Defining the Eyre Conductivity Anomaly with the Tumby Bay MT transect

Kate Robertson[1,2], Ben Kay[2], Lachlan Loader[2], Graham Heinson*[,2] and Stephan Thiel[1,2]
Kate.Robertson2@sa.gov.au

1Geological Survey of South Australia, GPO Box 320, Adelaide, SA 5001
[2]School of Physical Sciences, The University of Adelaide, Adelaide, SA 5005

SUMMARY

We present results of 36 broadband magnetotelluric (MT) stations along a 70 km ENE-WSW profile across the southern Eyre Peninsula, South Australia. The transect crosses the Eyre Peninsula Anomaly (EPA), first identified by induction arrows, and visualised in 3D from AusLAMP resistivity models. The significantly smaller site spacing of the Tumby Bay MT profile compared to AusLAMP (2 km instead of 55 km) has allowed us to image the EPA in high resolution which has defined the EPA into a very conductive (< 0.1Ωm) region from depths ~2-17 km and a width of about 30 km. At greater depths (~17-22 km) the conductor becomes widespread across the transect but less conductive (~30 Ωm). On the eastern third of the profile, upper crustal conductive fluid pathways are identified and may connect to the main body of the EPA.

Key words: Magnetotellurics, Eyre Peninsular, lithosphere, conductivity anomaly, electrical resistivity

INTRODUCTION

Electrical conductivity anomalies have been observed across Australia and around the world since the early 1970's, using Geomagnetic Depth Sounding (GDS) data which only involves measurement of time-varying magnetic field data (as opposed to magnetotellurics which uses magnetic and electric fields), and thus lacks the ability to accurately determine depth and absolute values of resistivity structure. Within Australia these include; the Eyre Peninsula Anomaly, the Carpentaria Anomaly, the Tamar Anomaly, the South-west Queensland Anomaly, the Canning Basin Anomaly, the Otway Anomaly and the Flinders Conductivity Anomaly. Most of these extend hundreds of kilometres, see Wang et al., 1997, for a summary of anomalies.

The acquisition of AusLAMP (Australian Lithosphere Architecture Magnetotelluric Project) data (55 km spaced array of long period MT data, eventually to image the electrical resistivity of the entire lithosphere of Australia) in the last 5 years has allowed greater definition of these anomalies (Robertson et al 2016, Carpentaria anomaly reference). For example, the Flinders Conductivity Anomaly is now known to occur as separate anomalies within the Nackara Arc in the Flinders Ranges, and Curnamona Province (Robertson et al 2016). One of the primary outcomes of AusLAMP is to identify anomalous regions for targeted infill surveys. This has also been applied to the Curnamona Province (Kay et al., 2018) with a high resolution broadband MT transect defining the Curnamona conductor (one of the components that makes up the previously known FCA), and revealed upper crustal fluid pathways.

The Eyre Peninsula Anomaly (EPA) was first identified from GDS data in 1984 (White & Milligan). It has since been revealed to have conductivities as low as 0.1 Ωm (more conductive than seawater, 0.3 Ωm) from AusLAMP 3D resistivity models. The EPA appears long and continuous over several hundred km (Figure 2) from 3D inversion of AusLAMP data appears to potentially continue into the conductive crustal conductor extending around the eastern and northern margin of the Gawler Craton (Thiel et al., 2016). The EPA was determined to be caused by a major fracture or shear zone located within the top 10-15 km of the crust (White and Milligan (1984).

The southern Eyre Peninsula hosts a variety of graphite deposits (Siviour, Kookaburra Gully and Uley), Pb-Zn-Ag and Fe ore in the Hutchison Group, plus possible Archaean volcanic massive sulphides. A combination of the presence of the very conductive EPA and the prospectivity of the region made this an ideal region for a targeted AusLAMP infill survey.

A total of 36 broadband MT sites were collected along a ~70 km stretch of road just south of Mount Hope on the western coast of the Eyre Peninsula, to Tumby Bay on the eastern coast, with the aim of better defining the EPA in this region and to develop an understanding of its implications for prospectivity in the region.

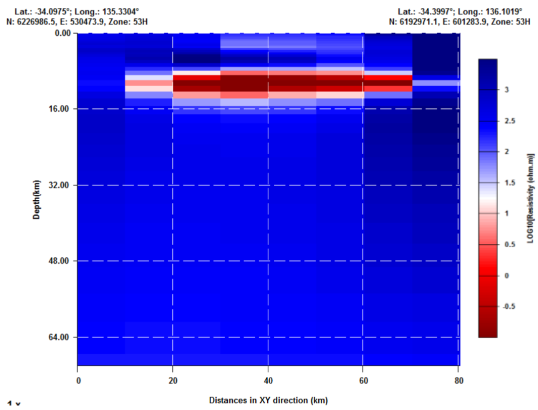

Figure 1: Cross section extracted from AusLAMP resistivity model along the Tumby Bay MT transect showing the very conductive EPA.

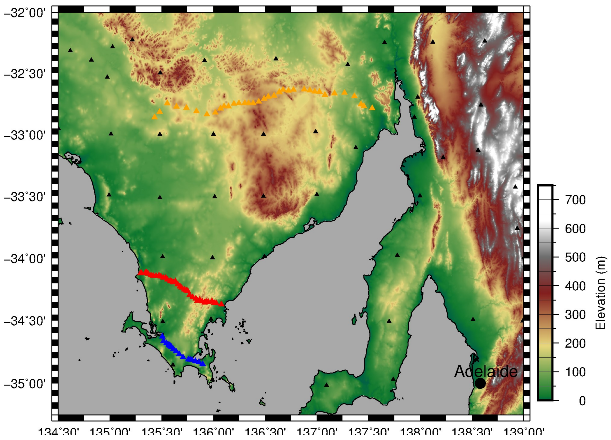

Figure 2: Topographic map showing the location of MT and GDS sites referred to in the abstract. The Tumby Bay MT sites are in red, the AusLAMP MT sites in black, the southern Eyre Peninsula GDS sites in blue, and the ?? MT sites in orange.

METHOD AND RESULTS

Magnetotellurics is a passive electromagnetic technique measuring natural variations of Earth's magnetic and electric at the surface of Earth (Cagniard, 1953). Interactions of solar wind with Earth's magnetosphere and global lightning activity that traverses the ionosphere, cause magnetic field variations, which act as a source for the induction of electric eddy currents in the Earth.

MT data were acquired using the LEMI-423 data logger and LEMI induction coils with a sample rate of 1000 Hz. Instruments recorded for an average of 43 hours. After pre-processing the time series, the 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 ~.001to 1000 s. A representative site is shown in Figure 3.

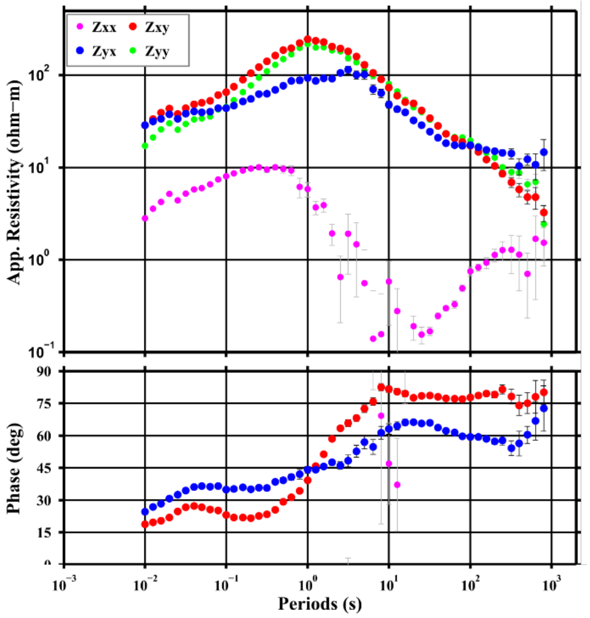

Figure 3. Apparent resistivity (top) and phase (bottom) plots of site TMB22 showing an example of the data quality.

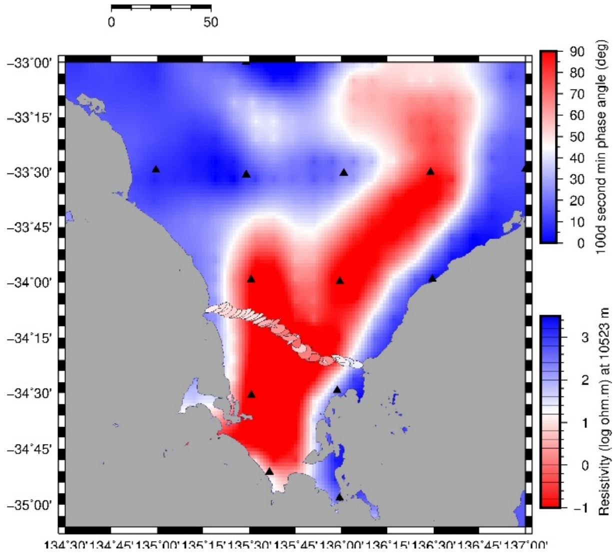

Figure 4. AusLAMP electrical resistivity depth slice at 10.5 km showing the large ECA, with phase tensor ellipses for a period of 100 s overlain. Black triangles show the locations of the AusLAMP MT sites inverted to obtain the resistivity slice.

MT data can be visualised as phase tensor ellipses. The orientation of the major or minor axes of the ellipse shows the direction of preferred current flow (ambiguity discerned using geological information). In Figures 4 and 5 ellipses are shaded by minimum phase angle which gives an indication of how resistivity changes with depth, angles larger than 45 ° show that the subsurface is becoming for conductive with depth, less than 45 ° more resistive with depth. A circle shows a 1D resistivity structure, an ellipse either 2D or 3D. The Shoal Point Fault (SPF) marks a change in conductivity structure as shown by the phase tensor ellipses at a period of 50 and 100 s (roughly upper to mid-crustal depths), from NE-SW to NNW-SSE, quickly changing to closer to E-W.

Preliminary results of the 2D inversion of the TMB MT stations using Occam2D (reference) reveals the main part of the EPA to be about 30 km across in a depth range of about 2 to 17 km beneath the surface. This is about 20 km from the west of the profile edge to 50 km from the west of the profile edge. The resistivity values here are less than 0.1 Ωm. Resistivities this low (less than seawater) only have a few known causes including interconnected sulphides and graphite (check?). From ~17-22 km the EPA extends across most of the transect, but is a little more resistive (~10-30 Ωm). The eastern 20 km of the transect has some conductive pathways in the upper 5 km which may have a connection to the deep parts of the EPA. Overall there is good agreement with the features identified from the AusLAMP resistivity model (Figure 1) but upper crustal pathways are now revealed with the considerable increase in resolution of the TMB MT transect (55 km down to 2 km). The depth extent of the EPA is deeper (~22 km instead of 16 km). Further testing needs to occur to resolve this discrepancy.

Interpretations of the cause of the anomalous conductivity of the EPA have included saline fluids in fractures connecting with the ocean, graphite in a shear zone, current channelling effects from induced currents in the ocean into the continent (all White and Milligan, 1984)). To the north, Curtis and Thiel

(2019) image the EPA to be slightly deeper down to ~25 km in places and buckled to reflect individual shear zones. It is generally dipping to the west with the shallowest part to the east.

To the south, the GDS transect to the south (labelled Thiel 2005 on Figure 3) showed a steeply dipping
resistivity contrast between the Sleaford Complex (10-100 Ωm) and the Donington Suite (>1000 Ωm) coinciding with the surface expression of the Kalinjala Shear Zone. In this study the EPA was imaged as shallow high conductivity (1-10 Ωm) interpreted to be caused by graphite confined to the top 4 km beneath the surface. This contrast to our depth extent of the EPA to ~20 km may be due to a few factors; our models are still preliminary and need the depth to the base of the conductor tested for robustness, the EPA may shallow considerably to the south, and Thiel et al (2005) used GDS data which suffers from an inability to constrain the depths of resistivity structures, and resolve absolute resistivities.

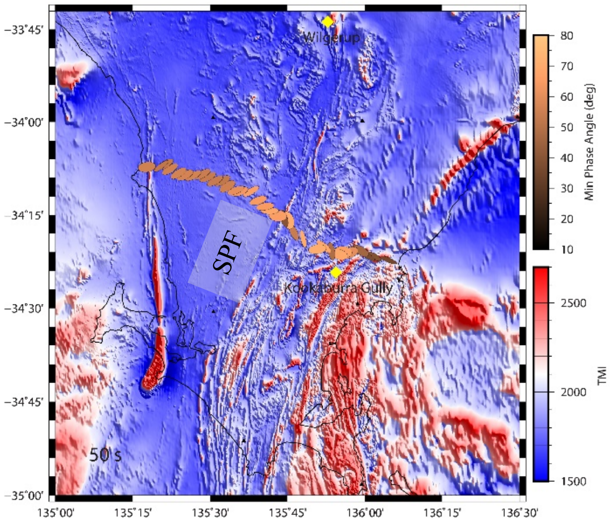

Figure 5: Total magnetic intensity (TMI) with phase tensor ellipses for a period of 50 s overlain. Two deposits, Kookaburra Gully (graphite) and Wilgerup (iron-ore) are shown. SPF is the Shoal Point Fault.

CONCLUSIONS

A total of 36 broadband MT sites were collected along a 70 km transect across the southern Eyre Peninsula. The transect represents a scale reduction from the long-period AusLAMP deployment across South Australia which highlights the very conductive Eyre Peninsula Anomaly. The transect crosses multiple faults which are defined with higher resolution from the TBMT transect, and can be identified to have varying conductivity structure as imaged using phase tensor ellipses. Upper crustal conductive fluid pathways are also identified in the eastern part of the transect and may connect to the main body of the EPA.

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