Intraplate volcanism and mantle stratification sustained by upwelings rising out of stagnant slabs

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The study of volcanism can further our understanding of Earth's mantle structure, dynamics and composition. Continental intraplate volcanism commonly occurs above subducted slabs that stagnate in the Mantle Transition Zone (MTZ), such as in Europe, eastern China, and western North America. Here, we use 2D numerical models to explore the evolution of stagnant slabs in the MTZ and their potential to sustain mantle upwellings that can support volcanism. We find [1] that weak slabs may go convectively unstable within tens of Myr. Upwellings rise out of the relatively warm harzburgitic underbelly of the slab, entrain small amounts of eclogitic crust and hydrated mantle rocks, and reach the base of the lithosphere, where decompression melting of entrained enriched lithologies may occur. These predictions can account for the geochmical characteristics of intraplate basaltic volcanism, e.g. in Europe and China.

Convective instability rising out of the slab also acts to separate the slab's components. Harzburgite tends to rise into the shallow mantle and eclogite to sink toward the base of the MTZ, and ultimately into the lower mantle. Such a process of "un-mixing" may sustain long-term mantle compositional stratification with mafic rocks enriched in the MTZ and lower mantle relative to pyrolite [2]. As an additional mechanism to sustain stratification, mantle plumes rising from the deep mantle may intermittently stagnate above the MTZ [3] (as evident by seismic tomography for the Hawaiian Plume [4]) and promote un-mixing. Combining 3D numerical models with seismic constraints from underside reflections, we show that eclogitic heterogeneity from the outskirts of the Hawaiian Plume tends to slowly sink to enhance the MTZ by eclogite, whereas the hot plume core tends to rise to sustain hotspot melting. As indicated by variable depths of slab stagnation, e.g. at ~1000 km depth, un-mixing of mantle heterogeneity can indeed sustain moderate compositional stratification, even in the presence of whole-mantle convection [2].

[1] Motoki & Ballmer (2015), *G-cubed* **16**, doi:10.1002/ 2014GC005608. [2] Ballmer *et al.* (2015), *Science Advances* **1**, e1500815. [3] Ballmer *et al.* (2013), EPSL 376, 155-164. [4] Cheng *et al.* (2015), *AGU Monograph* **208**, 19-34.