A brief history of the plume hypothesis and its competitors: Concept and controversy

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ABSTRACT
The modern plume hypothesis began as a concept for a special form of thermal convection in which narrow, geographically well-defined regions of upwelling are balanced by diffuse downwelling in a manner similar to atmospheric phenomena such as thunderheads (Morgan, 1972b). These narrow active upwellings were an alternative to giant convection cells (e.g., Holmes, 1929, 1944; Hess, 1962); they drove plate tectonics and fueled the asthenosphere. The number of plumes has varied from the original "~20" to recent estimates of 5200 for the number of moderate-sized plumes and 6 or so for the number of "primary" plumes; this suggests some uncertainty in what constitutes a plume. Tozer (1973) showed that what geologists had in mind for mantle upwellings could not be the same as fluid dynamic plumes and could not be explained by the same physics. The effects of pressure on material properties reinforce these conclusions. Interest in various versions of the diapir and plume hypotheses peaked in 1950, 1970, and especially 1990, but these versions fell into disfavor or disinterest in the intervening years because of various paradoxes, contradictions, and increasing interest in alternative mechanisms. The physical basis of plumes was questioned, and still is. Since 1990 specialists in diverse disciplines have adopted the plume hypothesis in spite of the various paradoxes and the still outstanding lack of a physical basis under conditions appropriate for the Earth's mantle. In this highly selective view of the history of explanations for "melting anomalies" we focus on the underlying assumptions, physics, and philosophy and on key turning points in that history. We concentrate on the anomalies, neglected physics, petrology, and deep mantle aspects rather than on the better-known tectonic, geochronological, and geochemical ones. We also discuss briefly the alternatives to the plume hypothesis.

A primary assumption of the plume hypothesis is that the mantle is to the first order composed of a homogenous lherzolite or pyrolite. Mantle homogeneity is the cornerstone of petrological models that attempt to estimate the potential temperature and magma productivity of the mantle. A general theory of plate tectonics, one that involves recycling, incipient and reactivated plate boundaries, and ephemeral plates, may remove the necessity to have different theories for plate tectonics, large igneous provinces, and linear island chains. Cooling of the mantle from above, and forces from cooling plates and subducting slabs, may be adequate to drive the plates, break the plates, close up or reactivate plate boundaries, reorganize plates, and drive underlying mantle flow. In such a scenario the mantle—variable in fertility and melting point because of recycling—is by and large passively responding to gravitationally driven motions of the top; dikes and plate boundaries are the result of variable stress in the lithosphere, and melting anomalies reflect the variable fertility of the underlying mantle.