Plates vs. Plumes: An Exercise in Understanding Scientific Method

by

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This article outlines the results of a group of Durham University students' attempts to test the two opposing hypotheses in the contentious 'Plates vs. Plumes' debate. Eight groups each chose a different "hot spot" to research. Working under the principle of Popper's falsificationism, each group aimed to find evidence in the literature that would contradict the predictions made by each hypothesis, whilst critically analysing the authors' approach to the subject. The following is a summary of each groups PowerPoint presentations, organised in terms of predicted observations.

Predictions of the plume hypothesis:

- Precursory uplift – This phenomenon seems to be missing at most of the "hot spots" studied. Neither Hawaii nor the Azores show any precursory uplift, and Tristan is thought to be related to the uplift of the continental margins either side of the South Atlantic, but even this is speculative. The postulated Iceland plume is suggested to have originated beneath Greenland (among several other places including Siberia), yet uplift here is not symmetrical.
- Flood basalt eruption – An inconsistent definition of what constitutes a LIP amongst workers makes this criterion very difficult to assess. Some are absent, but in the case of Samoa, suggested to have been subducted. Whilst others are present, they may not be in the form expected. The LIP postulated to be associated with Tristan has a composition indicative of an upper mantle source.
- Plume tail to CMB – Seismic tomography remains our only way of imaging the internal Earth, yet yields highly speculative results. At Afar, a plume is hypothesised, rising at an angle that is not physically possible. Consistency between different research groups seems to be at its worst for Yellowstone, where there is scant evidence for a plume like structure at all.
- Time progressive chain – All the researched hotspots show a time progressive chain to a degree, but "to a degree" is the key point here; none of the hotspots are of an entirely time-progressive nature, and for most of them, this progression is not consistently agreed upon between workers. At Samoa, volcanic rejuvenation has been hypothesized as a cause for this deviation from expected progression.
- High temperatures – Little data seem to be available for temperature, although Afar has been described as an anomalously "cold plume", and Yellowstone has been described as "luke-warm" with a temperature anomaly of 200°C.
- Geochemistry indicative of a deep mantle source – for all examples, the geochemistry is indicative of a heterogeneous mantle source. At Afar, the osmium spike expected for material rising from the CMB is not observed. At Hawaii, the high $^{3}He/^{4}He$ ratios expected to arise from the CMB are observed, yet recently it has been argued that a CMB origin is not required for high $^{3}He/^{4}He$.

Predictions of the plate hypothesis:

- Overall, the plate hypothesis seems to have been harder to falsify. Much of the evidence used to falsify the plume hypothesis supports the plate hypothesis, including evidence of shallow mantle structures and recycled material.
- The key prediction of this hypothesis is that extraction of existing melt is permitted by lithospheric extension. Mid-ocean ridges, continental rifts and back-arc basins are obvious extensional environments. Some hotspots neatly sit in such settings, Iceland being a prime example. The Azores also straddles the mid-ocean ridge, but interestingly also sits at a triple junction. Others occur in areas of localised extension. Yellowstone sits on the edge of the Basin and Range Province, whilst Samoa is located where stress concentration at bend in plate has resulted in localised extension. However, not all "hot spots" are extensional. Hawaii cannot be conclusively explained by a plate tectonic cause.

Ultimately, the result of this exercise was a mutually agreed requirement for more definitive terminology (just how high a temperature is abnormal for example?), and improvement in multiple scientific techniques. Seismic tomography is probably the most important tool in our arsenal for understanding the internal structure of the Earth, yet its limitations are frequently ignored. The underlying difficulty across all of the groups' research seems to be repeatability, with contradictions not only occurring between different workers but also within the same piece of work. If a solution is ever to be found, out results must be consistently repeatable, and the terms of our hypotheses rigidly defined.

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