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A geodynamic model of plumes from the margins of Large Low Shear Velocity Provinces

Bernhard Steinberger[1,2], Trond H. Torsvik[2,3,4]
[1] *Section 2.5, GFZ German Research Centre for Geosciences, Potsdam, Germany*
[2] *Physics of Geological Processes, University of Oslo, Oslo, Norway*
[3] *Centre for Geodynamics, Geological Survey of Norway, Trondheim, Norway*
[4] *School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa*
bstein@gfz-potsdam.de

Large Igneous Provinces (LIPs) are commonly assumed to be caused by plumes forming in the thermal boundary layer (TBL) above the core-mantle boundary. Eruption sites of most LIPs as well as kimberlites during the last few hundred Myr lie — like many present-day hotspots — above the margins of the two Large Low Shear Velocity Provinces (LLSVPs) of the lowermost mantle. The African and Pacific LLSVPs are probably chemically distinct from and heavier than the overlying mantle. Geodynamic models explaining why plumes are almost exclusively created at these margins are only beginning to evolve [1]. Here we present a model that provides an explanation and is based on subduction locations and fluxes inferred from global plate reconstructions [2-4] and ocean floor paleo-ages [5].
Sinking subducted slabs not only form a heavy chemical layer to dome-shaped structures that resemble the two LLSVPs in size and shape, but also push the TBL towards the chemical domes. At the steep edges it is forced upwards and begins to rise — in the lower part of the mantle as sheets, which then split into individual plumes higher in the mantle. Plumes preferentially form at corners, and locations of model plumes partly resemble those of actual plumes – Hawaii at the northern corner of the Pacific dome, Iceland at the northwestern corner of the African dome, Kerguelen at its southeastern corner. Plume conduits tend to get tilted – with bases moving towards the centers and tops remaining closer to the margins of domes. Occasionally subduction moving towards the Pacific dome erodes off parts of it, and plumes become separated or form above a separated part. One of those split-off plumes might correspond to the Columbia River Basalts/Yellowstone plume, another one to a smaller LSVP and possibly plume beneath Russia and Kazakhstan. Our model supports that mantle plumes are more intimately linked to plate tectonics than commonly believed. Not only can plumes cause continental break-up, but conversely subducted plates may trigger plumes at the margins of LLSVPs near the CMB.

References

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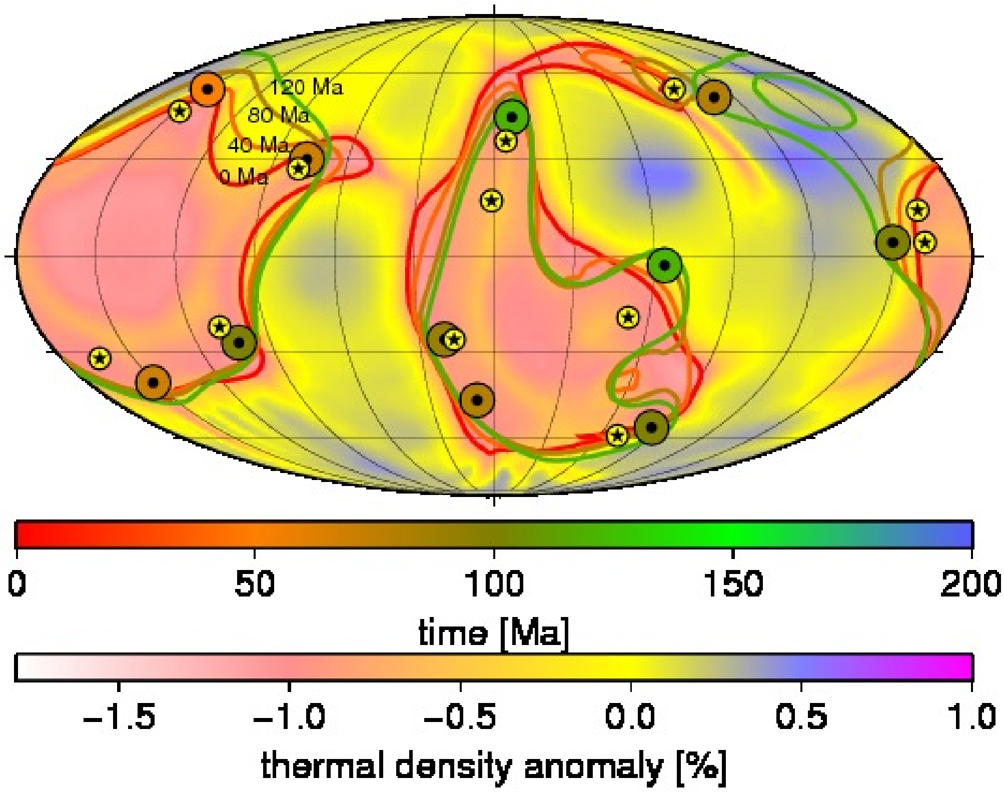

Figure 1: Top left: Viscosity structure used [6] for convection computation. Top right: Distribution of slabs, plumes and chemical "domes" in the mantle at 50 Ma. CMB thermal density contrast -1.2%; chemical anomaly 2.3%; compressible flow computation. Map view centered on Greenwich with "slabs" plotted whenever at a given depth (represented by color) positive thermal density anomalies exceed +0.2%, and "plumes" when negative thermal anomalies exceed -0.25%. Bottom left: Computed present-day positions of upwellings close to the surface ("hotspots"; yellow circles with stars) and positions where plumes initially reach the surface ("LIPs"; colored circles with time corresponding to color). Bottom right: "Real Earth" for comparision: Present-day hotspots and reconstructed LIPs [7] plotted together with LLSVPs according to the smean [8] tomography model.