Geochemical variations at intraplate hotspots caused by variable melting of a veined mantle plume

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A major form of volcanism on Earth occurs as chains of island-forming volcanoes, often associated with "hotspots" in the underlying mantle. Many of these hotspots are formed by plumes of hot ductile rock that rise from deep in the mantle and melt beneath the overriding tectonic plates. The compositions of these lavas, in terms of trace element and isotope ratios that finger-print material with different long-term evolution, provide a invaluable means by which to understand the compositional structure and evolution of the Earth. We use the 3D mantle convection code CITCOM to investigate the geochemical consequences of the dynamics of flow and melting of a mantle plume interacting with a lithospheric plate. We assume that the mantle is a uniform mixture of heterogeneities with small scales ($\leq \sim 10^3$ m) and that begin melting at different depths. Models predict that the regional-scale, spatial variations in mantle temperature and flow associated with plume-lithosphere interaction create geographic zoning in the composition of lava rising out of the melting zone (Figs. 1 and 2). Consequently a volcano that passes over this melting zone with the moving plate is expected to sample different compositions as a function of time. Such changes in composition can explain some of the overall trends in isotope composition as observed between volcanoes and in stratigraphic records of the Hawaiian islands. The results illustrate that magma geochemical zoning at the surface is not necessarily a map of zoning in the mantle, and this impacts further inferences about the chemical structure of the deep source that feeds mantle plumes.

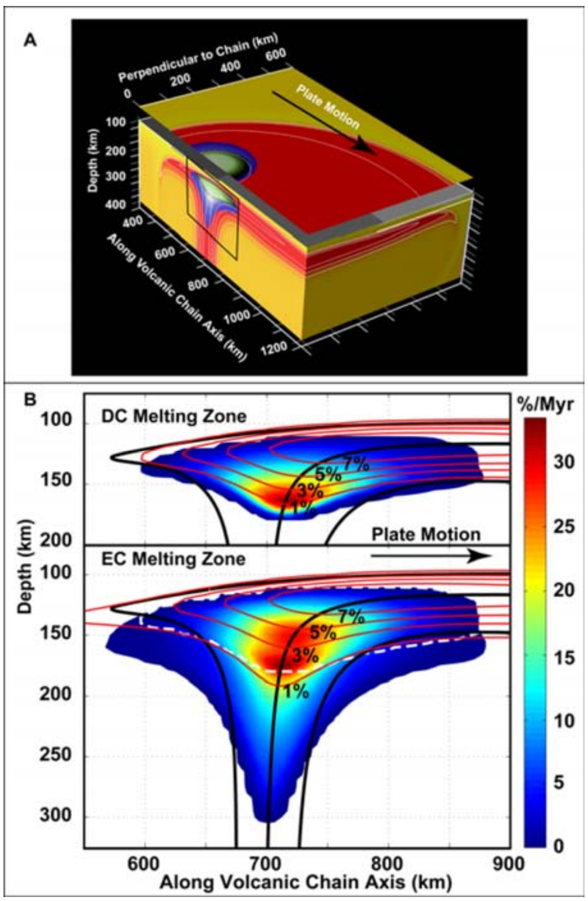

Figure 1. **(a)** 3D temperatures in shades of yellow (warm) and red (hot) of a mantle plume interacting with the lithosphere. Blue and light green areas show melting zones of two compositional components "EC" and "DC". **(b)** Melting rate contours in the cross section in small box of (a). DC is more refractory than EC and melts in a smaller volume that overlaps the EC melting zone. Red lines are contours of fraction of partial melting; black lines are solid streamlines. The surface is moving to the right to simulate plate motion.

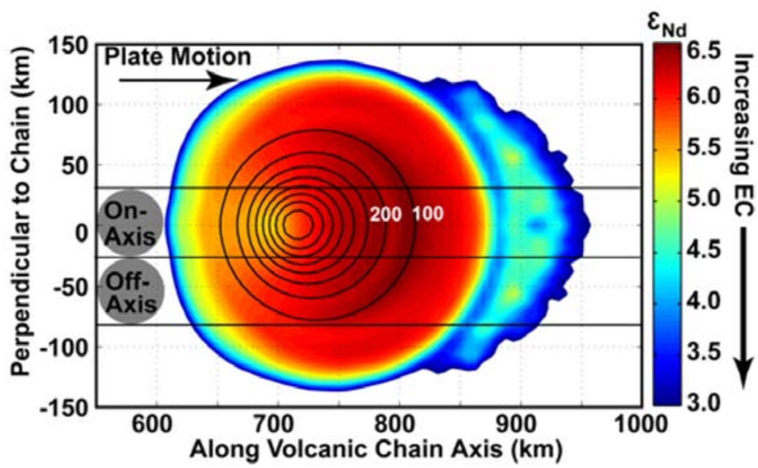

Figure 2. Map view of model Nd isotope composition (colored as ε_{Nd}) assuming EC (low ε_{Nd}) and DC (high ε_{Nd}) melts rise vertically and mix perfectly at the surface. Black contour lines are eruption rates in km^3/Myr (100 and 200 km^3/Myr are labeled); the center of these contours is the center of the hotspot. Gray circles mark areas from which volcanoes will sample magma; horizontal lines show the paths that two volcanoes take as they move with the plate.

References:

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