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Localisation of edge driven convection beneath the Australian continent

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Mantle plumes are frequently invoked to explain the widespread occurrence of intraplate volcanism. However, many volcanic provinces do not conform to this paradigm and, hence, alternative explanations are required for a number of hotspots around the world. To date, these include: (i) lithospheric cracking; (ii) ductile removal of lithosphere via gravitational instability; (iii) glacial rebound; (iv) slab tear; (v) shear induced melting of the asthenosphere; and (vi) edge driven convection (EDC). In the latter case, a variety of studies have shown that a step change, or sharp transition in depth to the base of the lithosphere, drives a small-scale thermally induced convective instability, which can result in dynamic melting of upwelling mantle. However, intraplate volcanic centres in the vicinity of lithospheric steps (e.g. between continental shield regions and young lithosphere) only manifest at isolated locations, and show little tendency to elongate parallel to the lithospheric step, which might be expected for such a phenomenon.

The Newer Volcanics Province (NVP) in southeast Australia is the most recent example of intraplate volcanism on the Australian continent, with the last eruption dated at approximately 4.5 ka. It comprises over 700 eruption points with an east-west distribution, which is roughly perpendicular to current plate motion. The basaltic plains are generally less than 60 m thick, implying a low eruption volume, whilst topographic response is of the order of 100 m. Evidence for the mantle source of the NVP has so far been equivocal, but a general consensus is emerging that an underlying mantle plume is unlikely.

In this study, we present new 3-D teleseismic tomography results, which suggest that the source of the NVP is confined to the upper mantle. Motivated by these results, we use a new and detailed lithospheric thickness model of southeast Australia to examine the influence of out-of-plane variations in thickness on EDC, via geodynamical models. The main lithospheric step occurs to the north of the NVP, but strong variations are evident in the third dimension. Our results show that significant localisation and amplification of mantle upwelling occurs almost directly beneath the NVP, as a result of the out-of plane effects. Moreover, the inclusion of current plate motion in the calculations adds a shear component to the flow, which: (i) further localises the edge-driven cell to the uppermost mantle; and (ii) has the effect of subduing EDC along lithospheric steps that lie approximately parallel to plate motion. These results have significant implications for the study of intraplate volcanism in various parts of the world.