Plumes are redefined by plumologists!

Don L. Anderson, 15th December, 2006

The existence of mantle plumes has been questioned on the basis of theoretical, thermodynamic, fluid dynamic, geophysical, petrological and geochemical arguments. These studies do not question the presence of mantle convection and diapirs or the ability of magma to rise. They address the criteria that Morgan and others have used to distinguish a hypothetical form of small-scale focused jet-like convection, fueling by core and lower mantle heat, from normal petrological and convective processes. If these criteria are changed as new data accumulate, then the hypothesis cannot be tested.

Alternative mechanisms for forming melting anomalies such as Hawaii, Iceland and Yellowstone include chemical inhomogeneities, incipient melting of the lower crust and asthenosphere, delamination, and ponding and stress release. These all involve, at some point, buoyant upwellings, so a formal definition of a 'geophysical plume' is required in order to distinguish that unique form of convection, as used in the Earth science literature for 40 years, from features and shallow processes such as dikes, diapirs, overthrusting, isostasy, crustal detachment, foundering and stoping, and mid-ocean ridges.

The plume hypothesis for the mantle carries with it the implication that upwellings are from deep thermal boundary layer instabilities that are relatively fixed with respect to each other, and that exceed normal upper mantle temperatures by amounts that cannot be explained by normal plate tectonic and mantle convection processes. These upwellings are independent of plate tectonics and are the method that the core uses to get rid of its heat. Plumes were defined an narrow, ~100-km, upwellings, to distinguish them from normal mantle convection.

More recently, geochemical plumes have been defined by 'anomalous' geochemical properties, compared to MORB, that range from depleted to enriched. Since none of the assumptions, predictions or criteria set forth by Morgan in his mantle plume papers have been confirmed, recent authors have dropped the depth, fixity, heat-flow, size and thermal constraints and have returned to the formal fluid dynamic definition of a plume. Following McKenzie et al. (2004), recent authors have used the term 'plume' in a strictly fluid-dynamical sense, that is 'a buoyant upwelling or downwelling whose buoyancy results from the material in the plume being hotter or colder than the surrounding mantle with no implications whatsoever about the depth to which the circulation extends, or about whether or not relative motion between different plumes occurs, or whether the thermal buoyancy is associated with compositional or isotopic variations'.

With this definition, dikes, mid-ocean ridges, and in fact all volcanoes are plumes since they are certainly due to the ascent of material that is less dense than their surroundings. Isostatically rising mountains are plumes, and downgoing slabs also satisfy the fluid dynamic definitions of plumes.

McKenzie, D. et al. Source enrichment processes responsible for isotopic anomalies in oceanic island basalts, *Geochim. Cosmochim. Acta* **68**, 2699–2724, 2004.