How thermochemical piles initiate plumes at their edges

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Deep-rooted mantle plumes are thought to originate from the margins of the Large Low Shear Velocity Provinces (LLSVPs) at the base of the mantle. Visible in seismic tomography, the LLSVPs are often numerically modeled as dense and viscous thermochemical piles. Although the piles force lateral mantle flow upwards at their edges, it is not clear if, and how, plumes are predominantly initiated at the pile margins. In this study, we develop numerical models that show a series of plumes periodically rising from the margin of an approximately 300 km thick dense thermochemical pile, with each plume temporarily increasing the pile's local thickness to almost 370 km due to upward viscous drag from the rising plume. When the plume is pushed towards the pile center by the lateral mantle flow, the viscous drag on the dense material at the pile margin decreases and the pile starts to collapse back towards the core-mantle boundary (CMB). This causes the dense pile material to extend laterally along the CMB (about 150 km), locally thickening the lower thermal boundary layer on the CMB next to the pile, which initiates a new plume. The resulting plume cycle is reflected in both the thickness and lateral motion of the local pile margin within a few degrees of the pile edge, while the overall thickness of the pile is not affected. The frequency of plume generation is mainly controlled by the rate at which slab material is transported to the CMB, and thus depends on the plate velocity and the sinking rate of slabs in the lower mantle. Within Earth, this mechanism of episodic plume initiation may explain the suggested link between the positions of hotspots and Large Igneous Provinces (LIPs) and the LLSVP margins. Moreover, a collapse of the southeastern corner of the African LLSVP, and subsequent triggering of plumes around the spreading pile material, may explain the observed clustering of LIPs in that area between 95 and 155 Ma.