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The 2016 Case for Mantle Plumes and a Plume-Fed Asthenosphere (Augustus Love Medal Lecture)

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The process of science always returns to weighing evidence and arguments for and against a given hypothesis. As hypotheses can only be falsified, never universally proved, doubt and skepticism remain essential elements of the scientific method. In the past decade, even the hypothesis that mantle plumes exist as upwelling currents in the convecting mantle has been subject to intense scrutiny; from geochemists and geochronologists concerned that idealized plume models could not fit many details of their observations, and from seismologists concerned that mantle plumes can sometimes not be 'seen' in their increasingly high-resolution tomographic images of the mantle. In the place of mantle plumes, various locally specific and largely non-predictive hypotheses have been proposed to explain the origins of non-plate boundary volcanism at Hawaii, Samoa, etc. In my opinion, this debate has now passed from what was initially an extremely useful restorative from simply 'believing' in the idealized conventional mantle plume/hotspot scenario to becoming an active impediment to our community's ability to better understand the dynamics of the solid Earth. Having no working hypothesis at all is usually worse for making progress than having an imperfect and incomplete but partially correct one. There continues to be strong arguments and strong emerging evidence for deep mantle plumes. Furthermore, deep thermal plumes should exist in a mantle that is heated at its base, and the existence of Earth's (convective) geodynamo clearly indicates that heat flows from the core to heat the mantle's base. Here I review recent seismic evidence by French, Romanowicz, and coworkers that I feel lends strong new observational support for the existence of deep mantle plumes. I also review recent evidence consistent with the idea that secular core cooling replenishes half the mantle's heat loss through its top surface, e.g. that the present-day mantle is strongly bottom heated. Causes for discrepancies between idealized plume/hotspot models and geochronological observations will also be briefly discussed.

A further consequence of the existence of strong deep mantle plumes is that hot plume material should preferentially pond at the base of the lithosphere, draining towards and concentrating beneath the regions where the lithosphere is thinnest, and asthenosphere is being actively consumed to make new tectonic plates — mid-ocean ridges. This plume-fed asthenosphere hypothesis makes predictions for the structure of asthenosphere flow and anisotropy, patterns of continental edge-volcanism linked to lateral plume drainage at continental margins, patterns of cratonic uplift and subsidence linked to passage from hotter plume-influenced to cooler non-plume-influenced regions of the upper mantle, and variable non-volcanic versus volcanic modes of continental extension linked to rifting above '$\sim$1425K cool normal mantle' versus 'warm plume-fed asthenosphere' regions of upper mantle. These will be briefly discussed. My take-home message is that "Mantle Plumes are almost certainly real". You can safely bet they will be part of any successful paradigm for the structure of mantle convection. While more risky, I would also recommend betting on the potential reality of the paradigm of a plume-fed asthenosphere. This is still a largely unexplored subfield of mantle convection. Current observations remain very imperfect, but seem more consistent with a plume-fed asthenosphere than with alternatives, and computational and geochemical advances are making good, falsifiable tests increasingly feasible. Make one!