Scoring hotspots: The plume and plate paradigms

Don L. Anderson*

California Institute of Technology, Seismological Laboratory 252-21, Pasadena, California 91125, USA

We see that many assumptions used in previous hypotheses can be discarded as unnecessary...there is no need to locate the source of plumes in the lower mantle.
—Richter and Parsons (1975)

ABSTRACT

The origin of midplate and along-ridge melting anomalies is controversial. Hypotheses involve, at one extreme, concentrated hot mantle upwellings from the deepest mantle and, at the other extreme, shallow processes dominated by stress, plate tectonics, and fertility variations, along with an asthenosphere that is near the melting point. An updated hotspot list is presented and is tested against criteria relevant to both the deep thermal plume and the shallow (plate and asthenosphere) hypotheses. The unique polling approach of Courtillot et al. (2003) is applied to the plume hypothesis and to other hypotheses for melting anomalies. Although some "primary" (i.e., potentially deep-seated) hotspots (Iceland, Hawaii, Easter, Louisville, Afar, Réunion, and Tristan) score well using the chosen subjective plume criteria, they score poorly using criteria more appropriate to deep or thermal processes, such as magma temperature, heatflow, transition zone thickness, and high-resolution upper and lower mantle seismic tomographic results. In particular, Iceland, Easter, Afar, Tristan, and Yellowstone have not been confirmed by tomography. They are shallow features with well-defined plate tectonic explanations. For most melting anomalies (aka "hotspots") the plume hypothesis scores poorly against competing hypotheses such as stress- and crack-controlled magmatism, mechanisms that are associated with plate tectonics. Based on the results, most "hotspots," including proposed "primary" or plume-candidate hotspots, are unlikely to be caused by thermal plumes from deep thermal boundary layers. Melting anomalies, on- or off-ridge, appear to be a natural result of nonrigid plate tectonics, including recycling, and do not require an extraordinary explanation, such as narrow thermal instabilities that traverse the whole mantle. Thus plate tectonics, plate boundaries, global plate reorganization, normal magmatism, melting anomalies, volcanic chains, and mantle geochemistry can be unified into a single theory.