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Challenges to Plume and Plate – Telling it like it is

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The modern quest for alternatives to the mantle plume hypothesis arose shortly following the turn of the 21st century. It offers the exciting prospect of a new generation of theories, models and viewpoints. However, progress will quicken if there is more widespread acceptance of a number of basic, fundamental truths that are not new. Most damaging is the problem of the definition of a mantle plume. A theory cannot be tested if there is no agreement about what it is. This problem has been highlighted repeatedly over the last few years, but as yet no resolution has been reached. "Definitions" range from an excess of CO_2 in the lithosphere, to "any flow driven by thermal buoyancy", to a hot, cylindrical, mushroom-like upwelling from the core-mantle boundary.

The most fundamental observation at melting anomalies is amounts of magma perceived to be unusually large. Both the quantity and composition of this melt need to be explained. Melting anomalies usually have ocean-island-basalt (OIB) geochemical signatures, which almost certainly results from the presence of recycled near-surface material in the source. The OIB geochemical signature does not require a lower-mantle, or plume origin. This fact has not been universally taken on board, however, and failure to do so continues to impede progress. It is also commonly assumed that high helium isotope ratios (high $^3He/^4He$) uniquely require a lower-mantle origin, despite strong evidence to the contrary. Continuing to cling to unsafe assumptions amounts to ignoring fundamental problems instead of addressing them.

Explaining the volume of magma at melting anomalies, in particular high-volume tholeiitic provinces such as Hawaii, is clearly the single most important challenge in front of us. Despite oft-repeated assumptions to the contrary, mantle plumes cannot explain the eruption rates and volumes observed at many localities, unless the lithosphere is assumed to have been thinned and the temperature raised much more than is

observed. Alternatives have been suggested, e.g., long-term ponding of melt followed by rapid release, and fluxing of fertile source material by volatiles. However, few tests have been done and these theories remain speculative and unquantified. Explaining the melt volumes is the most important thing that needs to be done, but few people are working on it.

Closely linked to volume is the issue of temperature. Are melting anomalies hot or not? The most direct approach to determining the temperature of the source is using petrology. However, it is still highly controversial what is and what is not a valid approach. Similar data have been used to obtain wildly different results, depending on the a priori assumptions. For example, high-MgO basalts from melting anomalies and mid-ocean ridges have been variously interpreted to indicate source temperature differences of up to hundreds of degrees, a difference of zero, or as being incapable of indicating temperature. It is urgent to sort these problems out.

It is commonly assumed that seismology is essentially the only way of determining the depth of origin of a melting anomaly. However, in truth it is not at all clear whether traditional seismological approaches can be of much help. The fundamental problems are a) resolution, b) ambiguity of interpretation, and c) poor data coverage. Problem c) may one day be solved, but problems a) and b) are likely to remain. Seismic tomography is very unlikely to ever be able to attain the resolution required to detect objects with the narrow dimensions suggested for deep mantle plumes. Phase (including liquid/solid), composition and temperature all affect seismic wave speeds and these cannot normally be separated out. Red does not necessary mean hot and rising, and indeed this may be the least likely interpretation.

Seismology is powerful to provide information about the interior of Earth, but what it can and cannot do need to be understood and it needs to be used to do what it can and not what it can't. This simply homily urges an adjustment of attitude that could be applied to all areas of endeavour within the subject and would set the entire subject on a more conservative and safer course.