Linear volcanic ridges due to small-scale convection driven by partial melting - a numerical study

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Oceanic intraplate volcanic chains unrelated to plumes have yet been related to a dynamic (small-scale convective instabilities, SSC) or static mantle (e.g. lithospheric cracking, Sandwell et al. 1995). In the Earth's uppermost mantle SSC is likely to develop due to instabilities of the thickened thermal boundary layer below mature oceanic lithosphere (usually ~70 Ma). They are characterized by convective rolls aligning with plate motion, whose onset is earlier for higher Rayleigh numbers (e.g. hot or wet mantle), adjacent to fracture zones, or hotspot tracks. Beneath young (< 50 Ma) and thus thin lithosphere partial melt is potentially emerging in the upwellings. Melting changes particularly the compositional buoyancy by melt retention and additional depletion of the residue, and therefore promotes upwelling and allows for further melting (buoyant decompression melting (BDM), Raddick et al. 2002). This process allows for a few percent of partial melting before the advected heat dissipates.
Here we present the first results of a 2D/3D thermo-chemical numerical mantle flow study on the interaction of SSC and BDM with a realistic, temperature-dependent rheology. We explore the crucial geologic features to trigger first melting and to initiate the above described process. We examine duration, amount and degree of melting and melt extraction of the BDM, and study the 3D-geometry of SSC and melting. We vary parameters such as mantle temperature, plate speed, thermal and compositional Rayleigh numbers. We look at cases with or without refreezing of partial melt to eclogite and fractionation of water between the melt and the solid, and show the importance of considering these processes.
This study thus puts additional constraints on the SSC hypothesis for intraplate volcanic chains. We show, that a significant amount of melt is emerging due to SSC for low mantle viscosities and usual temperatures. We postulate lateral thermal or compositional anomalies to focus melting and to obtain the observed patterns of volcanism (i.e. chains). We find that positive temperature anomalies (~50 K) are required to trigger a similar amount of melting in a static mantle.

REFERENCES

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