Results from long-period MT array in the Newer Volcanic Province, Western Victoria, Australia

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SUMMARY

The Newer Volcanic Province (NVP), western Victoria, Australia, represents the most extensive and youngest volcanism of the entire intraplate volcanic field of eastern Australia. The nature of, and mechanism(s) for, melting of the source magma of the NVP is still unclear. Previous teleseismic studies associate the magma genesis for the NVP to conduits of a mantle plume. Here we present data from a long-period MT array conducted over the same grid as the teleseismic survey, across the southern end of the Lachlan and the Delamerian Orogenies, western Victoria in a rectangular grid with nominal 270 km x 150 km dimensions. Forward modelling of MT data suggests that the lithosphere beneath the Lachlan orogeny is more conductive than the Delamerian counterpart by several orders of magnitude, perhaps associated with thinning of the lithosphere beneath the Lachlan orogeny. The phase tensor analysis illustrates that there is an increasing conductivity trend beneath the Central Highlands, observed up to 500s, that is perhaps associated with NVP magma source region. Furthermore, the geoelectric strike direction beneath the Central Highlands is aligned parallel to the NW-SE Mesozoic-Cenozoic fracture zones, which coincides with the highest density of eruptions of the volcano field.

Key words: Magnetotelluric, Phase tensor, Lachlan, Volcano, Australia

INTRODUCTION

The NVP is the youngest and the most extensive volcanic field in the entire intraplate volcanic field of Eastern Australia. The nature of, and mechanism (s) for, melting of the source magma of the NVP is still unclear. The NVP is located within the Australian-Indian plate and is far from any plate boundaries that may be associated with subduction-related volcanism. Rifting has occurred in Victoria, related to the separation of Australia and Antarctica, but was initiated 90 to 55 Ma (Vogel and Keays, 1997; Cas et al., 2011), long before the eruptions of the Newer Volcanics Province. Furthermore, the lack of a linear age progression of the NVP volcanoes is inconsistent with the mantle plume model for magma genesis.

Several teleseismic studies have been conducted in southeast Australia to study the mantle beneath the Delamerian and the Lachlan orogenies (Graeber et al., 2002; Rawlinson and Kennett, 2008; Rawlinson et al., 2011; Rawlinson and Fishwick, 2012). The latest teleseismic tomography study show that there is a zone of low velocity seismic waves extended from 50 km to 150 km beneath an area to the northwest of Melbourne, associated with the NVP volcanism (2012). Although this zone is not profound below 150 km depth, it is interpreted as a mantle plume conduit (Graeber et al., 2002; Rawlinson and Kennett, 2008; Rawlinson et al., 2011; Rawlinson and Fishwick, 2012). Moreover, the study of Rawlinson and Fishwick (2012) show that the seismic velocities within the lithospheric mantle of the Delamerian and the Lachlan orgenies increase eastward, which is associated with elevated temperatures at the lithospheric mantle of the Lachlan caused by lithospheric thining during separation of Antarctica and Australia.

In 2010 and 2011, long-period MT data were collected across the southern end of the Lachlan and the Delamerian Orogenies, western Victoria, in a rectangular grid with nominal 270 km x 150 km dimensions, bordered by the towns of Geelong in the southeast, Casterton in the southwest, Nhill in the northwest, and Bendigo in the northeast. This MT array comprises four parallel approximately NW-SE trending profiles (A, B, C and D) with 50 km spacing and a total number of forty stations with 30 km spacing. These stations occupied approximately the same location as the teleseismic stations of Graeber et al.(2002). The aim of this study is to map the electrical resistivity variations to understand the lithospheric structures of the area with particular focus on the magma genesis of the NVP. Here, we present results from dimensionality analysis and forward modelling of the NVP array.

METHOD AND RESULTS

Induction arrows are a qualitative illustration of lateral variations of the electrical resistivity. Using Parkinson

convection (Parkinson, 1962), the real parts of the induction arrows point to enhanced conductivity zones. The phase tensor of MT data is coordinate invariant and can be represented by an ellipse (Caldwell et al., 2004). The major and the minor axes of the ellipse illustrate the maximum and minimum phase, respectively. The orientations of the major axes of the phase ellipse are parallel or perpendicular to the regional geoelectric strike direction in a two-dimensional case. Phase tensor ellipses along with induction arrows are shown on top of the total magnetic intensity (TMI) data for periods of 50 s to 1000 s (Fig. 1). The colours used to fill the phase tensor ellipses are the values of the minimum phases. The minimum phase values $(\phi_{\min})$ smaller than 45˚ indicate the conductivity decreases with increasing depth, while for values exceeding 45˚, the conductivity increases for the underlying layers.

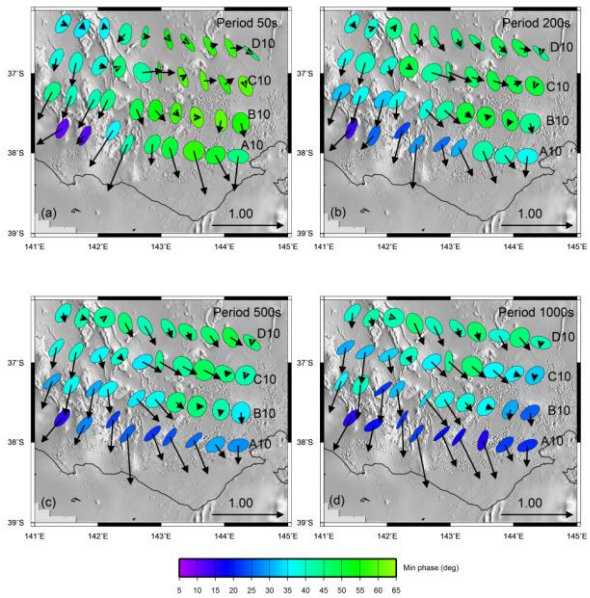
Induction arrows of the observed data define two distinctive areas with different lateral variations of the resistivity. The first area is to the west of the Moyston fault and spatially correlates with the Delamerian orogeny and is characterised by large vectors pointing south and southwest. Forward modelling of the ocean and Phanerozoic sediments suggests that the ocean effect and effect of thick sediments of Otway basin deflects the vectors to the S and SW. The second area, situated to the east of the Moyston fault and spatially correlates with the Lachlan Orogeny and the Central Highlands of the NVP, is identified by small vectors that point towards the east and southeast. The location of these small-size vectors coincides with the negative seismic anomalies (not shown here) and negative gravity anomalies (not shown here). Forward modelling shows that these small-size vectors, spatially correlated with a high-density zone of NVP volcanoes, are consisitent with the presence of a conductive zone in the lower crust and upper mantle beneath the Central Highlands.

Furthermore, with increasing period, the vectors to the east of Moyston fault rotate southward while vectors to the west of the Moyston fault rotate eastward. Forward modelling of the lithosphere beneath the Delamerian and the Lachlan orogeny suggest that the lithosphere beneath the Lachlan is more conductive than the Delamerian counterpart, thus providing supporting evidence for the different seismic characteristics of these two orogenies (Rawlinson and Fishwick, 2012). The deflection of vectors to the SE at long periods is due to inductive coupling of the ocean and lithosphere of the Lachlan orogeny.

Similar to induction arrows, the observed phase ellipses on either side of the Moyston fault represent dissimilar responses for short and long periods. In general, the observed minimum phases on the western side of the Moyston fault are less than 45˚, indicating that resistivity increases beneath the Delamerian orogeny for underlying layers. The major axes of these ellipses are mostly aligned parallel to the gradient of the bathymetry profiles. For the eastern side of the Moyston fault, the observed minimum phases exceeding 45˚, indicate conductivity increases with depth beneath the Lachlan orogeny up to 500s. The major axes of ellipses to the east of the Moyston fault are either perpendicular to the gradients of the bathymetry profiles or are parallel to the NW-SE Mesozoic-Cenozoic fracture zones, which coincides with the highest density of eruptions of volcanoes field (Lesti et al., 2008).

Figures and Tables

Figure 1. Phase tensor ellipses and induction arrows of observed data at periods of 50 s to 1000 s on top of TMI (total magnetic intensity) data. The filled colours are minimum phases calculated from Caldwell et al. (2004).



CONCLUSIONS

Dimensionality analysis and forward modelling shows that the ocean have the most profound effect 50 km inland from coastline of Victoria and 130 km inland from South Australian coastline. The effect of Otway basin sediments is observable only for the south western part of the survey. Forward modelling shows that the southward rotation of the induction vectors with increasing period, is associated with coupling between the ocean and the lithospheric mantle beneath the Lachlan Orogeny. Forward modelling results suggest that the lithosphere beneath the Lachlan orogeny is more conductive than the Delamerian counterpart, which is in agreement with the eastward transition of seismic velocities from high to low velocities, respectively. The phase tensor analysis illustrates that there is an increasing conductivity trend beneath the Central Highlands, observed up to 500s and is perhaps associated with the NVP volcanism. Furthermore, the geoelectric strike direction of the Central Highlands is aligned parallel to the NW-SE Mesozoic-Cenozoic fracture zones, which coincides with the highest density of eruptions of volcanoes.

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