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The Effect of Plate Motion History on the Longevity of Deep Mantle Heterogeneities

Abigail Bull (1), Mathew Domeier (1), Trond Torsvik (1,2,3)

(1) University of Oslo, Centre for Earth Evolution and Dynamics, Virtual Earth, Norway (a.l.bull@fys.uio.no), (2) Geodynamics, Geological Survey of Norway, 7491 Trondheim, Norway, (3) School of Geosciences, Witwatersrand University, WITS 2050 Johannesburg, South Africa

Numerical studies of mantle convection have attempted to explain tomographic observations that reveal a lower mantle dominated by broad regional areas of lower-than-average shear-wave speeds beneath Africa and the Central Pacific. The anomalous regions, termed LLSVPs ("large low shear velocity provinces"), are inferred to be thermochemical structures encircled by regions of higher-than-average shear-wave speeds associated with Mesozoic and Cenozoic subduction zones. The origin and long-term evolution of the LLSVPs remains enigmatic. It has been proposed that the LLSVP beneath Africa was not present before 240 Ma, prior to which time the lower mantle was dominated by a degree-1 convection pattern with a major upwelling centred close to the present-day Pacific LLSVP and subduction concentrated mainly in the antipodal hemisphere. The African LLSVP would thus have formed during the time-frame of the supercontinent Pangea as a result of return flow in the mantle due to circum-Pacific subduction. An opposing hypothesis, which propounds a more long-term stability for both the African and Pacific LLSVPs, is suggested by recent palaeomagnetic plate motion models that propose a geographic correlation between the surface eruption sites of Phanerozoic kimberlites, major hotspots and Large Igneous Provinces to deep regions of the mantle termed "Plume Generation Zones" (PGZs), which lie at the margins of the LLSVPs. If the surface volcanism was sourced from the PGZs, such a link would suggest that both LLSVPs may have remained stationary for at least the age of the volcanics. i.e. 540 Myr. To investigate these competing hypotheses for the evolution of LLSVPs in Earth's mantle, we integrate plate tectonic histories and numerical models of mantle dynamics and perform a series of 3D spherical thermochemical convection calculations with Earth-like boundary conditions. We improve upon previous studies by employing a new, TPW-corrected global plate motion model to impose surface velocity boundary conditions for a time interval that spans the amalgamation and subsequent break-up of Pangea. Our results are distinct from those of previous studies in several important ways: our plate model explicitly includes (i) absolute longitudinal reconstructions and (ii) TPW-correction, and (iii) our model extends back to the mid-Paleozoic (410 Ma). We find that, were only the Pacific LLSVP to exist prior to the formation of Pangea, the African LLSVP would not have been created within the lifetime of the supercontinent. We also find that, were the mantle to be dominated by two antipodal LLSVP-like structures prior to the formation of Pangea, the structures would remain relatively unchanged to the present day and would be insensitive to the formation and break-up of the supercontinent. Our results suggest that both the African and Pacific LLSVPs have remained close to their present-day positions for at least the past 410 Myr.