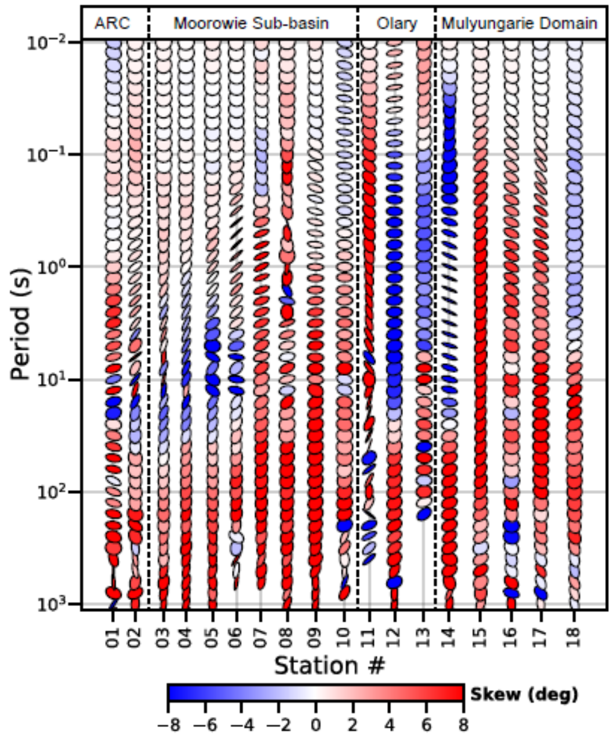

Figure 3. Phase tensor pseudosection with ellipses coloured by skew angle. Geological domains after Conner and Preiss (2006). ARC = Adelaide Rift Complex; Olary = Olary Domain.

CONCLUSIONS

A total of 18 MT sites were collected along a 160 km transect across the southern Curnamona Province. The transect is an exercise in scale reduction from the long-period AusLAMP deployments of 55 km site spacing to the 10 km site spacing for the East Link line. This scale reduction has narrowed the space and increased the resolution of the resistivty structure along the transect and shows good correlation with the 03GA-CU1 Curnamona deep crustal seismic reflection line.

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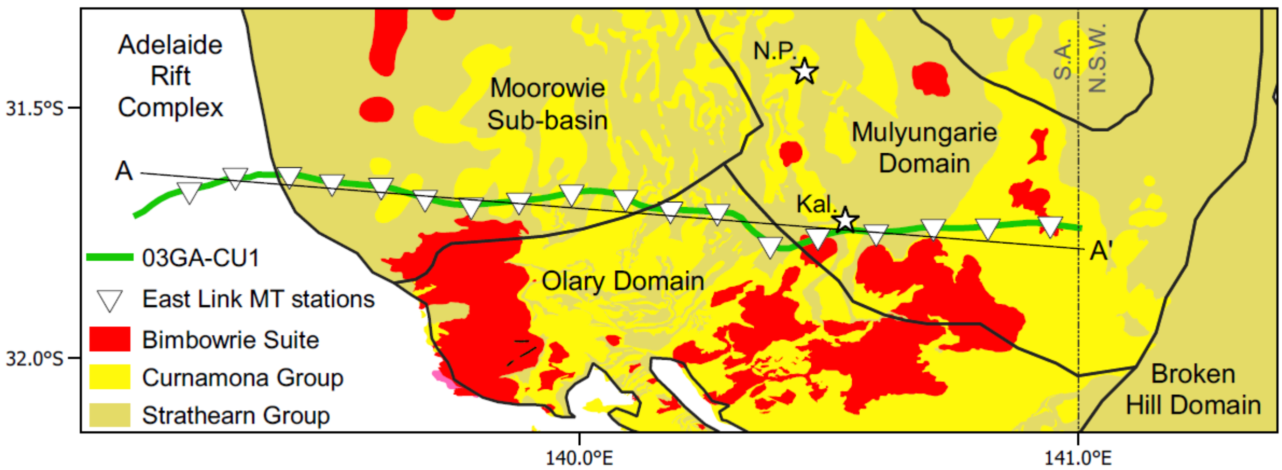

Figure 1. Simplified geological map of the Southern Curnamona Province, South Australia, overlain with 03GA-CU1 seismic line, East Link MT stations and geological domains after Conner and Preiss (2006). Kal. = Kalkaroo; N.P. = North Portia.

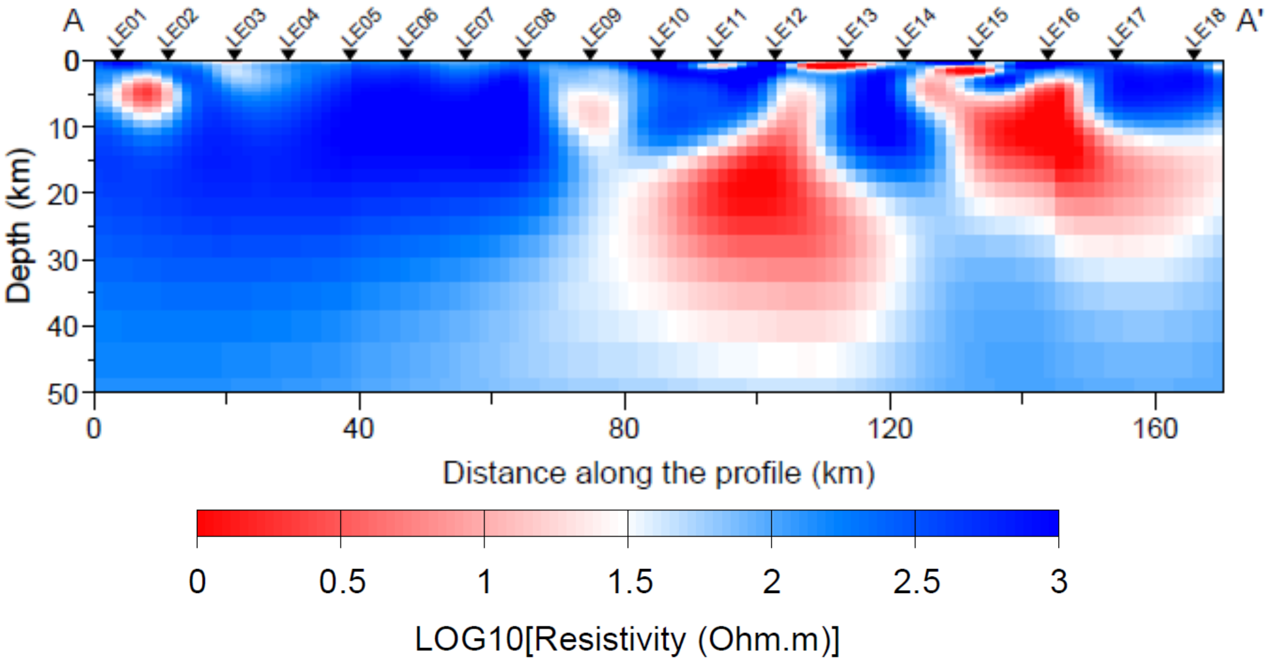

Figure 4. Resistivity cross section from the 3D resistivity model from the East Link MT data.

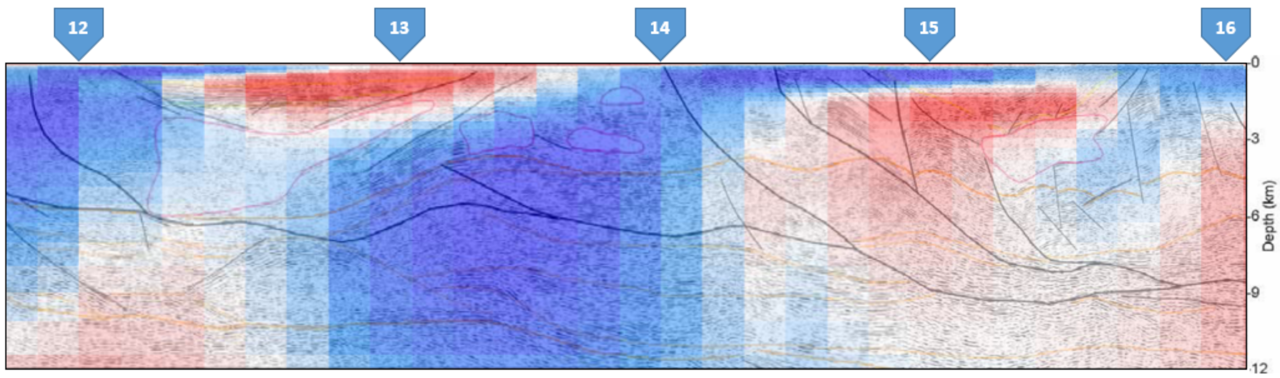

Figure 5. Resistivity cross section from the 3D resistivity model from the East Link MT data overlain with the 03GA-CU1 Curnamona deep crustal seismic line interpreted in Goleby et al. (2006).