MT Traversing the Delamerian and Lachlan Orogens of Victoria to illuminate geological structures, fossil fluid pathways and serpentinisation

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Summary

We have used the passive geophysical method of magnetotellurics (MT) to image the crust and upper mantle beneath the Delamerian and Lachlan Orogenies, in Victoria, Australia. Three broadband (0.001-2 000 s) MT transects collected over this region in the last few years (Dennis et al., 2012 in the east, Robertson et al., 2014 in the west, and Stepan, 2014 in the centre) are joined together to create a 450 km east-west traverse following deep crustal seismic lines collected in 2006-2011 (Cayley et al., 2011, Cayley et al., in prep). The transitional boundary between the orogens runs along the Stawell Zone (Miller et al., 2005) with geochemistry suggesting this region changed from being an extended continental passive margin during the Proterozoic (Gibson et al., 2015) into an Andean-style margin in the Cambrian (Kemp 2003; Foden et al., 2006) - see geological evolution section.

Mineralised copper porphyry prospects were discovered in the Grampians-Stavely Zone in the 1970s—late 1990s (Rajagopalan, 1999) which is above this possible subduction zone. Lack of confidence about the geological setting, poor exposure and deep weathering meant that the initial discovery of shallow propylitic alteration was never followed up with deeper drilling for potentially better mineralized potassic alteration. The fact that Andean style subduction margins can host large deposits provides a good economic reason for better understanding the geological evolution of this region- and the porphyries.

From the mid crust and into the mantle, the MT phase tensor ellipses show a distinct change in resistivity structure from west to east between the Delamerian and Lachlan Orogens at mid crustal to shallow upper mantle depths—see mortlake discontinuity section. This phase tensor change matches the location of the Mortlake Discontinuity which was defined as a change in the Sr and Pb isotope chemistry of Pliocene to Recent intraplate basalts that erupted across this region as the Newer Volcanics. The difference in isotopes was interpreted as reflecting differences in either the geochemistry of the mantle source of the basalts (Price et al., 1997) or the degree of crustal contamination. As we observe a distinct mantle change in the electrical resistivity structure at the Mortlake Discontinuity, we support the differing mantle sources hypothesis. Do these mantle differences exist because the Delamerian was a region of thinned Proterozoic continental lithosphere whilst the western Lachlan was floored by (now deformed) Cambrian oceanic lithosphere? Results of 2D inversions along the MT profile (see Figure 5) reveal that the mantle under the Stawell Zone is more conductive. Within the 100 km depth resolution of the MT, this conductive zone appears to dip westward as would be expected for the Cambrian subduction zone. Conductive pathways emanate off this conductive zone up into the crust. The greatest conductivity in these pathways occurs in the mid crust, which is shown by rock slivers in major faults and high reflectivity in the seismic to consist of mafic rocks. Perhaps these pathways mark fossil alteration zones associated with dehydration and slab-fluxed fluid melts generated from the subducted slab. In modern subduction zones, serpentinisation of mafic rocks by fluid flux is documented to create significant conductivity—like that seen in our profile—through the interconnection of magnetite that can increase by shearing —see crustal conductors section. This MT work provides another data set that continues to support the geological model for west dipping subduction under the Grampians-Stavely region during Cambrian deformation of southeastern Australia.

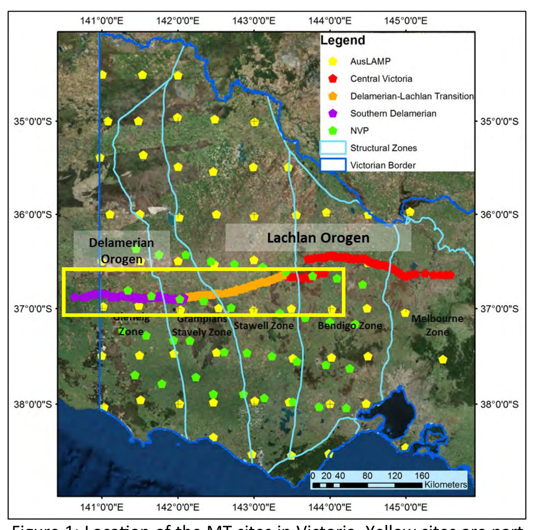

Figure 1: Location of the MT sites in Victoria. Yellow sites are part of the Australia-wide AusLAMP project involving collection of long -period (deep sounding) MT data every 0.5 degrees. All sites shown are used in Figure 3, and only the sites in the yellow box are used in the inversion shown in Figure 5.

Geological Evolution

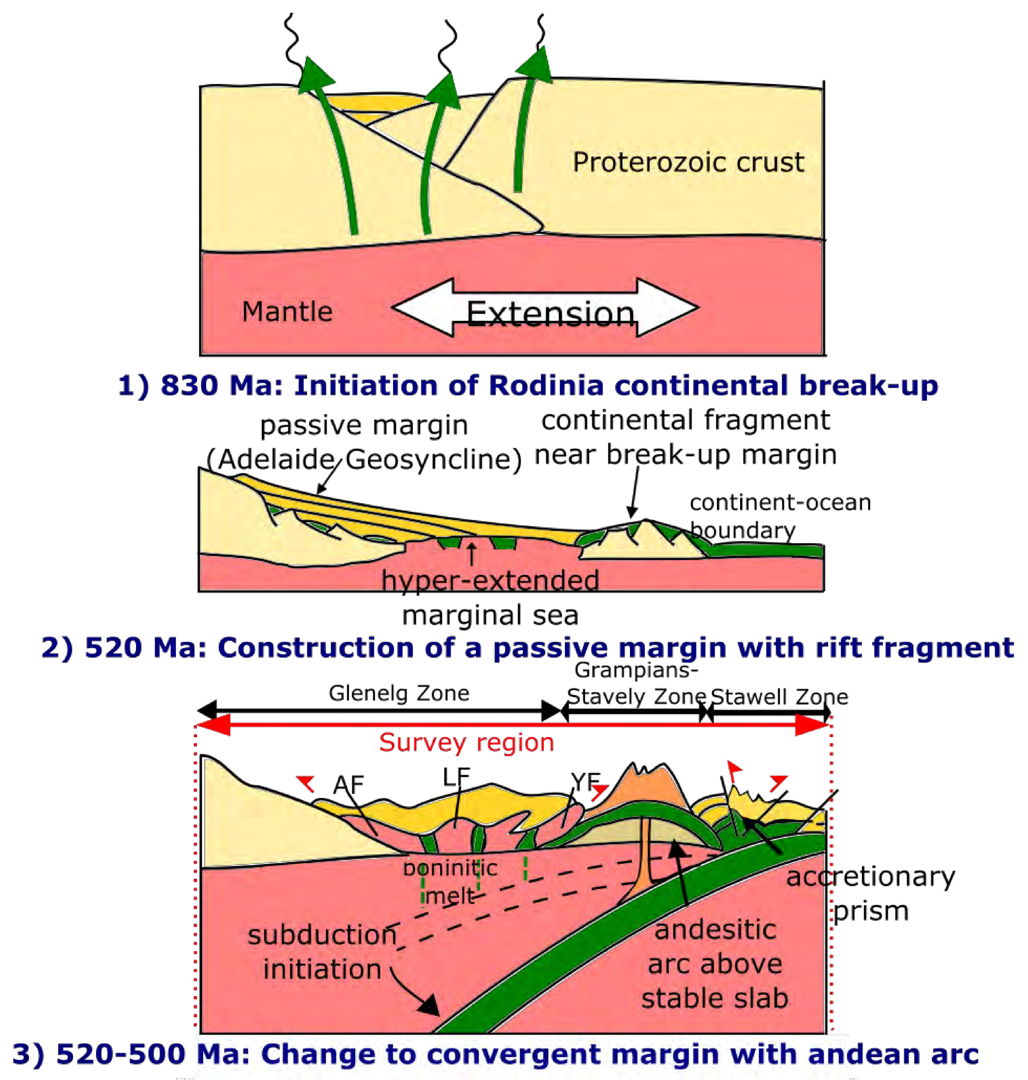

Figure 2: Schematic Geological evolution cartoon for the survey region showing the changed from an extended passive margin in the Proterozoic into a shortened convergent margin in the Cambrian

Mortlake Discontinuity

Phase tensor ellipses show a large change from west to east across Victoria. Red shades indicate conductive over resistive material, and green shades indicate resistive over conductive material. The change in resistivity matches the location of the Mortlake Discontinuity (MD) that was delineated by a change in lead and strontium isotopes geochemistry of young, Newer Volcanic basalts erupted across the region. This was attributed to a change in the mantle source of the basalts either side of the MD (Price et al., 1997).

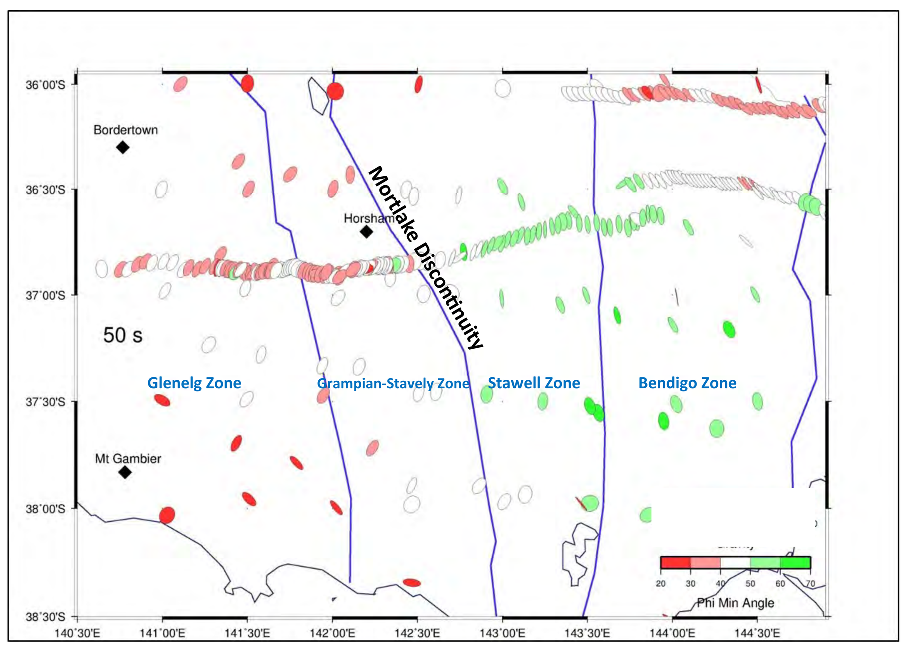

Figure 3: A distinct change in phase tensor ellipses occurs across the Mortlake Discontinuity. An ellipse is shown for each MT site, at a period of 50 s, which corresponds to mid crustal depths. We observe these trends to longer periods (~200 s), suggesting the change in resistivity structure continues in the upper mantle beneath the boundary of the Delamerian and Lachlan Orogens.

Crustal Conductors

The resistivity profile shows that most of the crust is generally resistive (blue). Several conductive pathways (red) appear to originate from the mantle and move up into the crust, often along major faults as interpreted from deep reflection seismic surveys. In modern subduction settings, a similar phenomenon has been observed and are interpreted to represent subduction associated fluids moving up into the crust and serpentinising mafic rocks. As magnetite grows in the alteration assemblage, conductivity increases. A further increase in conductivity occurs if grains become interconnected by shearing.

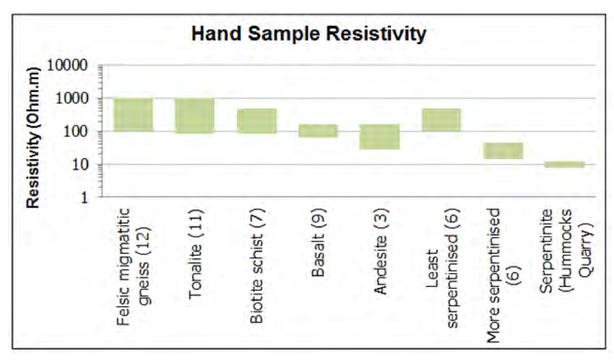

Figure 4: A table showing the range of conductivity in the main rock types present in the survey region (number in bracket is the VIMP drill hole number providing the fresh core). Interconnected magnetite in serpentinised mafic rocks increases conductivity and the degree of interconnectivity of this magnetite can be increased with shearing to significantly enhance conductivity.

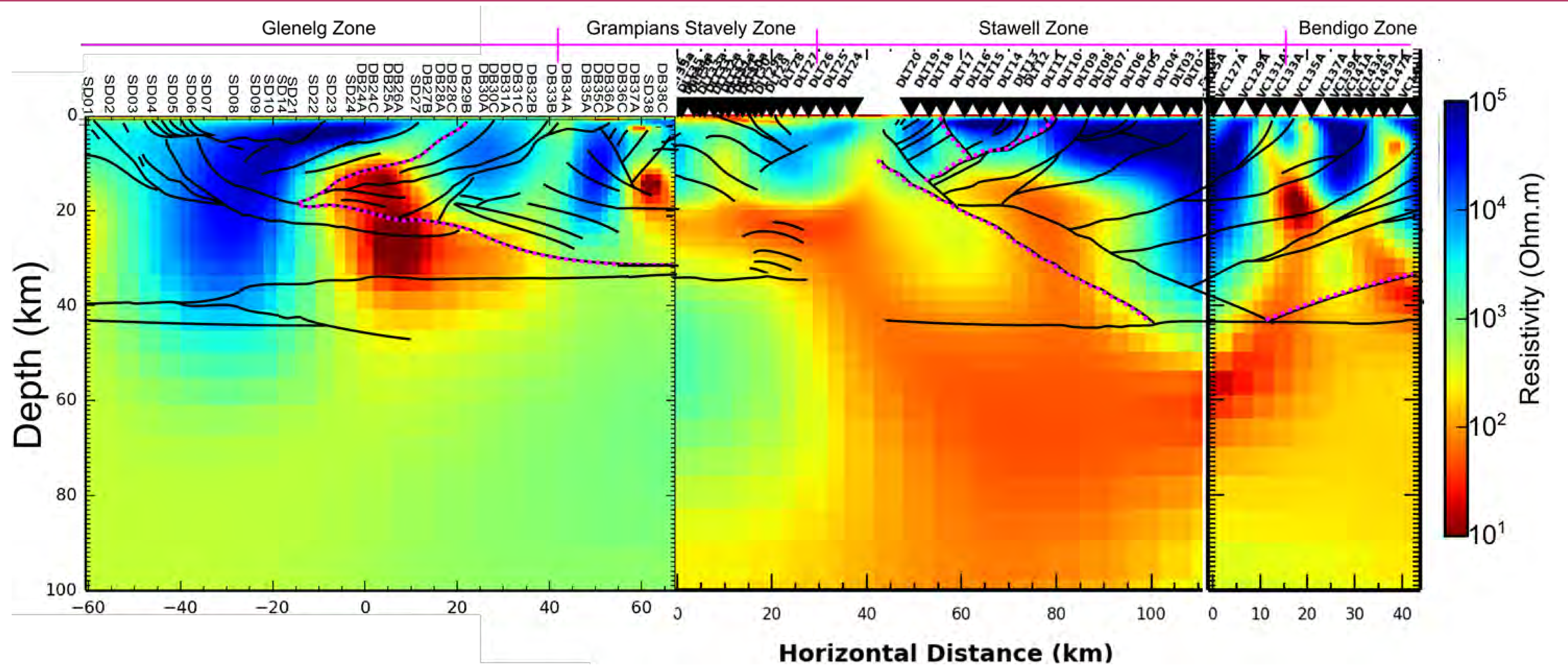

Figure 5: Electrical resistivity slice from the surface to 100 km depth, along the profile of sites in the yellow box from Figure 1. Black lines are faults interpreted from deep reflection seismic surveys (Cayley et al., 2011). Red indicates conductive regions, blue are resistive.

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