The electrical resistivity of the Australian lower crust

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SUMMARY

The resistivity structure of the crust is broadly expected to be homogeneous, with highly resistive lower crustal rock overlain by more conductive rock in the upper crust. However, observed data shows that although the upper crust is typically resistive, the lower crust can be much more conductive. The presence of such high electrical conductivity in the lower crust is remarkable and suggests a substantial highly connected material, melt or fluid. Has the low resistivity structure been present since inception, or is it the result of a later overprinting event. The secondary objective to establish how such a low resistivity region can be preserved over such an extended time scale.

Data has been collated from magnetotelluric (MT), and geomagnetic depth sounding (GDS) surveys collected over the last thirty years. Three different methods have been used to model thousands of data points. A thin-sheet inversion of thousands of GDS data has been used to place constraints on the regional scale electrical conductance. Inversions of the MT data in both 2D and 3D have provided more detailed models of how the Moho is connected to the upper crust.

Strong correlations were observed between major tectonic domains (such as the Gawler Craton) and regions of high resistivity within the crust. The 2D profiles show broad regions of low resistivity at the boundary between the upper and lower crust (10-15 km depth), with low resistivity zones extending for tens of km. Above the boundary, the low resistivity regions transform in to narrow pathways penetrating through the resistive upper crust and the areas with the lowest resistivity were found to have a strong correlation with known major mineral provinces. This leads to the suggestion that crustal low resistivity anomalies are likely a product of fluxes of fluid and possibly melt from the upper mantle and lower crust.

Key words: Magnetotellurics, Gawler Craton, Exploration, Electromagnetic Induction, Fluids

INTRODUCTION

The crust is predominantly made up of silicate rocks with an expected high electrical resistivity while in the solid phase. However, while the upper crust typically has an electrical resistivity in excess of 1000 Ω.m, the lower crust commonly contains regions where resistivity is less than 100 Ω.m, and in places lower than 1 Ω.m. The proposition that regions of the lower crust (15 km depth to the Moho) can be as electrically conductive as seawater as astonishing, and can only be explained by the presence of melt, fluid or a large area of a high connected mineral. The mechanisms that would lead to such a region of low resistivity are poorly constrained by both present day observational data and laboratory measurements.

METHOD AND RESULTS

Data has been collated from magnetotelluric (MT) and geomagnetic depth sounding (GDS) surveys undertaken over the last thirty years, including; the Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP), detailed MT transect data, legacy MT data and GDS data collected during smaller surveys (Figure 1). These data have been collated in a database consisting of thousands of individual site locations across Australia.

Three different methods of modelling have been utilised to understand the data. A thin sheet modelling technique (Lilley, 1993; Wang, 1999) has been used to invert the induction arrows of the GDS data to constrain the regional scale electrical conductance in order to determine regions of interest. Strong correlations were observed between regions of high resistivity and major tectonic domains such as the Gawler Craton, showing consistency with previous observations by Jones (1992) and Wannamaker (2000). Fixed conductance values were assigned to cells corresponding with regions of known conductance, such as oceans, to provide a more accurate model.

Inversion in both two dimensions (2D), using the OCCAM algorithm (deGroot Hedlin, 1990) and three dimensions (3D) was carried out using subsets of the MT data in order to provide further detail on how the Moho is connected to the upper crust. The 3D models provide more detailed information on the location of large scale high resistivity regions and the edges there of. A solid spatial relationship was observed between the locations of known mineral deposits and the steep resistivity gradients observed along the edges of the highly resistive regions. Further to this, the 2D profile modelling shows broad areas of low resistivity at the boundary between the upper and lower crust (10 – 15 km depth). Below the transition depth, the low resistivity region is broad, extending for tens of km in both the horizontal and vertical planes. But above the transition depth, the low resistivity regions appear as much narrower pathways in an otherwise resistive upper crust, linking the lower crust to the near surface.

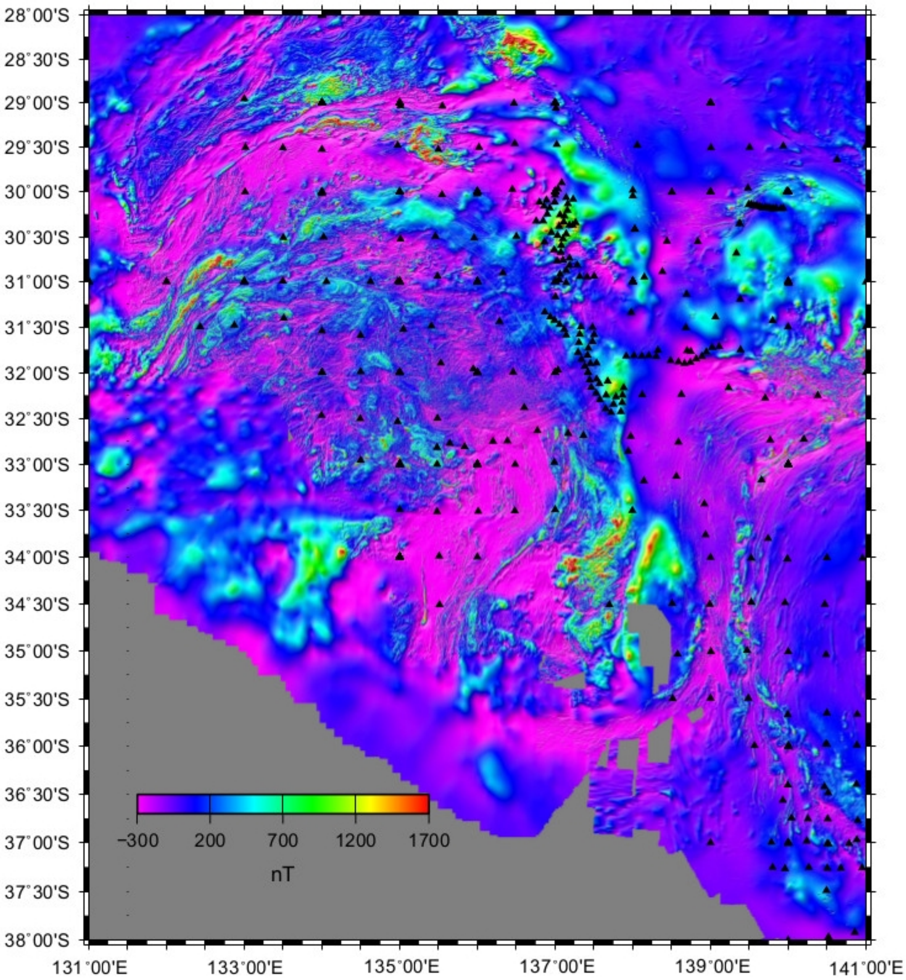

Figure 1: Total magnetic image of South Australia showing the MT and GDS site locations.

CONCLUSIONS

Modelling of the data has shown the major tectonic provinces such as the Gawler Craton are largely electrically resistive and homogeneous. At the margins of these resistive regions, a steep resistivity gradient is observed, coinciding with the locations of many major mineral provinces. Low resistivity regions were observed at the boundary of the upper and lower crust, in the brittle ductile transition zone. These regions are broad and extend for tens of kilometres below the transition zone, but are narrow and extend as conduits linking the lower crust to the near surface in the upper crust. The low resistivity anomalies appear to be associated with an event that results in fluxes of fluids and potentially melt from the upper mantle and lower crust.

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