Foulger, G.R., The Great Plume Debate, invited paper, "Our Dynamic Planet", Annual Symposium of the Open University Geological Society, Lancaster, 17-20 August 2007.

The Great Plume Debate

Gillian R. Foulger

Durham University, Durham, UK (g.r.foulger@durham.ac.uk)

Mantle plumes were originally proposed in 1971 by W. Jason Morgan, who defined precisely their characteristics and consequences. However, subsequent research was variable in its success in confirming the predictions. Despite this, instead of the theory being abandoned as would have occurred, for example, in medical research if a drug were found to not produce the predicted results, the plume model was progressively adapted to encompass unpredicted observations. Plumes have been proposed to come from almost any depth, to rise vertically or tilt, and to flow for thousands of kilometres laterally. They may have narrow or broad conduits, no plume head, one head, or multiple heads, they may produce steady or variable flow, be long- or short-lived, speed up or slow down, have a source that is either depleted, enriched, or both, and have either high or low $^3He/^4He$. Often, several mutually inconsistent plume models have been proposed for a single "hot spot", to account for data from different sub-disciplines within the Earth Sciences. In short, the theory of mantle plumes as it is applied today is so flexible it amounts to an unfalsifiable, data-independent, *a priori* assumption. Much applied research comprises reporting observations and explaining how the plume model must be adapted to fit them. Such an approach is unscientific, and cannot increase our fundamental understanding of how the Earth works.

In a quest to find models that fit the observations without *ad hoc* assumptions or appeals to coincidence, there has recently been a resurgence of interest in alternative models for "hot spots". The most promising of these, the Plate Tectonic Processes, or "Plate" model, attributes anomalous volcanism to permissive volcanism in areas of extension. The volumes of melt produced, which may vary from being large to little, are attributed primarily to variations in source fertility. Source volatile content (CO_2 and H_2O) and temperature will also affect melt volumes. Extension occurs at spreading plate boundaries, close to which a third of all "hot spots" lie, and intraplate regions such as the East African Rift, the Basin & Range Province, W USA, and back-arc basins. Fertility may be imparted to the mantle by subducted slabs of oceanic lithosphere, the crustal portion of which transforms to eclogite at depth, and recycling of delaminated continental lithosphere into the asthenosphere when continents break up. Mantle fertilised by eclogite or recycled continental lithosphere has a solidus as much as 200˚C lower than that of standard depleted mantle peridotite, and where such material is tapped at a ridge or intraplate extensional area, large volumes of magma will be produced at relatively normal temperatures.

This alternative model for the genesis of "hot spots" raises many new questions and challenges. Can the melt volumes observed be quantitatively modeled? How should seismic tomography images be interpreted? How hot are "hot spots"? Are deep mantle plumes physically possible? What is the relationship between large igneous provinces and volcanic chains? Can geochemical observations be reconciled with a fertile source at relatively normal temperatures? What is the origin of high $^3He/^4He$? What are the most promising “Plate” models for the ~ 20 “hot spots” advocated by Morgan (1971)? The present challenge to the plume hypothesis and the innovative thinking it requires, is ushering in a wealth of novel new research problems previously unconsidered.

Foulger, G.R. & Natland, J.H., 2003. Is "hotspot" volcanism a consequence of plate tectonics? *Science*, **300**, 921-922.

Morgan, W.J., Convection plumes in the lower mantle, *Nature*, **230**, 42-43, 1971.

visit: http://www.mantleplumes.org/