



Basaltic continental intraplate volcanism as sustained by shear-driven upwelling

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While most volcanism on Earth occurs at plate boundaries, the study of intraplate basaltic volcanism may provide an opportunity to scrutinize the make-up and dynamics of the mantle. In continental settings, a range of mechanisms were proposed to sustain mantle decompression and hence to support such volcanism. These include mantle plumes, fertile melting anomalies, self-sustaining buoyant decompression melting, lithospheric dripping, and edge-driven small-scale convection. Recently, Conrad et al. showed that basaltic continental volcanism occurs more often where shear across the asthenosphere is greatest, and hence propose shear-driven upwelling (SDU) to support such volcanism¹.

SDU does not require density heterogeneity to drive convection, in contrast to other mechanisms. Rather, it develops when rapid shear across the asthenosphere meets lateral viscosity variation². For example, in a case with a low-viscosity pocket in the mantle, asthenospheric shear is accommodated in a different manner across the pocket than across the ambient mantle. This contrast drives vertical flow close to the margins of the pocket, and may be sufficient to sustain decompression melting, particularly if the viscosity anomaly is supported by higher water contents or temperatures². Mantle melting is also expected for situations in which asthenospheric shear flow enters a lithospheric cavity, or decompresses across a step in lithospheric thickness³ – and even more so if a low-viscosity pocket is entrained in such a flow. Seismic observations indicate that sublithospheric topography, and heterogeneity in mantle viscosity are indeed common beneath continents (regardless of whether the imaged anomalies are thermal or compositional in origin).

We use three-dimensional numerical models to explore shear-driven flow, and investigate a range of cases with pockets of variable viscosity contrast and shape, lithospheric steps of variable offset and spacing, and asthenospheric flow with variable vigor (of its Poiseuille and Couette components). We find that asthenospheric shear of magnitudes that are realistic for the Western US, Eastern Australia, and Western Europe¹ is sufficient to sustain SDU for moderate viscosity heterogeneity. We show that SDU supports significant volume fluxes of volcanism – particularly for the case of viscosity heterogeneity supported by anomalously high temperatures instead of water contents, and/or large steps in lithospheric thickness. We compare model predictions of volcanic patterns in space and time – as well as volcanic fluxes – to constraints from basaltic provinces such as e.g. Crater Flat (Nevada, USA), High Lava Plains (Oregon, USA), Massif Central (Auvergne, France), and McBride Volcanic Province (Queensland, Australia).

¹ Conrad, C. P., T. A. Bianco, E. I. Smith, P. Wessel (2011): Nature Geoscience, 4, 317-321.

² Bianco, T. A., C. P. Conrad, E. I. Smith (2011): J. Geophys. Res., 116, B11103.

³ Conrad, C.P., B. Wu, E.I. Smith, T.A. Bianco, A. Tibbetts (2010): Phys. Earth Planet. Interiors, 178, 162-175.