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Coupled evolution of supercontinents and lower mantle structure

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The relationships between plate motions and basal mantle structure remain poorly understood, with some models implying that the basal mantle structure has remained stable over time, while others suggest that it could be shaped by the aggregation and dispersal of supercontinents. Here we investigate the plate-basal mantle relationship through 1) building a series of end-member plate tectonic models over one billion years, and 2) creating mantle flow models assimilated by those plate models. To achieve that, we build synthetic plate tectonic models dating from 1 Ga to 250 Ma that we connect to an existing palaeogeographical plate reconstruction from 250 Ma to create a relative plate motion model for the last 1 Gyr, in which supercontinent breakup and reassembly occur via introversion. We consider three distinct reference frames that result in different net lithospheric rotation. We find that the flow models predict a dominant degree-2 lower mantle structure most of the time and that they are in first-order agreement (~70% spatial match) with tomographic models. Model thermochemical structures at the base of the mantle may split into smaller structures when slabs sink onto them, and smaller basal structures may merge into larger ones as a result of slab pushing. The basal thermochemical structure under the superocean is large and continuous, whereas the basal thermochemical structure under the supercontinent is smaller and progressively assembles during and shortly after supercontinent assembly. In the models, plumes also develop preferentially along the edge of the basal thermochemical structures and tend to migrate towards the interior of basal structures over time as they interact with the slabs. Lone plumes can also form away from the main thermochemical structures, often within a small network of sinking slabs. Lone plumes may migrate between basal structures. We analyse the relationship between imposed tectonic velocities and deep mantle flow, and find that at spherical harmonic degree 2, the maxima of lower mantle radial flow and temperature follow the motion path of the maxima of surface divergence. It may take ~160-240 Myr for lower mantle structure to reflect plate motion changes when the lower mantle is reorganised by slabs sinking onto basal thermochemical structures, and/or when slabs stagnate in the transition zone before sinking to the lower mantle. Basal thermochemical structures move at less than 0.6 °/Myr in our models with a temporal average of 0.16 °/Myr when there is no net lithospheric rotation, and between 0.20-0.23 °/Myr when net lithospheric rotation exists and is induced to the lower mantle. Our results suggest that basal thermochemical structures are not

stationary, but rather linked to global plate motions and plate boundary reconfigurations, reflecting the dynamic nature of the co-evolving plate-mantle system.