Fundamentals of the Plates vs. Plumes Debate

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The “plumes debate” concerns whether anomalous volcanic areas result from a) leakage of melt from the mantle, permitted by lithospheric extension (the Plate hypothesis), or b) the delivery of high-temperature material from the core-mantle boundary by thermally buoyant, deep-mantle plumes (the Plume hypothesis). This debate does not merely involve igneous petrology and mantle convection. It is extraordinarily cross-disciplinary and almost every branch of geology and geophysics is relevant. It is fundamental to how the Earth works, from the core to the surface.
The Plate hypothesis predicts that magmatism is driven, either directly or indirectly, by plate tectonics [http://www.mantleplumes.org/]. Magmatism is envisaged to be a passive reaction to lithospheric extension. Its quantity and chemistry are predicted to reflect source fusibility and composition. Thus, where “anomalous” magmatism occurs, lithospheric extension is expected to be observed, e.g., an extensional plate boundary, a back-arc basin, distributed intraplate extension or a continental rift zone. It is a common misunderstanding that the mere existence of melt in the mantle is sufficient to explain surface eruptions–that the lithosphere is passive and melt in the mantle can pass through it unimpeded as light passes through a glass window. This is not the Plate hypothesis, which predicts that lithospheric extension is required for melt to escape to the surface. The Plate hypothesis views surface volcanism as mapping lithospheric extension, not the existence of melt in the mantle. Where melt volumes are large, the chemical fingerprints of high source fusibility are predicted.
The Plume hypothesis predicts a) surface uplift tens of millions of years before flood volcanism, b) flood volcanism lasting a few tens of millions of years, c) a “plume tail” extending from the surface to the core-mantle boundary, d) a time-progressive volcanic chain, and e) high source temperatures. These predictions are rarely confirmed with confidence and have never all been confirmed at a single “anomalous” volcanic province. The Plume hypothesis has survived for the last four decades only because it has been extensively modified in ad hoc ways to accommodate unpredicted observations. Modifications include proposals that plumes can arise from almost any depth, that plume material can flow sideways for thousands of kilometres, that plumes may have a wide range of geochemical compositions, and that where a predicted characteristic has not been observed, even in the face of extensive searching, it may be assumed that the characteristic exists. The plume model has become the default explanation for anomalous volcanism because it can be adapted to explain anything, the absence of anything, and the inverse of anything. It has evolved into a model that cannot be falsified, no matter what is observed or not observed.
The scientific method involves testing predictions against observations in an attempt to falsify an hypothesis. In the case of the origin of anomalous volcanism, science has strayed from this path. In my presentation I shall outline the fundamental issues underpinning the “plumes debate”, I shall describe the challenges scientists face in resolving the issue, and I shall suggest research approaches that can potentially resolve this fundamental question.

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