What alternatives are there to the plume hypothesis?

Below are six alternatives which could help us understand "hotspot plumes" better:

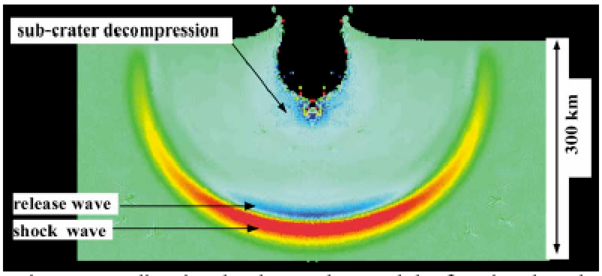


Figure1: Indicative hydrocode model of a simulated impact Red=high pressure, blue=low pressure.

Meteorite Impacts

Craters larger than 200km are absent on Earth compared to other terrestrial planets. Modelling (**Figure1**) combined with known mantle melting behaviour suggests a 20km diameter iron impactor travelling at 10km/s would cause decompression melting in the lithosphere and produce enough magmatism to auto-obliterate the crater(Jones et al 2002). Impact could trigger a long lived mantle up-welling or an impact plume (I plume) in the upper mantle, requiring no pre magmatic thermal doming. This is supported by the below sea level emplacement of the Ontong Java Plateau. However critics doubt whether decompression melting even occurs (Ivanov & Melosh 2003).

Ridge Transform Intersections (RTI)

Small seamounts exist with "hotspot" geochemical signatures at or near RTI. 3D finite element models showed increasing transform strength caused increased extensional stress at the RTI in the lithosphere (**Figure 2**) and in the mantle.

Build up of stress can cause the ridge to propagate or the stress can become concentrated at the ridge tip (prior to propagation or if ridge tip propagation is prevented). It is in the latter scenario where seamount formation at the RTI is proposed, aided by localized normal faulting, crustal thinning and mantle decompression, either from a heterogeneous mantle source or by drawing a plume from the ridge.

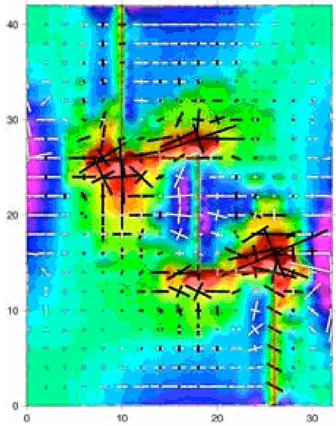


Figure 2: Mapview of stress in lithosphere at a strong transform. Red=extension, blue=compression

RTI highlights the importance of lithospheric stress state on production of hotspot geochemical signatures and raises the question of what role stress plays in all volcanic anomalies e.g. could changes in lithospheric stress account for LIP?

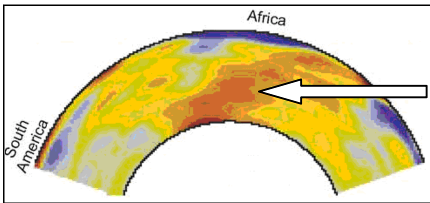
Plate Tectonic Processes (PTP)

Proposes volcanic anomalies are "by products" of plate tectonics. Key requirements:

1. Intraplate deformation, plates are not rigid, they move coherently and deform internally in response to changes in stress. Deformations are most likely along pre-existing lines of weakness e.g. old sutures.
2. Upper mantle is compositionally variable, becomes de-homogenised at ridges and subduction zones. Allows tapping of fertile source rocks e.g. eclogite to produce the vast amount of magma in LIP's.

- Location of volcanism controlled by plate stress field. Extension=volcanism.
- Amount of melt controlled by fusibility of mantle beneath plate. Shallow sourced melt.

PTP theory offers a unifying theory of volcanism and convection in Earth's mantle.



Reheated Slabs

Figure 3: seismic tomography model. Arrow points to low velocity zone (coloured red in figure)

Deep seismic tomography models (**Figure3**) show large low velocity anomalies in the mantle. Suggested the anomalies may be recycled lithospheric slabs transported from subduction zones by penetrative convection. The slabs transform from high velocity to low velocity anomalies as they are heated, small amounts of fluid or melt can dramatically lower the seismic velocity even if the density remains. Heated, uprising slabs from convection could explain "hot spots" and eliminate the need for plumes at all. However deep seismic tomography has a tendency to widen artificially vertical anomalies and resolution is currently low. The model is not fully developed or understood.

Lithospheric Delamination

Can explain continental volcanic anomalies e.g. Flood Basalts, but not oceanic LIP. Requires 2 Siberian criteria:

- Lower lithosphere beneath continent gravitationally unstable (denser than surroundings)
- Viscosity lowered=limiting factor.

Cause melt by a 3 fold process (see **figure 4**):

- Asthenosphere sucked into void
- Horizontal temperature gradients drive convection
- Dewatering of fallen lithospheric block

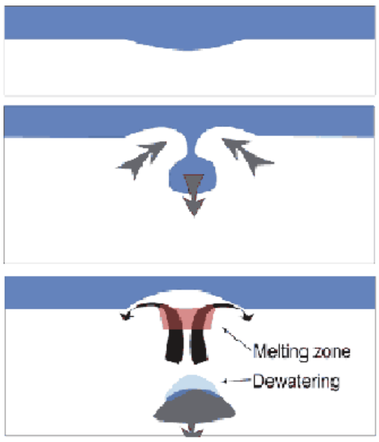


Figure 4: Lithospheric Delamination Process

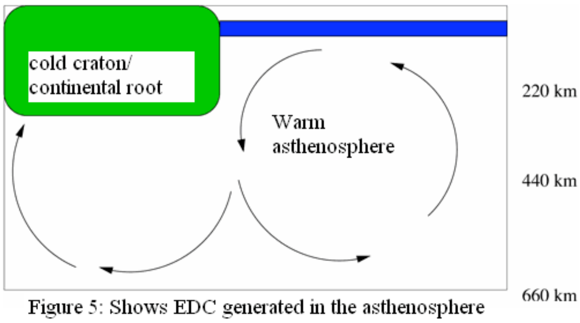
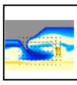


Figure 5: Shows EDC generated in the asthenosphere



Edge Driven Convection (EDC)

Instability at the boundary between thick stable lithosphere (Archean craton) and thinner lithosphere (oceanic) promotes convection (**Figure 5**), because of the temperature difference along the "edge" between colder craton and warmer asthenosphere. Predicts up welling and subsequent volcanic anomalies. EDC relatively weak can be suppressed by other temperature anomalies.

Conclusions:

Alternatives to the plume hypothesis have there individual criticisms which require further work to either substantiate or disprove their claims and allow the scientific reality to be realised.

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