

Mantle melting and intraplate volcanism due to upwellings from the stagnant slab

The study of intraplate volcanism contributes to our understanding of mantle composition and dynamics. While the origin of oceanic intraplate hot-spot volcanism is rather well understood, the mechanisms that sustain continental intraplate basaltic volcanism remain controversial. In several regions (e.g. NE China, central Europe), such continental volcanism is associated with slab stagnation in the underlying mantle transition zone (MTZ). Here, we explore the role of the stagnant slab and of an associated hydrous layer in the MTZ on the formation and evolution of intraplate volcanism using two-dimensional numerical models. We explicitly account for the effects of mineral water on mantle density and melting behavior. Because of the intrinsic buoyancy of the hydrous layer atop of the stagnant slab, upwellings develop within a few million years and rise to ~410 km depth. At these depth, they lose some of their intrinsic buoyancy due to dehydration. However, they are readily entrained by small-scale sub-lithospheric convection to reach the base of lithosphere, and to support intraplate volcanism. The timing of upwelling and volcanism is controlled by mantle viscosity, as well as water content in (and thickness of) the hydrous layer. Water contents of ~2000 wt.-ppm (~0.2 wt.-%) in a ~40 km thick layer atop the slab are sufficient for early melting to account for the patterns of volcanism in e.g. NE China. We also explore effects of the lateral heterogeneity within the slab and find that any heterogeneity (e.g. subducted fracture zone) helps to advance upwelling and related volcanism. Our models with 2%~5% of basalt in the hydrous layer can account for the geochemical signatures of NE-China volcanoes, which indicate melting of two mantle components (EM1-like and HIMU-like). We conclude that an interaction between (bottom-up) self-buoyant upwelling of a hydrated MTZ and (top-down) sub-lithospheric small-scale convection can sustain mantle melting soon after the slab reaches the MTZ.