Electrical resistivity structure of the southeast Australian lithosphere

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ABSTRACT

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In its ability to retain signatures of tectonic events that enrich or deplete its fertilization state, the lithosphere holds the key to the tectonic evolution and history of Earth. Dewatering of the subducting slab leads to released fluids and induced melt which act to fertilize the overlying mantle in incompatible elements such as hydrogen. Conversely, rifting events lead to partial melting with fertile elements entering the melt, leaving behind a depleted lithosphere. Signatures such as these can remain in the lithosphere for hundreds of millions of years in the absence of further high temperature/melt events.

Magnetotellurics (MT) is a passive geophysical tool that images the physical property of electrical resistivity and is capable of penetrating the entire lithosphere. MT is highly sensitive to minor interconnected conducting mineralogy and fluids, and thus is ideal for distinguishing between lithosphere of different degrees of enrichment. Additionally, the sensitivity to these minor phases means that fossil fluid pathways associated with the ascent of mineralising fluids and metals are detectable with MT. This is the cornerstone on which one of the main directions of the UNCOVER (Australian Academy of Science, 2012) initiative is based on- increasing the detectable signature of ore deposits by imaging the underlying fluid pathways and lateral dispersion of deposits.

With these capabilities in mind, MT surveys were undertaken across western Victoria, Australia and the Ikara-Flinders Ranges and Curnamona Province in South Australia, Australia. The collection, processing and modelling of new MT sites were conducted for this thesis, with many other existing MT sites utilised to expand the dataset.

In Chapter 2, 74 broadband (period of 0.001-2000 s) MT sites along the 1.2-5 km spaced east-west Southern Delamerian transect were processed, modelled and interpreted across western Victoria. The crust beneath the Delamerian Orogen has a heterogeneous resistivity structure, with low-resistivity fossil-fluid pathways stemming from Moho depths, intersecting an otherwise resistive upper crust. Serpentinite with interconnected magnetite is known to occur within the vicinity of the survey region, and conductivity measurements of hand samples indicate substantially lower resistivities for the serpentinised rocks, leading to the interpretation that serpentinite contributed to the low resistivity zones.

Chapter 3 expands on the Southern Delamerian transect of Chapter 2 by modelling the transect using a 3D inversion code, along with four other pre-existing datasets which, when combined, create a 500 km continuous east-west transect. Importantly, this transect traverses the transitional zone between the Delamerian and Lachlan Orogens. The elusive boundary between these Orogens has most recently been interpreted as a gradual boundary within the Stawell Zone. Results from modelling show that the lower crust and shallow upper mantle of the Delamerian Orogen are at least an order of magnitude more resistive than the adjacent Lachlan Orogen. If the location of this sharp gradient in resistivity is chosen as the Delamerian-Lachlan transition, then the boundary occurs about 20 km to the east of the Moyston Fault in a NNW-SSE orientation, in reasonable agreeance with seismologically and geochemically determined boundaries.

Finally, Chapter 4 involved the collection of the first set of AusLAMP measurements across an array of 50 km spaced long-period (2-17,000 s) MT sites across the Ikara-Flinders Ranges and Curnamona Province in South Australia. This longer-period dataset was capable of imaging the entire lithosphere, and resulted in the imaging of a surprisingly low resistivity crust for the Palaeo-Mesoproterozoic Curnamona Province, indicating either a long-lived retainment of enrichment from the Olarian Orogeny (over 1.5 Ga), a more widespread reworking of the province from the Delamerian Orogeny (540 Ma), or another unrelated more recent enrichment event. The Broken Hill Domain remains largely resistive, indicating that enrichment events associated with the emplacement of the word-class Broken Hill deposit may have been erased during a high temperature or melt event. Further, two conductivity anomalies were identified in the Nackara Arc of the Ikara-Flinders Ranges, and when combined with the Curnamona Conductor, can explain the phenomenon of induction vectors across eastern South Australia all pointing toward an anomalous zone spanning the Ikara-Flinders Ranges north to south in an arcuate fashion, which had previously been interpreted as one single continuous conductivity anomaly, the Flinders Conductivity Anomaly. Coincidence of the Nackara Arc Conductors with locations of discovered kimberlites give evidence for zones of lithospheric weakness, with pathways where CO_2-rich kimberlitic melts may have deposited graphite on ascent.

Thesis Supervisors: Prof. Graham Heinson and Dr. Stephan Thiel

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