What is a "Typical" Mantle Plume?

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Process models for mantle plumes, and indeed arguments for the existence of mantle plumes, are largely based on expected characteristics for these upwelling features. Typically plume models have large heads (>500 km), moderately slender tails (~100 km), uniform compositions (lower to upper mantle/Lherzolite), and high excess temperatures (200 °C or more). Here we present laboratory models of mantle convection with recycled, chemically laminated lithosphere which reveal a diversity in size, composition, temperature and both surface geological and geophysical expressions. Results suggest there is no typical mantle plume, but rather a range in plume classes. Examples from within the different classes can readily explain the diversity in plume surface expressions, from large igneous provinces with associated tails (time progressive island chains), to headless plumes and large (or small) headed plumes with no tails. The traditional large headed, uniform composition, high excess temperature plume was rarely seen in the 25 experiments conducted to date. Laboratory models utilized a glucose syrup (Ra=$10^5 \div 10^6$) for a working fluid. Mixtures of syrup and water were used to introduce density and viscosity contrasts between the ambient fluid and a dyed, chilled and layered slab representing recycled lithosphere. Generally, one layer of the slab was less dense than the ambient fluid (representing Harzburgite) and one layer was denser than the ambient fluid (representing Eclogite). A thermal boundary layer was developed at the base of a 20×20×15 cm tank by uniform basal heating. Interaction between the slab layers and fluid within the thermal boundary layer had a strong influence over the distribution of thermochemical heterogeneity within upwelling plumes. A range of repeatable plume styles emerged from this study. One prominent plume style is characterized by upwellings growing shortly after slabs enter the thermal boundary layer. These plumes are Harzburgite-rich and range from cooler (~100 °C) than ambient mantle to nearly equivalent with background temperature. Two common forms of chemical heterogeneity are seen, one in which these plumes have a thin (~10 km), Eclogite core. Plumes of this type that form from the edge of a slab pile have near perfect bilateral symmetry, containing half Harzburgite and half Lherzolite material from within the thermal boundary layer. Another common style of upwelling is recorded over a range of parameter combinations and occurs well after recycled material has reached and spread within the thermal boundary layer. These are hotter plumes (~200—400 °C excess temperature) with predictable distributions of both slab components (Harzburgite and Eclogite) and ambient thermal boundary layer material (Lherzolite). Length scales of thermochemical heterogeneity range from 1 km to >100 km depending on chemical density contrasts and local processes of instability formation within the basal boundary layer. A number of cases from distinct upwelling classes are digitized and used to drive synthetic melting and seismic models. Results show that more typical "plume-like" patterns can occur, but more commonly cases show extreme spatial and temporal discontinuities in melt production and seismic velocity patterns.