COUNTERFLOW: A comment on Paul Tackley's review of P^3

by

Don Anderson, Caltech
dla@gps.caltech.edu

Arguments against plume-alternative mechanisms are usually based on the propagating crack idea, or on the perceived fixity of hotspots. Paul Tackley (2006), in reviewing mechanisms for hotspots, has recently posed the following questions: Why do the Pacific hotspots exhibit little relative motion as the plate moves over them? If they are caused by propagating cracks, why do all the cracks propagate at the same rate? Plate boundaries tend to be linear; why then are flood basalts, and hotspots that occur at spreading centers, not linear, following the plate boundary?

Shallow counterflow mechanisms explain the small relative motions of the Pacific hotspots, and the measurable relative motions between groups of hotspots on different plates. Heterogeneities in the upper mantle flow in the opposite direction to the overlying plate and at a small fraction of the plate velocity. This mechanism gives tracks, on a given plate, that are parallel. Statistical compatibility tests show that the ages and trends of volcanic chains are incompatible with fixed hotspots (Wang & Liu, 2006). Furthermore, hotspot rates are consistently lower than those predicted by best-fitting absolute plate motion models. This may be explained by fertile spots in the mantle moving systematically opposite to the plate motion, as predicted by counterflow models of mantle convection (Harper, 1978; Chase, 1979). The locations, trends and relative motions of melting anomalies are then due to asthenospheric flow that is almost exactly opposite to plate motion, as in the lubrication models of plate tectonics (Harper, 1978) and in recent models of relative motions (Wang & Liu, 2006). Dense sinkers that bottom out at upper mantle phase changes may also exhibit little relative motion, particularly if they return to the surface rather quickly.

Plate boundaries and fracture zones tend to be linear, as do so-called hotspot tracks. Many flood basalts, and hotspots are not linear because they occur at triple junctions, and are transient in nature. Fertile streaks in the upper mantle do not need to follow plate boundaries nor do they need to be linear. The intersections of fertile blobs with ridges, triple junctions reactivated sutures, and with new plate boundaries, and the configurations of tensile stress domains, are what control the shape of melting anomalies. Nevertheless, much of the fabric of the seafloor is parallel to plate motions, and linear volcanic chains are expected for incipient–and dying–plate boundaries. It is not obvious why the linearity of long-lived volcanic constructs, and the non-linearity of short-lived constructs and those at triple junctions are arguments against plate tectonic control and shallow origins of 'midplate' phenomena *(e.g.* Tackley, 2006).

Tackley (2006) also asks "If plumes are not the answer, what is?". He then asserts "Here the arguments presented by the contributors sometimes get awkward. Often a different detailed explanation seems to be required for each case." This is an ironic criticism since

Morgan expressed the viewpoint that plumes cannot be defined because all mantle plumes are different (http://www.mantleplumes.org/Chapman/GPDFinalReport.pdf). This is the crux of a major objection that skeptics have leveled at the plume hypothesis – that in the extreme it is defined a-posteriori at individual localities by what the local observations are and is, in practice, not disprovable (see Foulger et al., http://www.mantleplumes.org/Chapman/GPDFinalReport.pdf).

References: Classical and recent papers on counterflow; a result of plate-tectonic-driven mantle flow in the presence of a low-viscosity channel, and a plausible explanation for relatively fixed hotspots due to entrained fertile blobs

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See also:
http://www.mantleplumes.org/Chapman/GPDFinalReport.pdf