Small-scale sublithospheric convection, a mechanism for non-hotspot volcanism

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Whereas hotspot theory accurately predicts many observations at some volcano chains, it is insufficient to explain the whole spectrum of intraplate volcanism worldwide. Though aligned by plate motion, many chains in the Pacific violate the predictions of hotspot theory in terms of linear age-distance relationships. One of the few alternative mechanisms put forward is small-scale sublithospheric convection (SSC). We use an extended version of the finite element code CITCOM to explore this concept in 3D geometry. SSC evolves at the bottom of mature oceanic lithosphere. In regions of the upper mantle with anomalously low viscosity (e.g., the South Pacific or, in the Cretaceous, the West Pacific), SSC may develop early enough (i.e., beneath sufficiently thin lithosphere) to support partial melting, and volcanism [1, 2]. SSC first removes the base of the depleted harzburgite layer, the residual from mid-ocean ridge melting.

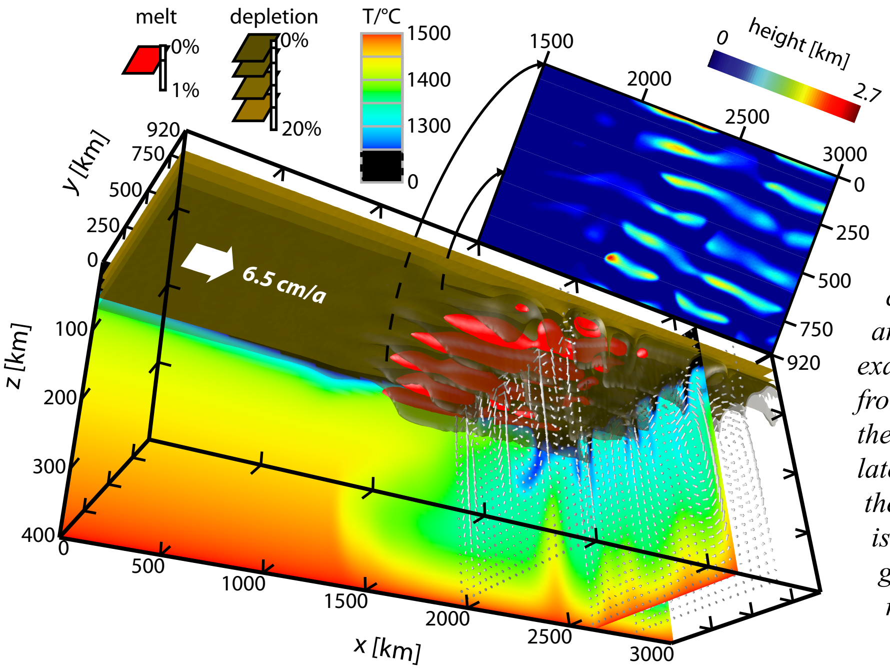

Fig.: Isosurfaces of melt fraction and depletion, and cross-sections of the velocity and temperature fields for an example calculation. Lifted from the top is a plan view of the thickness of melt accumulated onto a plate moving over the box. The harzburgite layer is partly removed in down-going sheets. Hence, partial melting emerges above SSC upwellings (Fig. from [1]).

Upwellings hereinafter bring fresh and warm asthenospheric mantle to depths of 80-100 km hence undergoing decompression melting. Melting zones from SSC are elongated and align with plate motion [1, 2], and thus reconcile quasi-synchronous volcanism over large distances (~1500 km) along a volcanic chain as well as longevity of activity at an individual volcano. Vigorous SSC occurring beneath young seafloor is capable of melting the mantle matrix yielding depleted volcanism on seafloor of age 20-55 Myrs. In contrast, SSC occurring slightly later is only capable of fusing fertile blobs embedded in this matrix [3] yielding enriched volcanism on seafloor of age 35-70 Myrs [4]. Our numerical model predictions are consistent with geochemical observations, geochronological constraints, volcano heights, and the lateral spacing of the sub-chains of the Wakes, Marshalls, Gilberts, and Cook-Australs. Furthermore, ages along the Pukapuka ridges and the Line Islands are in concert with an origin from SSC [2], so as potentially some other volcano chains, for which only few or no reliable ages are available.

1. Ballmer, M.D., et al., *Non-hotspot volcano chains originating from small-scale sublithospheric convection.* Geophysical Research Letters, 2007. **34**(23).
2. Ballmer, M.D., et al., *Intraplate volcanism with complex age-distance patterns – a case for small-scale sublithospheric convection.* Geochem. Geophys. Geosyst., 2009: p. submitted.
3. Ito, G. and J.J. Mahoney, *Flow and melting of a heterogeneous mantle: 1.Method and importance to the geochemistry of ocean island and mid-ocean ridge basalts.* Earth Planet. Sci. Lett., 2005. **230**: p. 29-46.
4. Ballmer, M.D., et al., *Small-scale sublithospheric convection reconciles geochemical and geochronological constraints from the Cook-Austral and Marshall Islands.* to be submitted to Geochem. Geophys. Geosyst., 2009.