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Crust and upper mantle structure beneath southeast Australia from ambient noise and teleseismic tomography

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A B S T R A C T

In the last decade, the lithospheric structure beneath southeast Australia has been intensively studied using passive seismic data from WOMBAT, the largest transportable seismic array in the southern hemisphere. The two primary imaging methods that have been applied are ambient noise tomography for the crust and teleseismic tomography for the upper mantle. Despite these recent studies, no attempt has yet been made to provide an integrated view of the crust–mantle system. Here, we perform teleseismic tomography using WOMBAT data that includes a detailed crustal model from ambient noise tomography in the starting model. A Moho surface from the Australian seismological reference Earth model (AuSREM) is also included. This has the dual benefit of accounting for the unresolved crustal component of the teleseismic arrival time residuals, and producing a model that reveals a high level of detail in both the crust and upper mantle. Our new integrated P-wave model contains a number of noteworthy features, including (i) low velocity anomalies in the lower crust and high velocity anomalies in the lithospheric mantle beneath the Gawler Craton and Curnamona Province, which are of Paleoproterozoic–Archean origin; (ii) a marked velocity transition in the crust and lithospheric mantle near the Moyston Fault, which we interpret as the boundary between the Lachlan and Delamerian orogens; (iii) a rapid eastward decrease in upper mantle velocity ~200 km inboard of the east coast of Australia, which is consistent with a marked thinning of the lithosphere; (iv) an increase in upper mantle velocity north of the Gawler Craton and Curnamona Province, which points to the presence of thicker lithosphere associated with the Precambrian shield region of the Australian continent; (v) Cenozoic intraplate basaltic volcanic centres distributed exclusively above the zone of thinner lithosphere inboard of the east coast, with the exception of low volume leucitite volcanics.

1. Introduction

The Tasmanides of eastern Australia is a complex series of Palaeozoic to early Mesozoic orogens that is juxtaposed against the eastern margin of the Precambrian shield region of central and western Australia (Foster et al., 2005; Glen et al., 2009; Cayley, 2011; Glen, 2013). The subduction–accretion process was accommodated by retreat of the proto-Pacific plate along the eastern margin of Gondwana, which incorporated both Australia and Antarctica. Despite a protracted period of plate convergence, the orogenic process in the Pacific has not been terminated through continent–continent collision, as would be the case if it conformed with the classic Wilson Cycle of continent break-up and reassembly (Cawood, 1982).

The traditional division of the Tasmanides is into four separate orogenic belts (Fig. 1), the Delamerian, Lachlan, Thomson and New England orogens (e.g. Glen, 2005; Fergusson and Henderson, 2015). The Delamerian Orogen is the oldest and includes the Tyennan Orogen of western Tasmania, which is floored by Precambrian basement (Calvert and Walter, 2000). The relationship between the Lachlan and Thomson orogenies has been difficult to ascertain, partly because of the masking effect of the Mesozoic Murray Basin (Fig. 2) and the Mesozoic Eromanga Basin further north. However, recent evidence from deep seismic reflection profiling and forward modelling of gravity and aeromagnetic data suggests that they are both largely built on Palaeozoic oceanic crust and have a shared history from the mid-Silurian to the Carboniferous (Glen et al., 2013). The New England Orogen is the eastern-most and youngest fold belt of the Tasmanides, and formed as an east-facing convergent margin orogen between the Late Devonian and Triassic (Glen, 2005; Rosenbaum et al., 2012). Its relationship with the Lachlan Orogen remains somewhat equivocal due to the presence of post-emplacement sedimentary cover (Bowen, Gunnedah and Sydney Basins), but there is evidence of a shared Cambrian and Ordovician history (Glen, 2013).

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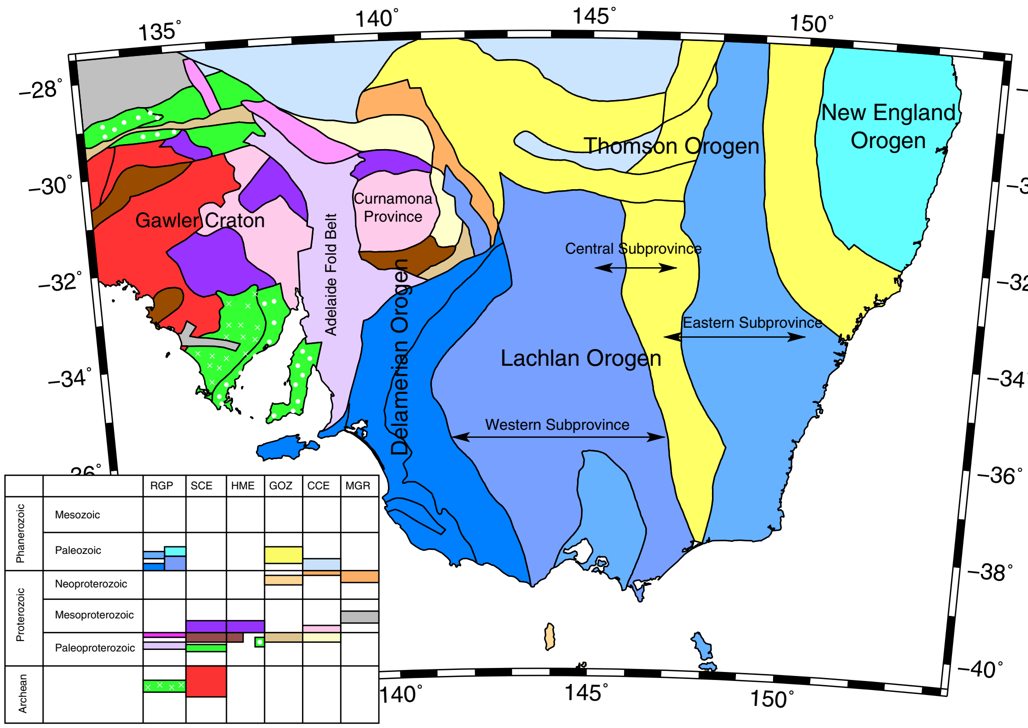

Fig. 1. The crustal elements of southeast Australia, inferred from potential field data, (see Shaw et al., 1996, for more details). RGP = relict geophysical pattern; SCE = standard crustal element; HME = highly magnetic element; GOZ = geophysically overprinted zone; CCE = covered crustal element; MGR = sub-element with muted geophysical response.

As noted by Glen (2013), accretionary orogens are not only characterised by the inclusion of oceanic crust, island arcs and sedimentary terranes, but also the embedding of continental fragments. A number of studies have pointed to the possible presence of fragments of Precambrian continental crust of Rodinian origin within the Tasmanides (Scheibner, 1989; Cayley et al., 2002; Cayley, 2011; Glen et al., 2013). The so-called Selwyn Block (Fig. 2), which is postulated to be a Proterozoic microcontinental block that lies beneath central Victoria, is thought to be part of a much larger fragment of Rodinian continent that extends southward and forms the Proterozoic core of western Tasmania (Cayley et al., 2002; Cayley, 2011). In a recent paper, Moresi et al. (2014) use 3-D geodynamic modelling to suggest that this continental fragment

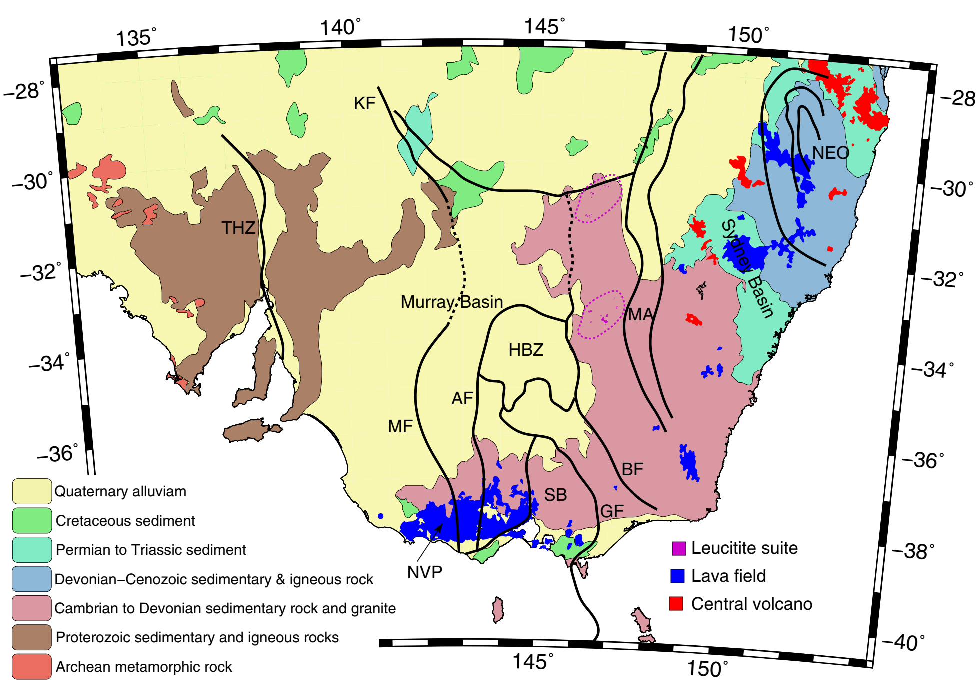

Fig. 2. Simplified geology map of southeast Australia. Cenozoic intraplate volcanic outcrop is denoted by red (central volcanos), blue (lava fields) and magenta (leucitite). In the latter case, locations are highlighted by dashed magenta circles. Thick black lines show the locations of major structural boundaries. AF = Avoca Fault; BF = Bootheragandra Fault; GF = Governor Fault; HBZ = Hay-Booligal Zone; KF = Koonenberry Fault; MA = Macquarie Arc; MF = Moyston Fault; NEO = New England Orogens; NVP = Newer Volcanics Province; SB = Selwyn Block; THZ = Torrens Hinge Zone.