Illuminating the upper mantle beneath the Newer Volcanics province, southeast Australia, using seismic body wave tomography

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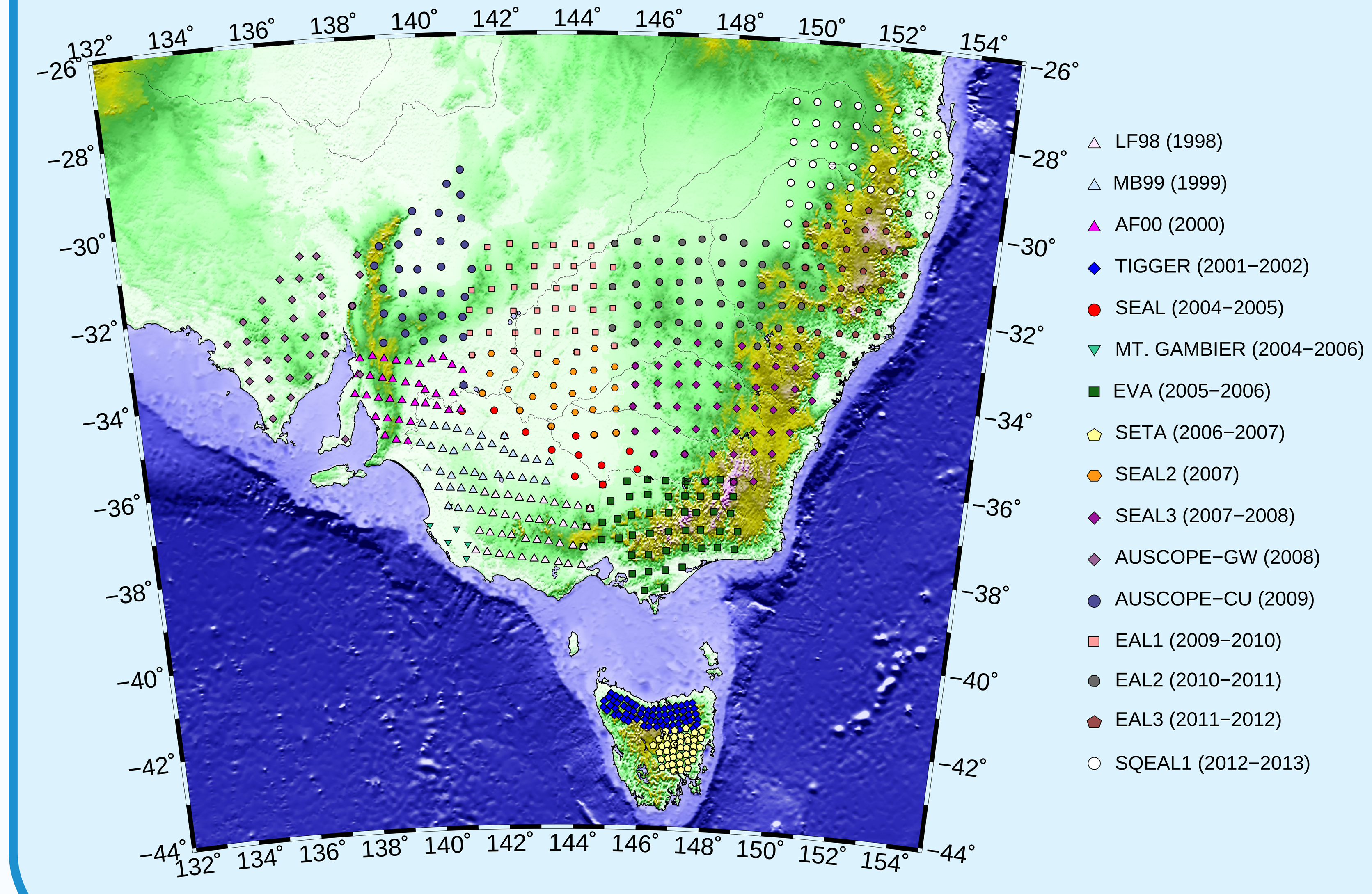
Introduction

Since 1998, a series of passive seismic array deployments has taken place in southeast Australia, resulting in an unprecedented coverage of approximately 650 seismic stations throughout Tasmania, Victoria, New South Wales, South Australia and Queensland. The large volumes of data recorded from teleseisms, atmospheric and oceanic disturbances, and local earthquakes, have enabled the crust and upper mantle beneath southeast Australia to be imaged in great detail.

Wombat experiment

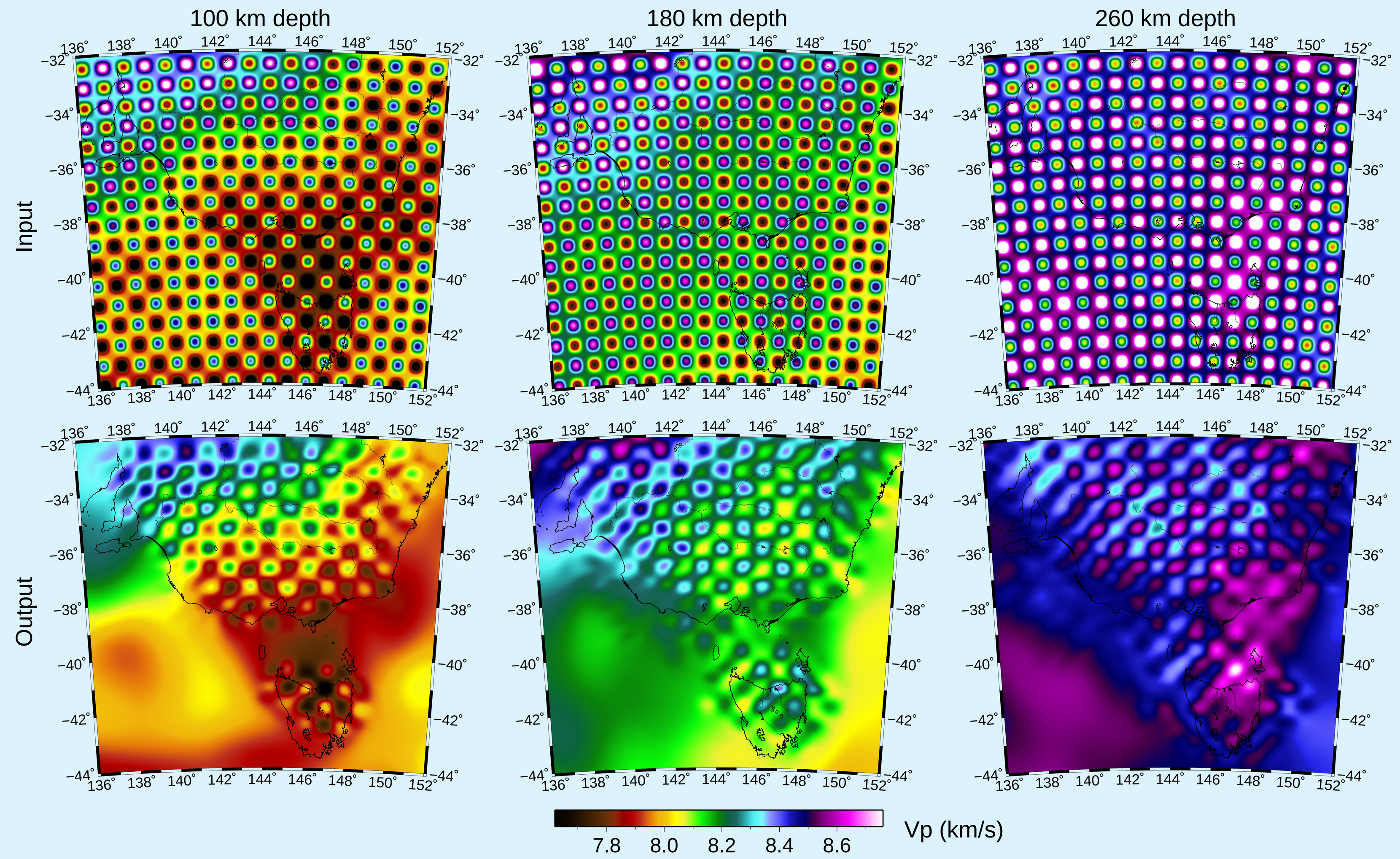


Newer Volcanics province

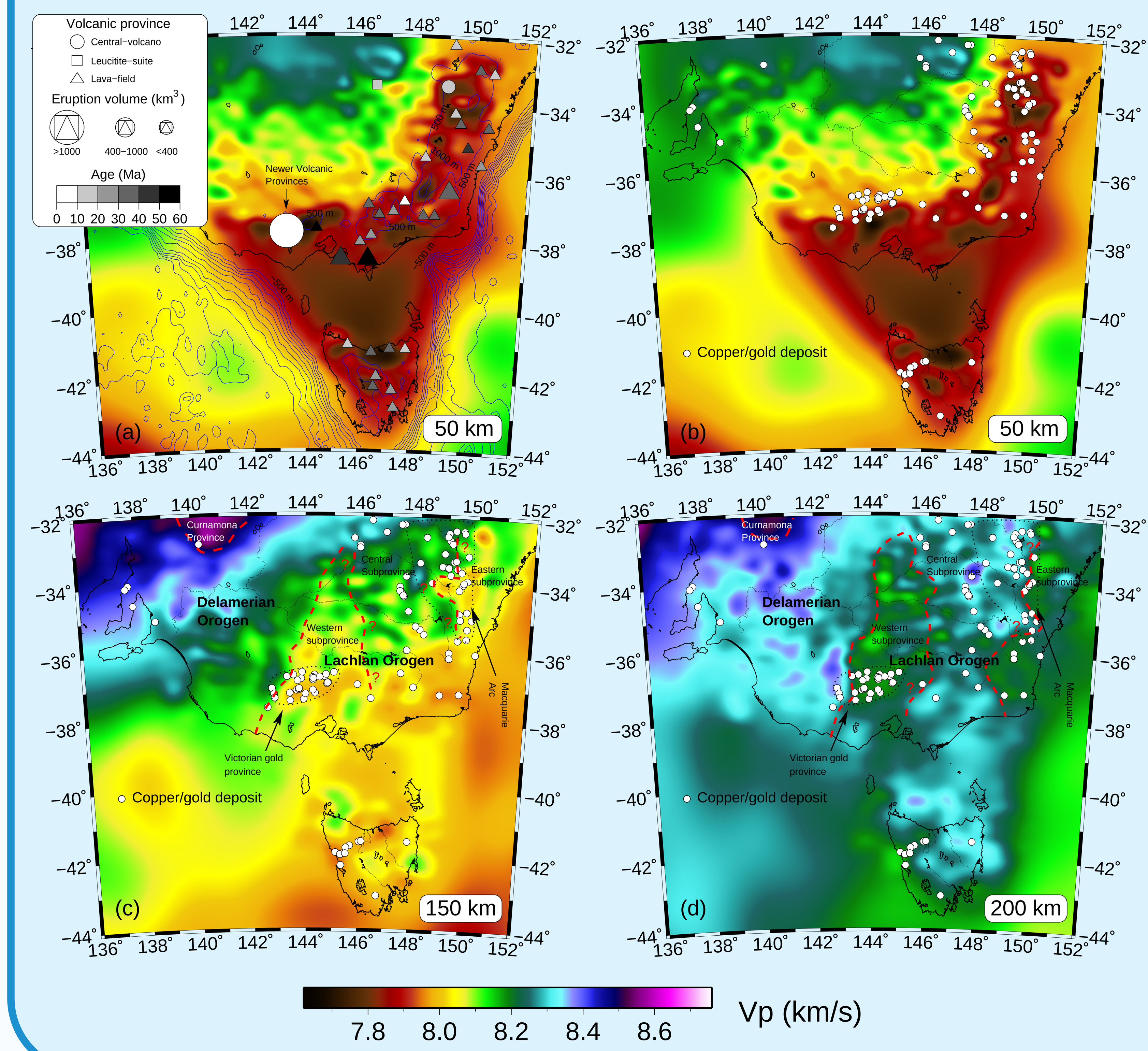
The Newer Volcanics province (NVP), located in the state of Victoria, represents the youngest evidence of basaltic intraplate volcanism in the Australian continent, with the most recent eruptions dated less than 5ka. Although one of many Cenozoic eruption centers that populate the eastern edge of the Australian mainland, the NVP is unique in that it is not obviously part of a hot-spot chain. For example, the distribution of NVP eruption centres is elongated in the east-west direction, perpendicular to plate motion. Moreover, it appears that the NVP is the latest phase of an eruption cycle that has operated intermittently since the early Eocene when fast northern motion of the Australian continent commenced. Coupled with modest surface topographic response (∼100 m) and a relatively low eruption volume (∼20,000 km^3) researchers have begun to suspect that the source of the NVP does not fit the mold of a traditional mantle plume model, but instead may be a phenomenon localised to the upper mantle.

Teleseismic tomography

We jointly invert teleseismic arrival time residuals from a subset of the mainland arrays for the 3-D P-wave structure of the lithosphere beneath southeast Australia. The plot below shows the result of a checkerboard reconstruction test.

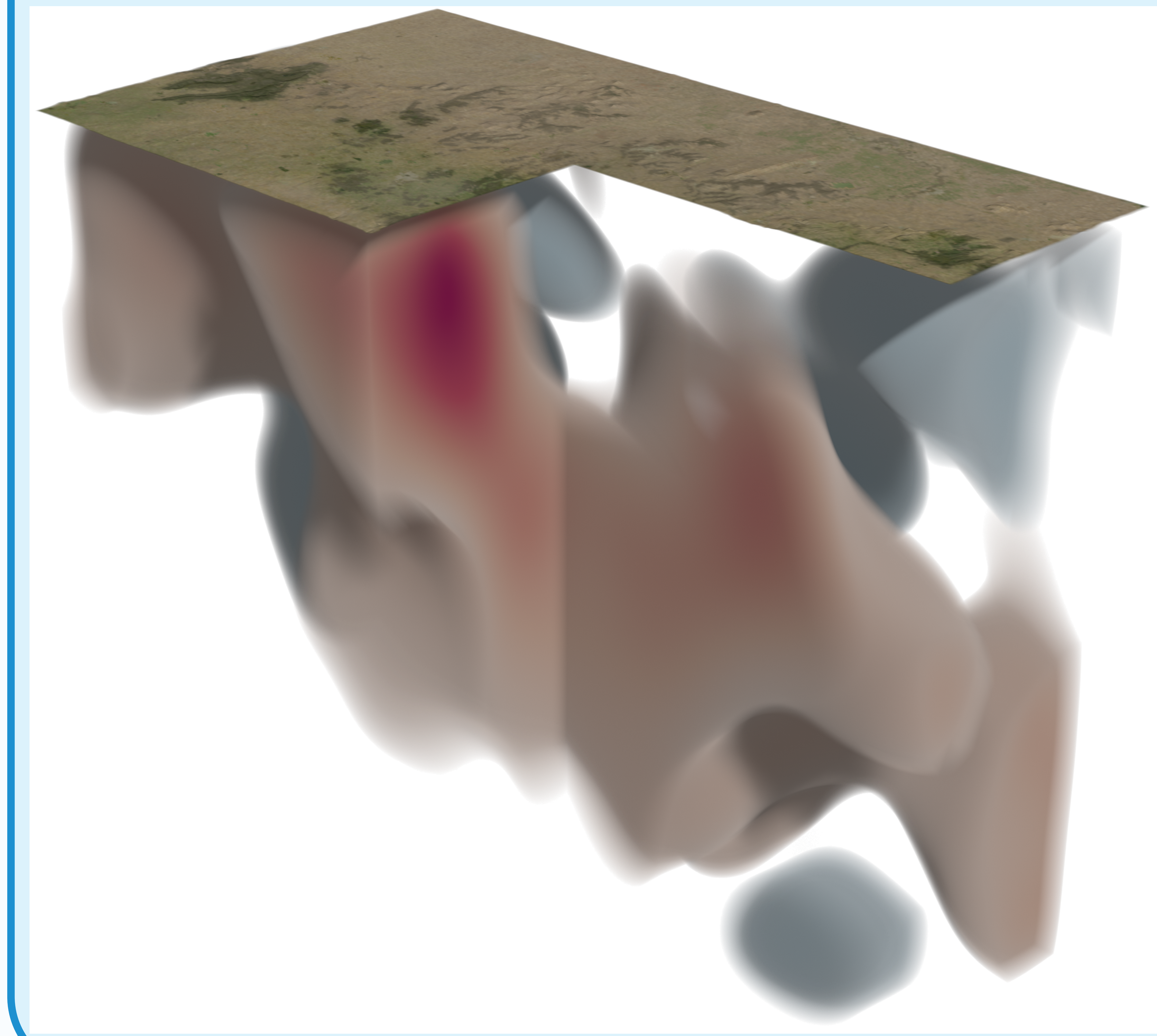


The final results presented below superimpose various information, including the location of Cainozoic volcanic centres, known copper/gold deposits, topography and interpreted boundaries.



The mantle beneath the NVP

The final P-wave velocity model shows a clear zone of low velocity underlying the NVP (maximum perturbation of -4% relative to AK135). It clearly extends to a depth of just over 200 km, before terminating, with no evidence of reduced velocities down to approximately 300 km, the maximum depth resolution of the seismic data.



Conclusions

The lack of evidence for a deep seated anomaly is consistent with the hypothesis that the source of the NVP is confined to the upper mantle, although an important caveat is that plumes are expected to be narrow as they rise through the mantle before broadening out as they encounter the base of the lithosphere; as such, it s possible that the limited spatial resolution of the data (approximately 50 km) is unable to detect narrow vertical structures at depth. However, combined with the observations discussed earlier, our results strengthen the argument for a localised upper mantle anomaly. One possible mechanism for such a phenomenon is edge driven convection, in which strong variations in lithospheric thickness coupled with the northward movement of the Australian plate periodically drives cells of warm, hydrous mantle upwards, resulting in the liberation of melt which then migrates to the surface.