Non-hotspot volcano chains originating from small-scale sublithospheric convection

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Although most of the intraplate volcanism in ocean basins is expressed in linear chains, not all of these can be attributed to a stationary hotspot. Many ridges do not show a linear age-distance relationship predicted by the hotspot hypothesis – such as the Cook-Austal, Magellan or Line Islands, and Pukapuka ridges. Cracking of the lithosphere and small-scale sublithospheric convection (SSC) have been invoked to account for this type of volcanism. The former presumes a partially molten asthenosphere, whereas the latter has not yet been tested and validated in a numerical model.

In the Earth's uppermost mantle, SSC is likely to develop in the asthenosphere due to instabilities of the thickened thermal boundary layer below mature oceanic lithosphere. It is characterized by convective rolls aligning plate motion. They develop beneath young and thin lithosphere for low mantle viscosities (e.g. for hot or wet mantle) or adjacent to lateral density heterogeneity. In these cases, partial melt potentially emerges in the upwelling limbs of SSC after removing the bottom of the residue from previous ridge-melting. This mechanism is further complicated considering the intrinsic stiffness of this residue due to dehydration - causing a sharp and compositionally defined lithosphere/asthenosphere interface.

In this study, we take the step towards fully thermo-chemical 3D-numerical models of SSC with a realistic, temperature- and depth-dependent rheology in order to quantitatively test the SSC-hypothesis on intraplate volcanism. We explore the 3D-patterns of melting associated with SSC, the age of seafloor over which it occurs, and the rates of melt generation by varying the key parameters mantle viscosity, and temperature T_m. We also investigate the effect of lateral density heterogeneity, and of a rheology dependent on composition (water and melt content).

Melting due to SSC is predicted to emerge in elongated features (~ 1000 km) parallel to plate motion and not just at a fixed spot. Therefore, irregular age-distance relationships of the associated volcanism are predicted - contrary to the hotspot model. The seafloor age over which volcanism occurs is sensitive to T_m. For moderate T_m (1350 °C), volcanism develops beneath a relatively young lithosphere (~30 Myr), and higher T_m retards the onset of SSC and volcanism because of the stabilizing influence of a thicker residue from previous mid-ocean ridge melting (e. g., ~50 Myr for T_m=1410 °C). Mantle viscosity controls the rate of melt production with decreasing viscosities leading to more vigorous convection and volcanism. Effective viscosity required to obtain km-high seamounts is ~10^{19} Pa·s, or significantly lower if stiffening due to dehydration is considered. Our calculations predict many of the key observations of the Pukapuka ridges, and the volcano groups associated with the Cook-Austral, Line and Marshall Islands.

REFERENCES

Ballmer, M. D., J. van Hunen, G. Ito, P. J. Tackley, and T. A. Bianco (2007), Non-hotspot volcano chains originating from small-scale sublithospheric convection, *Geophys. Res. Lett.*, *34*.