MEETINGS

The Great Plume Debate

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It has been 40 years since *Wilson* [1963] first suggested that the Hawaiian Islands were produced by the oceanic lithosphere moving over a stationary 'hot spot' in the mantle, and 30 years since *Morgan* [1971] suggested that plumes exist in the Earth's mantle and play an important role in convection. Subsequently, large igneous provinces (LIPs), volcanic continental margins, and large oceanic plateaus, along with smaller-volume seamounts and ocean-island chains, have all been attributed to mantle plumes.

For the last two to three decades, the tendency has been to focus research on those features of LIPs and hot spots that can be explained by the plume hypothesis and to neglect those that cannot. Many papers have treated the plume hypothesis as an a priori assumption, and there has been little questioning of the hypothesis.

However, during the last five years or so, there has been growing critical thought on the subject by earth scientists who are engaged in a global debate about the viability of alternative models, the number of deep mantle plumes, and even whether plumes truly exist (http://www.mantleplumes.org/).

A Chapman Conference, 'The Great Plume Debate,' brought together scientists with a wide range of viewpoints to exchange ideas and information pertaining to the existence or non-existence of plumes, and to identify the outstanding questions and the research approaches that have the greatest potential to address them. The meeting comprised eight sessions focused on discrete subdisciplines, each divided into plume-advocate and plume-skeptic sub-sessions. Approximately half the session time and the whole final afternoon were devoted to discussion.

Convection, Lithosphere, and Temperature

Many assertions made by both plume-advocate and plume-skeptic speakers were challenged. For example, the assertion that a plume must come from the core-mantle boundary was contested on the grounds that numerical convection modeling can produce plumes originating from within layers. Propagating cracks is a popular alternative mechanism for Pacific volcanic chains, but how a sufficient volume of melt could be produced by the small pressure release expected from cracking was questioned during the conference.

Numerical convection modeling readily produces plumes, but critics asked whether the properties of the deep mantle are sufficiently understood and realistically modeled by computer programs that cannot self-consistently simulate surface plate motions. Whether the absence of surface uplift can negate the plume theory was challenged by the results of modeling. If realistic continental lithospheric rheologies are used in model calculations, complex uplift patterns are predicted.

Whether 'hot spots' are really hot is dependent on the source temperature of primary melts, and this issue therefore was vigorously debated. One group proposed that the source of Hawaiian basalts is ~270 K hotter than that of mid-ocean ridge basalts, and that Iceland, which is considered to be a hot spot on the Mid-Atlantic Ridge, showed no such temperature anomaly. The competing view was that the sources of Hawaiian, Icelandic, and mid-ocean ridge basalts all have similar temperatures.

Tracks, Seismic Structure, Uplift, Planets, and Petrology

The geochronology of Pacific volcanism reveals varied patterns ranging from the regular, linear age progression of the Hawaiian chain to no recognizable temporal patterns in regions of diffuse volcanism such as the Western Pacific. Alternative mechanisms (e.g., plate tectonic processes) also predict time-progressive chains. The majority of those present agreed that volcanic time progression is not required by, nor diagnostic of, a mantle plume.

Seismic models and their interpretations were debated. Concern was expressed about the reliability of recent 'plume images' obtained using finite frequency tomography in view of the nonuniform sampling of the Earth. The correspondence between seismic velocity and parameters (e.g., temperature, composition, and melt content) is unclear, particularly since the Atlantic and Pacific 'superplumes' (large low-velocity bodies) are not thermal in origin [*Trampert et al.*, 2004] but are instead thought to be largely chemical. Nevertheless, the necessity remains of explaining the low-velocity anomalies under certain hot spots such as Iceland and Eifel, Germany.

Many scientists still consider substantial, broad uplift of the lithosphere to be a robust diagnostic of an arriving plume head. There was disagreement over whether uplift occurred prior to emplacement of large igneous provinces in Russia and India (the Siberian and Deccan Traps). Widespread uplift of the North Atlantic region contemporaneous with ocean opening occurred but was not centered beneath Greenland, the most frequently suggested plume center. A thermal origin for this uplift was nevertheless favored by many conference participants. Debate was vigorous over whether plume or meteorite impact models provide more likely explanations for the circular features on Venus, and LIP volcanism on Mars and Earth.

There was broad agreement that the presence of oceanic island basalt (OIB) is not a plume diagnostic; OIB and OIB-like basalt are often found in places where plumes are not expected. There was also agreement that OIB geochemical signatures derive from recycled near-surface materials, such as ocean crust. High helium isotope ratios are still argued by some to originate in the lower mantle, but it is a limited plume diagnostic since its absence is generally not considered to disprove a plume model.

What is a plume?

Plume advocates tended to favor fewer plumes than have commonly been suggested. Some popular lists involve up to ~50 plumes, but many advocates favored fewer than 10, or even fewer than five. Opinion differed regarding to which hot spots these correspond.

The final synthesis session was led by Ian Campbell (Australian National University, Canberra), on behalf of the plume advocates, and by meeting report co-author Gillian Foulger (Durham University, U.K.), on behalf of the plume skeptics. Campbell summarized his view that any hypothesis for the origin of LIPs must explain the sudden widespread eruption of basalt, high eruption rates, sudden contraction to a narrow volcanic chain, age progression along a chain, high magnesium oxide basalts, and thickened oceanic crust.

Campbell opined that the main problems with the plume hypothesis at some localities are the lack of a linked head and tail and/or the lack of a seismic anomaly beneath some hot spots. In light of the week of presentations and discussions, Foulger again questioned whether the plume hypothesis can be tested if the absence of predicted features (e.g., precursory uplift, petrological evidence for high temperature, or a downward extensive seismic anomaly) was not considered adequate to reject the hypothesis.

Efforts were made to agree on the definition of a plume. A plume is a well-defined fluid-dynamics term, but there were widespread variations in opinion regarding how the term 'mantle plume' should be defined. After considerable debate, the effort to attain agreement faltered. Meeting report co-author W. Jason Morgan (Harvard University, Cambridge, Mass.) expressed his view that the term cannot be defined because all mantle plumes are different. This is the crux of a major objection leveled by skeptics: that the term tends to be defined at individual localities by the local observations and is, in practice, not disprovable.

Plume advocates requested reiteration of the alternatives, which some felt were unclear. Concern was expressed that the alternatives comprise an assemblage of ad hoc models that are different for each locality. Foulger emphasized that a single, generic, one-size-fits-all replacement for the plume model was not envisaged for precisely the reason that Morgan gave for his reluctance to define the term mantle plume—the great diversity of hot spots. Bolide impacts comprise a special alternative theory, but the others share the common element of being linked to shallow, plate-tectonic-related processes that involve lithospheric extension and tapping of mantle made variably fertile by recycled near-surface materials. Beyond this broad commonality, the detailed characteristics of individual melting anomalies are predicted to be related to local features.

The hypothesis that plume arrivals cause supercontinents to fragment implies that plumes play a major role in driving plate tectonics. Morgan reiterated his opinion that plate tectonics is driven by plumes, a minority view among those present.

Future Goals

During the final discussion session, participants identified the primary future research goals in several categories.

- Mantle physics: Development of self-consistent models that can reproduce plate tectonics, and better understanding of critical mantle physical parameters (e.g., core-mantle boundary heat flow, viscosity, and temperature).
- Lithosphere physics: Understanding lithosphere behavior during a major thermal event (e.g., the arrival of a plume or bolide, delamination, or rifting).
- Temperature: Refined geothermometers; improved understanding of the phase equilibria of carbon dioxide-bearing systems, iron and magnesium partitioning between olivine and silicate melt, and understanding melting at various depths.
- Geochronology: More high-quality dates, and reanalysis of important chains and LIPs.
- Seismology: Improved interpretation of seismic anomalies in the mantle and near the core-mantle boundary—are they hot, cool, buoyant, or dense? Understanding material transfer between the upper and lower mantle, and innovative, high-resolution experiments to image the deep mantle.
- Planetary: Testing hypotheses for the circular structures on Venus, and geological evidence for terrestrial meteorite impacts.
- Field evidence: Observations that are diagnostic of proposed formation mechanisms; comparing quantitative models of uplift associated with plumes and rifting; refinement of lists of potential plume localities, and distinguishing cause and effect (e.g., rifting and volcanism).
- Petrology and geochemistry: Improvement of melt generation models to explain diffuse volcanism and the largest LIPs; high-pressure trace-element partition coefficients and eclogite-peridotite interactions; understanding the origins and sources of OIB and OIB-like basalt; and understanding why Hawaiian-like volcanism is unique in the modern geologic record.
- Educational: Communicating the mantle plume controversy to undergraduate geoscience students.

The Great Plume Debate conference was held 28 August to 1 September, 2005 at Fort William in Scotland, U.K.

For additional information, visit http://www.mantleplumes.org/Chapman/Information.html

Acknowledgments

The meeting was organized by Ian Campbell (Australian National University), Gillian R. Foulger (Durham University, U.K.), James H. Natland (University of Miami, Fla.), Dean C. Presnall (University of Texas and the Carnegie Institution), W. Jason Morgan (Harvard University, Cambridge, Mass.), and J. Godfrey Fitton (University of Edinburgh, U K.).

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FORUM

The Congressional Fellowship as an Ethnographic Extravaganza

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I knew my undergraduate degree in anthropology would come in handy one day. I never guessed, though, that with a Ph.D. in geology and two years of postdoctoral experience under my belt (and my anthropology days far behind), AGU would choose me for a year-long, total-immersion ethnographic extravaganza of my very own.

I have been dropped into the proverbial wilds, to live among the natives to attempt to understand their culture in all its byzantine ritual, hierarchy, and ceremony.

This is more than an academic exercise. Those I study are powerful indeed; their reputations as primitive brutes precede them. And yet here I am, and merely surviving is not enough. I must strive to assimilate into this fiercest of human tribes ever to walk the Earth.

I speak, of course, of the U.S. Congress.

As any good ethnographer knows, to attempt such a feat without proper preparation is folly. Fortunately, in early September, the American Association for the Advancement of Science provided my 'fellow fellows' and me with an informative orientation. Over the course of two intense weeks, we were immersed in the language and culture of the federal government, provided with historical perspective, and given guidance in mores, values, and ethics. I felt my perspective changed before I had even entered a congressional office building.

But regardless of how well-prepared any ethnographer feels, there is no avoiding the disarming moment when he or she is cut loose from civilization. That moment came when orientation ended and we began 'placement'—a free-for-all of several weeks duration when fellows seek offices to work in for the year. That chaotic but fascinating period ended for me in early October when, after interviewing in about a dozen offices—in the Senate and the House of Representatives, and personal and committee offices—I chose the office of Sen. Dianne Feinstein (D-Calif.) and began full-time work.

Thus far, the learning curve has been steep and the hours long, but the work is challenging and rewarding. I attend committee hearings; meet with constituent groups; draft letters, speeches, and talking points; write memos for the senator; and research legislative issues. Much of the research involves talking to people, a true culture shock compared with the solitary nature of most science.

I have already dealt with a large range of scientific matters, from geoscience issues such as naturally-occurring asbestos and seismic safety to areas far outside my expertise, such as air pollution standards and forestry. Yet in this setting, all scientific matters—regardless of my inherent comfort level with the subject—have something of a foreign feel as I approach them with specific policy questions in mind.

I am slowly developing an understanding of several fundamental aspects of congressional culture: hierarchy (how a congressional