Mapping and characterizing lithosphere discontinuities: examples of southern Australia using AusLAMP MT

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SUMMARY

Major lithosphere boundaries play an important role for the understanding of the geodynamic history of the continental lithosphere and have a primary control on the location of the deposits at the surface. In South Australia, the traditional approach to use potential field methods show large ambiguity to infer large-scale boundaries beneath cover. Here, we show examples of the integration of magnetotelluric data, collected from the AusLAMP (Australian Lithospheric Architecture Magnetotelluric Project) and higher density in-fill surveys, with other geophysics and isotope geochemistry data sets to characterize and constrain the location of crustal scale boundaries. The integration of various techniques shows the unique importance of the magnetotelluric method to identify zones of lithospheric weakness which have led to Proterozoic reworking of Archean lithospheric cores in southern Australia.

Keywords: magnetotellurics, AusLAMP, lithosphere discontinuities, isotope geochemistry

INTRODUCTION

The identification of lithospheric discontinuities plays an increasing role in the characterisation of Archean and Proterozoic terranes, as it allows the mapping of stable and old cratonic lithospheric blocks, as well as their margins. In recent years, the insight into the relative position of cratonic margins and locations of repeated lithospheric deformation, concentration of magmatic and fluid flux (Richards, 2011), as well as the position of mineral deposits (Griffin et al, 2013; Richards, 2013), has highlighted the importance of mapping and understanding these discontinuities. Aside form the aforementioned vertical discontinuities, horizontal boundaries also play a role for geodynamic processes, e.g. the ability for magmas and fluids to penetrate to the surface (Davies et al, 2015). As examples, horizontal boundaries include the lithosphere-asthenosphere boundary (LAB) (O'Reilly and Griffin, 2010), the mid-lithospheric discontinuity (MLD) (Aulbach et al, 2017; Selway et al, 2015), the crust-mantle boundary (Moho), and mechanical boundaries within the crust, e.g. the brittle-ductile boundary (BDT) (Thiel et al, 2016).

We show comparative data sets including isotope geochemistry, seismic tomography models, heat flow analyses, potential field data sets, and seismic reflection studies together with magnetotelluric modelling results from continent-wide long-period AusLAMP arrays to focussed broadband surveys.

The Gawler Craton in South Australia has been an area of extensive focus for magnetotelluric deployment over the last 15 years (Heinson et al, 2006; Thiel and Heinson, 2010, 2013; Selway et al, 2011; Robertson et al, 2016). Here, we present results of the long-period AusLAMP MT deployment across South Australia and the result of smaller scale in-fill surveys using broadband equipment. The deployments show a heterogeneous distribution of resistivity structure in both the mantle and crustal lithosphere. In the first order, the lithospheric cratons seem to exert a primary control on focussing fluid and magmatic events in the Proterozoic. As a result the location of major IOCG deposits and prospects across the Gawler Craton align with the observed craton margins. In-fill MT survey using broadband equipment illustrate crustal structural control on the position of IOCG and uranium deposits at the surface (Heinson et al, 2018; Thiel et al, 2016). It shows that magnetotellurics is a pivotal tool for mineral exploration and for understanding the fertility of the lithosphere.

AusLAMP MT program

The Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) is a national Australian initiative to map the Australian continental lithosphere using magnetotelluric (MT) stations to obtain a resistivity model of the subsurface. It is a joint project between Geoscience Australia, state surveys, and Universities. The station spacing of the AusLAMP program is roughly 50 km. The data coverage across South Australia exceeds 95%, totalling close to 400 MT sites. The data is processed using robust processing codes (Chave and Thomson, 2004), and inverted using the 3D ModEM code (Egbert and Kelbert, 2012; Kelbert et al, 2014).

Results

The main insights of the AusLAMP SA program are as follows:

- The resistivity models show large-scale trans-lithospheric boundaries aty the margins of the Archean core of the Gawler Craton extending through the crust into the mantle. The low resistivity regions correlate with gravity highs, while the central part of the Gawler Craton shows a very resistive core into the mantle and corresponds to a gravity low.
- The thickest zone of resistive core also correlates well with LAB estimates derived from seismic tomography studies and thermal models of the lithosphere (Kennett et al, 2013; Czarnota et al, 2014).
- The north-western part of the Gawler Craton shows an extensive area of metasomatised mantle at depths around 100 km - 150 km, near the MLD.
- Large-scale vertical low resistivity zones often demarcate long-lived terrane boundaries, and these correlate with changes in the heat flow measurements. The differences point to changes in the abundance of heat-producing elements in the upper crust, which may have been emplaced through enrichment due to magmatic processes localised along the margins of the Gawler Craton.
- At the lithospheric boundaries, the BDT marks a strong mechanical layer controlling the fluid flux through the lithospheric column. MT signatures suggest ponding of fluids beneath the BDT in the ductile regime of the crust. In some cases, fluids were then able to penetrate into the upper brittle crust forming narrow pathways to the surface, which appear different to the wide-spread nature of ductile deformation in the lower crust.
- Isotope geochemical analyses of felsic and mafic magmatic rocks across the Gawler Craton suggest that the low resistivity zones imaged with MT are footprints of past magmatic and fluid flux events within the crust in the Proterozoic.
- The resistivity signature of the high conductivities in the crust correlates with the position of major iron-oxide copper gold deposits and gold deposits at the surface, and represent the mineral system footprint of the large mineral occurrences.

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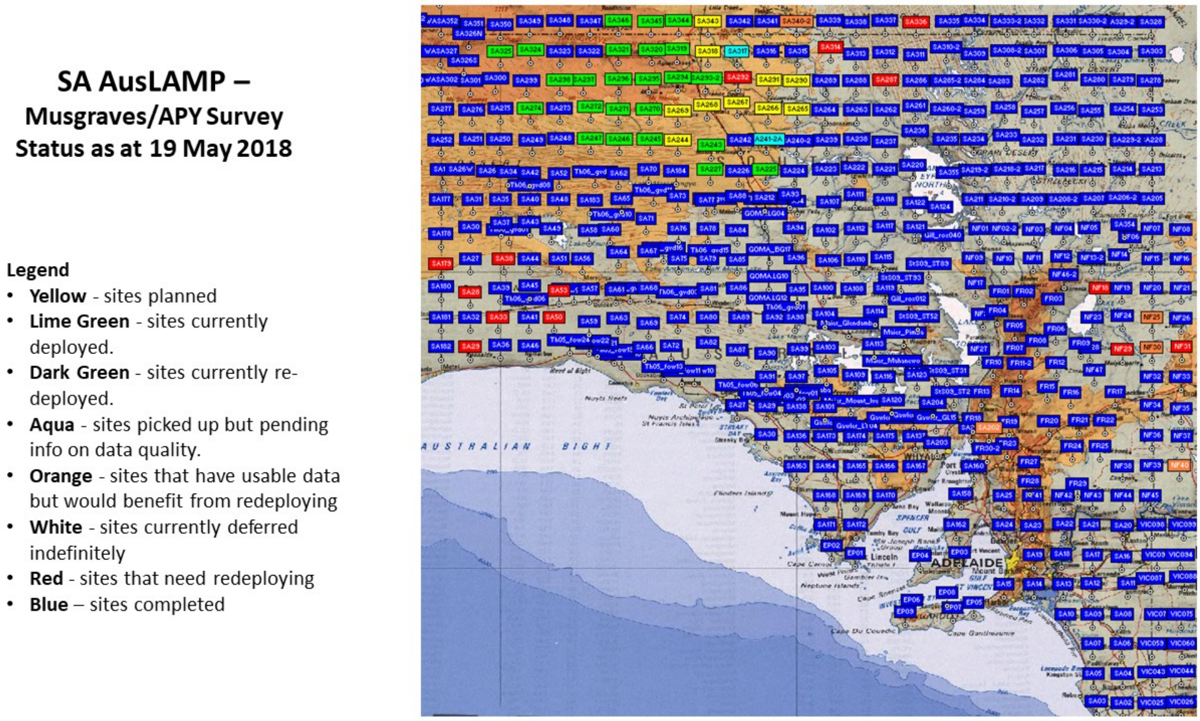

Figure 1: Deployment status of the South Australian AusLAMP deployment to date. Close to 400 long-period MT sites have been deployed to date spanning the Gawler Craton in the central-southern part of South Australia, extending across the Flinders Ranges and Curnamona Province in the east and the Eucla Basin to the west.