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Imaging crustal structure variation across southeastern Australia

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ABSTRACT

A broad-band seismic network of 28 three-component seismometers was deployed in southeastern Australia to examine variations in crustal thickness across the transition between Precambrian and Phanerozoic lithosphere. Receiver function observations and modelling of *P*-to-*S* conversions at the Mohorovičić discontinuity (Moho) have been employed to investigate: (i) the variations in the Moho depth across southeastern Australia, and (ii) the nature of the transition between crust and mantle. Data from temporary deployments were used together with data from the few permanent broad-band stations in the region. The extraction of *P*-receiver functions from high-quality seismic data recorded on these stations has enabled the determination of the crustal thickness across the region. The crustal thicknesses lie in the range 28–48 km. The Moho depth is generally well correlated with the Earth surface elevation in the southeastern Australia. The Moho estimates from receiver functions are in good agreement with results from reflection profiling. The average crustal thickness is found to be around 39 km beneath the Precambrian area in the west and even thicker beneath the Lachlan Orogen in the east (~43 km). The average crustal thickness in between, beneath the Murray Basin is thinner ~32 km. Interestingly, the crust in the Mount Gambier volcanic area is rather thick ~41 km, suggesting that the limit between the Delamerian and western Lachlan orogens is located east of Mount Gambier. Our results favour a position for the Tasman Line generally consistent with the interpretation by Direen and Crawford (2003) and thus to the east of the location favoured by many authors. The broader crust–mantle transition and thicker crust beneath the Lachlan Orogen suggest the presence of magmatic underplating at the base of the lower crust. The intermediate nature of the crust–mantle transition also suggests magmatic underplating beneath the Gawler Craton and the Curnamona Province.

1. Introduction

The crustal structure (crustal thickness and nature of the basement) of tectonic units is not well constrained in southeastern Australia due to the presence of sedimentary rocks and of thick regolith across most of the surface. Although active seismology can provide the most reliable and detailed information on crustal architecture, such information is confined to limited regions. A complementary source of information comes from passive seismic techniques such as receiver functions utilised in this study.

The Gawler Craton contains less than 5% basement exposure in an area of roughly 530,800 km^2 (Payne et al., 2009). Unravelling the nature of the crustal structure and the lateral extent of crustal provinces is necessary to improve understanding of the evolution of southeastern Australia. The primary aim of this study is therefore to investigate the lateral variation of crustal structure and nature of the crust to mantle transition between the Precambrian and Phanerozoic belts of southeastern Australia in a corridor extending from the Gawler Craton to the east coast of Australia.

Since 2004 more than 7000 km of full-crustal reflection profiles has been collected across Australia providing information on the variation in Moho depth. However, the estimates of crustal thicknesses based on reflection data rely on a simple assumption of an rms velocity of 6 km/s at the base of the crust (e.g. Drummond et al., 2006; Kennett et al., 2011). The secondary goal of our study is therefore to calibrate Moho depth estimates from recent seismic reflection profiles carried out in southeastern Australia (Cayley et al., 2011; Drummond et al., 2006; Fraser et al., 2010; Preiss et al., 2010) using our receiver function measurements, which are particularly sensitive to the gradients in seismic velocities.

1.1. Tectonic setting

The Lachlan Orogen in southeastern Australia (Fig. 1b) was accreted to the Precambrian core of the continent in a sequence of stages (e.g., Braun and Pauselli, 2004; Cayley, 2011; Collins, 2002; Direen and Crawford, 2003; Gray and Foster, 2004). We show in Fig. 1 a

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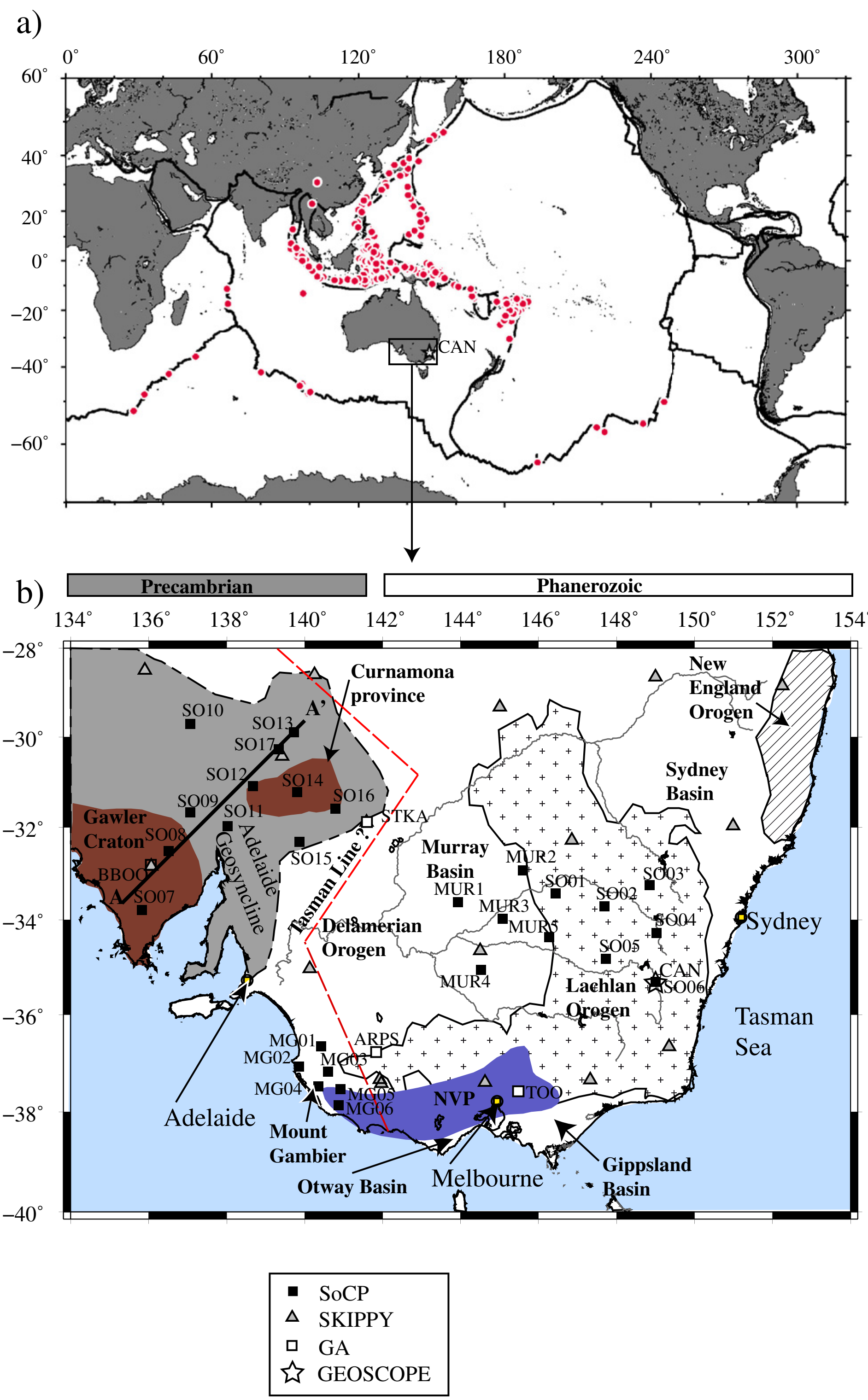

Fig. 1. a) Location of the 323 events used for receiver function (RF) analysis at station CAN. b) Simplified geological map of southeastern Australia modified from Gray and Foster (2004) with the location of the SoCP seismic network and the permanent seismic stations from Geoscience Australia (GA) and GEOSCOPE networks. Key to marked feature: NVP, Newer Volcanic Province. The red dashed line shows the location of the Tasman Line based on the reinterpretation of Direen and Crawford (2003). The line AA′ is shown in Fig. 6.

simplified model of a geological map for southeastern Australia. The map area is separated in two parts: (i) the western part formed by Precambrian units: the Gawler Craton, the Curnamona Province and the Adelaide Geosyncline and (ii) the younger eastern part with Phanerozoic terranes. The Gawler Craton contains Archean–early Palaeoproterozoic supracrustal and magmatic lithologies, which are surrounded, overlain and intruded by Palaeoproterozoic (2000–1610 Ma) to Mesoproterozoic (1590–1490 Ma) units (e.g. Payne et al., 2009). The basement of the Curnamona Province is of late Palaeoproterozoic age. Palaeozoic deformation affected the marginal