Mapping metasomatised mantle by integrating magnetotelluric, passive seismic and geochemical datasets – SE Australia

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SUMMARY

There is growing evidence that the distribution of significant giant magmatic and hydrothermal ore deposits are linked to the presence or absence of metasomatised lithospheric mantle. It follows that mapping the distribution of this mantle should be an important component of exploration programs for world class deposits, yet to date there has not been a robust means of spatially constraining the distribution of metasomatised mantle. Classically, metasomatism has been identified through petrological and geochemical analysis of mantle xenoliths and mantle derived melts which provide information on the vertical distribution of metasomatism beneath magmatic centres. Here, we show this classical information integrated with constraints on lithospheric thickness and conductivity, derived from passive seismic and magnetotelluric imaging of the lithosphere provide an effective means of mapping both the lateral and vertical distribution of mantle metasomatism. As a case study we show the integration of the aforementioned datasets over south-eastern Australia where the Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) was started.

Key words: AusLAMP, magnetotellurics, passive seismic, metasomatism, Australia, lithosphere.

INTRODUCTION

It is becoming evident that the economic search space for giant magmatic and hydrothermal ore deposits in Australia, and elsewhere around the world, is moving undercover (e.g. UNCOVER initiative, https://www.uncoveraustralia.org.au). This shift in exploration necessitates a greater reliance on a mineral systems understanding of ore deposit formation with emphasis on the derivation of geoscience knowledge from geophysical datasets. There is growing consensus that the formation of significant giant magmatic and hydrothermal ore deposits such as Kalgoorlie gold, Olympic Dam iron oxide-copper-gold and Carlin gold are associated with metasomatic fluids, which have passed through the lithospheric mantle (Czarnota et al., 2010; Skirrow et al., 2007; Griffin et al., 2013). Given the undercover search space in Australia is estimated spatially to be approximately double that of the outcropping search space, maps of the distribution of metasomatised mantle could be an effective means of selecting fertile greenfield areas for exploration. Classically, the distribution of metasomatised mantle has been constrained using xenolith or melt compositions (Griffin et al., 2008, Pilet et al., 2011), which provide excellent constraints on metasomatism beneath magmatic centres but limited potential to map metasomatised mantle distribution. Currently, mapping of metasomatised mantle distribution relies on passive seismic imaging of the lithospheric mantle and variations in Vp to Vs ratios (Griffin et al., 2009) yet most recently there is growing evidence that resistivity variations mapped out using magnetotelluric (MT) data, as acquired over the Olympic Dam deposit, map the pathways of metasomatic fluids (Heinson et al., 2015).

METHOD AND RESULTS

Through the integration of geochemical, passive seismic and MT data sets and models we show empirical evidence that conductive regions within the lithospheric mantle appear to be mapping the distribution of Palaeozoic age metasomatised mantle in south-eastern Australia and therefore can be used in mineral systems based exploration. South-eastern Australia (Figure 1a) is an excellent natural laboratory, as the geological history is generally well constrained consisting of convergent margin processes during the Palaeozoic (Moresi et al., 2014), a divergent tectonic setting during the Mesozoic and vertical motions associated with volcanism (Figure 1b) in response to mantle convective circulation during the Cenozoic (Czarnota, et al., 2014). Importantly, the gross present-day lithospheric architecture consisting of the lithosphere-asthenosphere boundary (Figure 1b) and Moho are well-constrained using passive seismic techniques (Fishwick and Rawlinson, 2012). These datasets provide strong constraints on the interpretation of modelled resistivity structure derived from the Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP). The most conductive part of the resistivity model corresponds with the distribution of lithospheric mantle underlying the Palaeozoic Lachlan Fold Belt, which is endowed with significant Orogenic Load Gold deposits (Figure, cf. 1a and 1d). Trace element chemistry of Cenozoic basalts over this region of conductive lithospheric mantle indicate the presence of metasomatised mantle within the melt source region or along the melt ascent paths. Taking into consideration the tectonic history of the region this metasomatism has been preserved at least from the mid-Palaeozoic until access by Cenozoic basalts. Given the temperature dependence on mantle peridotite conductivity it's surprising that the most conductive part of the model is not within the inferred hot asthenospheric mantle thought to reside beneath the < 6 Ma Newer Volcanic Province (cf. Davies et al., 2015). Even though the mineral phase responsible for the high observed conductivity values can't be identified at this stage as there is a generally a lack of consensus as to the cause of high conductivity anomalies within the lithospheric mantle (Selway, 2014) our weights of evidence approach suggests they are mapping out the distribution of ancient mantle metasomatism.

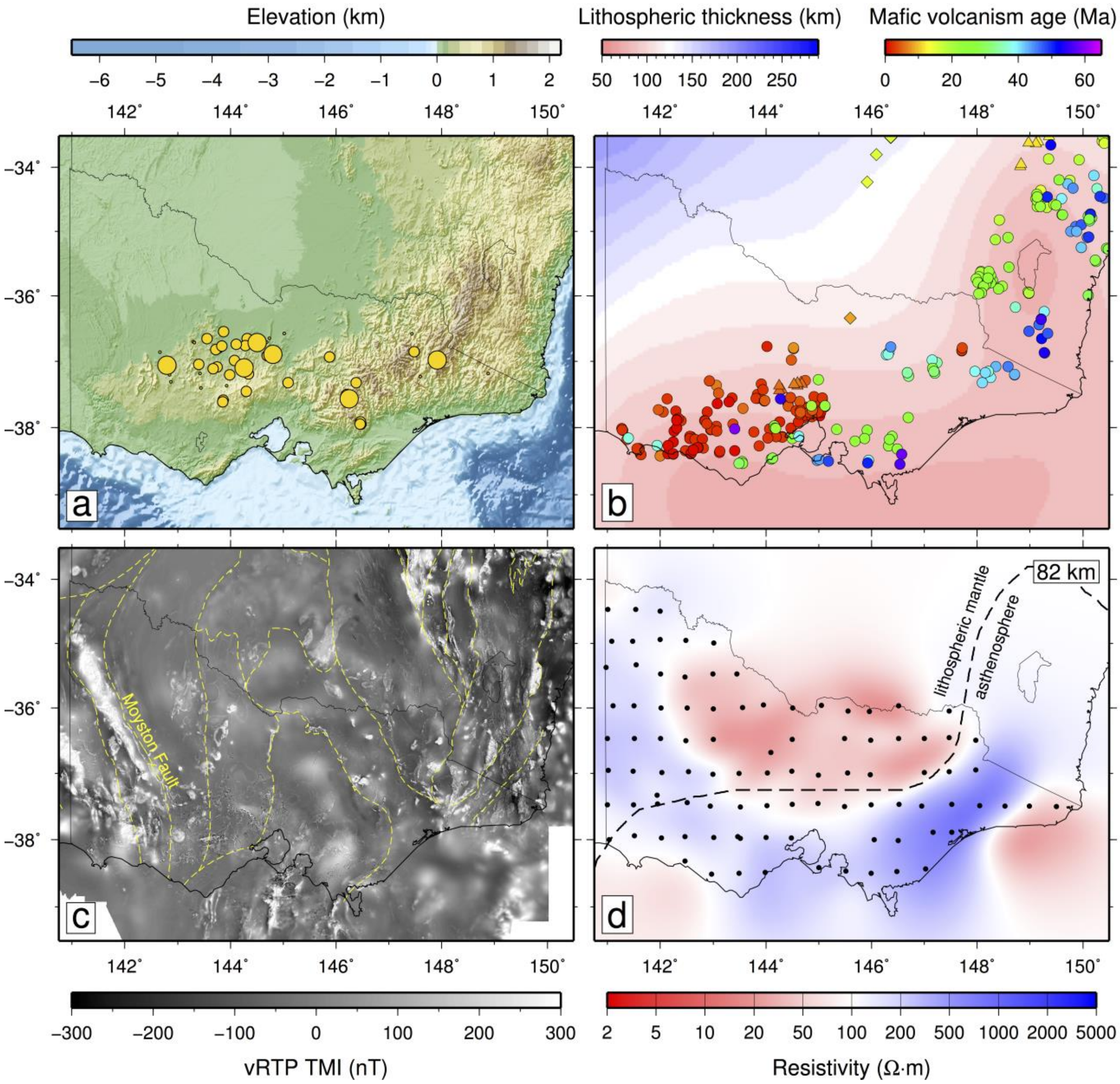

Figure 1: (a) ETOPO Elevation map of south-eastern Australia showing distribution of Orogenic Load Gold deposits as yellow circles of increasing size corresponding to <1 t, 1–10 t and > 10 t of gold. (b) The thermal lithosphere-asthenosphere boundary based on passive seismic surface wave velocity constraints (Czarnota et al., 2014). (c) Variably reduced to top total magnetic intensity map by Geoscience Australia overlain with major crustal boundaries (). The Moyston Fault demarks the boundary between the Delamerian Fold Belt to the west and the Lachlan Fold Belt to the east. (d) Resistivity map at ~82 km depth derived from magnetotelluric time series data acquired at stations marked by black circles. The dashed line shows the intersection between the lithosphere-asthenosphere boundary shown in (b) with the resistivity slice at 82 km.

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