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'Top-down' Intra-plate Volcanism: Present-day Hotspot Locations Controlled by Ancient Subduction

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Hotspots are anomalous regions of volcanism at Earth's surface that are widely regarded as the surface expression of mantle plumes: upwellings of abnormally hot rock from Earth's deep mantle. Their geographical distribution, therefore, provides a unique constraint on the nature of lower mantle dynamics. Recent studies propose that hotspots, and the reconstructed eruption sites of large igneous provinces, preferentially occur above the margins of two deep mantle large low shear-wave velocity provinces (LLSVPs) beneath Africa and the Pacific, which are widely believed to represent hot, but dense, thermo-chemical 'piles'. This correlation is interpreted to imply that 'piles' are long-lived, stable features, which have strongly influenced mantle dynamics and surface tectonics over several hundred million years (Myr). However, here, we re-analyse the correlation between hotspot locations and LLSVP margins, demonstrating that it has previously been overstated: it is strong for the African domain, but weak in the Pacific. We perform a similar analysis for an isochemical global mantle convection model, in which the distribution of heterogeneity is dictated by 200 Myr of assimilated plate motion histories. This 'top-down' tectonic model reproduces the observed geographical variability in correlation, in the absence of chemical 'piles'. Regional subduction history shapes a rounded Pacific LLSVP and an elongated African LLSVP and, consequently, due to the geometry of the latter, higher concentrations of plumes are generated close to its margin. Our results imply an intimate association between present-day hotspot locations and ancient subduction. They do not rule out the possibility that LLSVPs contain a dense chemical component, but suggest that, if present, chemical 'piles' play only a secondary role in dictating the form of mantle dynamics. This calls into question the stability of deep mantle LLSVPs on time-scales exceeding the 200-300 Myr subduction-Wilson cycles.