Hotspots and African mantle

from Peter J. Smith

EIGHT years ago Morgan (*Nature* **230**, 42; 1971) proposed the existence of hotspots, which he envisaged as manifestations at the Earth's surface of narrow plumes of hot mantle material rising from below. Ever since these supposed lithospheric penetrations have been a perpetual source of controversy. Do they exist at all? And if they do, how many are there — a few, or tens, or even hundreds? Are they really linked to deep mantle plumes? If so, are the plume positions laterally fixed in the mantle or do they (and hence the hotspots) move relative to each other? Do hotspots-plumes really account for the phenomena (Hawaiian volcanism, for example) often attributed to them? And so are linear volcanic age trends (the Hawaiian-Emperor chain, for example), hotspot traces, resulting from the motion of tectonic plates over (stationary?) plumes beneath?

Nothing like a consensus has yet emerged on any of these questions. Which makes it all the more fascinating to observe that Thiessen *et al.* (*Geology* **7**, 263; 1979) have had the temerity to superimpose this set of controversies on another uncertainty, namely, the mobility/immobility of Africa. A few years ago Minster *et al.* (*Geophys. J.* **36**, 541; 1974) concluded that for the past 10 million years Africa has been moving at the rate of about 2 cm a year. Burke and Wilson (*Nature*, **239**, 397; 1972), on the other hand, have taken the view that for the past 25 million years or so Africa has been stationary with respect to the underlying mantle; and there is much to be said for this suggestion. Palaeomagnetic data appear to rule out any major latitude changes during this period; and about 25 million years ago there was a dramatic increase in African volcanism, implying a continent that had come to rest relative to its underlying volcanic sources.

Of course, to anyone strongly committed to the existence of mantle plumes, African volcanism and African hotspots are synonymous; and to that extent Burke and his colleagues made the hotspot-immobility connection right from the start. According to this vision, the increase in African volcanism about 25 million years ago and the continued high level of volcanic activity since then simply reflect the relative ease with which mantle plumes may pierce stationary, as opposed to moving, lithosphere. Then regions of high relief/elevation without associated volcanisms are regarded as nothing less than incomplete hotspots, or highspots, resulting from the same underlying processes as the hotspots proper. Thus Africa's distinctive basin and swell topography, where the swells are seen as hotspots/highspots, becomes a natural consequence of the continent's immobility.

Those who remain unconvinced about the reality of mantle plumes, or who accept the existence of only a few of them, will find this proliferation of hotspots and quasi-hotspots outrageous. Nevertheless, it is interesting to see how Thiessen and his colleagues (who, incidentally, include Burke) combine hotspots and a stationary Africa into a consistent picture and then go on to develop the model in terms of its implication for the underlying mantle. For accepting that Africa is stationary (that is, that primary convection beneath the continent is suppressed) and that all volcanism and uplift is essentially hotspot activity, it becomes possible to speculate on the nature of the plume convection system beneath.

As Thiessen (R.) *et al.* see it, there are some 30–40 hotspots/highspots within Africa's boundaries. That is, there are some 30–40 narrow zones of upwelling mantle material; and as what comes up must go down (well, some of it), there will be downwelling of mantle material approximately midway between hotspots. For a random arrangement of hotspots, this downwelling must occur along the edges of polygons (as viewed in plan), one of which surrounds each hotspot. In other words, there will be a pattern of polygonal convection cells, as seen from above, such that any points within a particular cell will be nearer to that cell's hotspot than to any other hotspot.

The construction of such polygons in a mathematical sense was first carried out by Thiessen (A.H.) in 1911 in connection with an analysis of rainfall data, whence, as widely used in computer cartography, they have come to be known as Thiessen polygons. Of more geophysical interest, however, is the fact that Richter and Parsons (*J. geophys. Res.* **80**, 2529; 1975) were able to generate polygonal cells in laboratory convection experiments involving oil layers heated from below in cases where the upper layer was stationary. Moreover, assuming the real-Earth plume cells to extend down only to the 700 km seismic discontinuity, the experimental and African polygons had the same width-depth ratios. Thus laboratory work and observationally-based hypothesis combine nicely to produce a consistent picture.

Except that Morgan's original plumes were deep-mantle plumes, possibly originating as far down as the core-mantle interface, whereas Thiessen's plumes appear to be an upper-mantle phenomenon only. Something seems to have been lost here without acknowledgment.

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Atomic spectroscopy at Orsay

from Anne Thorne

Do you prefer to believe in 'action at a distance' or in 'hidden variables in quantum mechanics'? Put another way, if quantum mechanics affords a complete description of a system, it seems to be necessary to reject the idea of local causality — that is, the idea that the causes of effects are to be found inside the relevant backward light cone. Reviewing the present status of this old dilemma at a recent conference* J.S. Bell (CERN, Geneva) described a *Gedankexperiment* in which an excited atom in a state A undergoes the radiative cascade A→B→C, emitting a photon at each stage, where A and C have zero angular momentum and the same parity. Taking the particular case that the two photons are emitted in opposite directions, then if one is linearly polarised so also must the other be, with the electric vector in the same direction. Hence information from a perfectly efficient linear polariser on one side gives information about the signal from a second perfectly efficient linear polariser on the other side. Bell described attempts to translate *Gedanken* into reality, including a variant in which the angle between the polarisers is changed while the photons are actually in flight. Although the results so far seem to favour quantum mechanics rather than 'local causality', a sceptic can still find refuge in the allowances made for detector inefficiencies, finite acceptance angles, and so on. Attempts are now being made to close these loopholes and obtain what is expected to be incontrovertible evidence in favour of quantum mechanics. Meanwhile, most of us will continue to ignore the challenge of this intriguing problem by adopting the first of the three options Bell put forward — "Don't think about it at all"!

On the same day, nicely redressing the balance between the conceptual and the practical, H. Welling (Institute of Applied Physics, Hannover) discussed important

*The 11th Conference of the European Group for Atomic Spectroscopy was held at Orsay on 10-13 July. The Organising Secretary was Professor B. Cagnac, ENS.

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