Compressible thermo-chemical convection and application to lower mantle structures

Eh Tan[1] and Mike Gurnis[2].
[1] Seismological Laboratory, California Institute of Technology (now at Computational Infrastructure for Geodynamics, California Institute of Technology)
[2] Seismological Laboratory, California Institute of Technology

A new finite element code for compressible thermo-chemical convection is developed to study the stability of a chemical layer at the base of the mantle. Using composition-dependent compressibility and a density difference between compositions at a reference pressure, a composition-dependent density profile is derived. Together with depth-dependent thermal expansion, this combination of parameters yields a wide range of dynamic evolutions for the chemical layer. The chemical structures are classified into five major categories, classical plumes, mushroom-shaped plume, domes, ridges, and continuous layers, and a few abnormal cases, such as hourglass-shaped plumes and columnar plumes. Several models have a chemical structure morphologically similar to the African low V_S structure in the lower mantle, at least at a single time. Guided by our models, several dynamic scenarios are proposed for the dynamic nature of the lower mantle low velocity structures (a.k.a. superplumes), including plumes at an early stage, plume clusters, ridges, passive piles, sluggish domes, and high-bulk-modulus domes (Figure 1). We predict seismic velocity anomalies from these dynamic models. The thermo-elastic parameters used in the conversion are additional constraints. We compare the density structure with normal mode inversion, the predicted seismic signature observations, and the required thermo-elastic parameters with mineral physics data. Among the proposed scenarios, only the scenario of high-bulk-modulus domes satisfies all constraints simultaneously. The implication on the geochemistry and mineralogy of lower mantle chemical structures is discussed. (This work is published on *J. Geophys. Res.*, Vol. 112, B06304, doi:10.1029/2006JB004505, 2007)

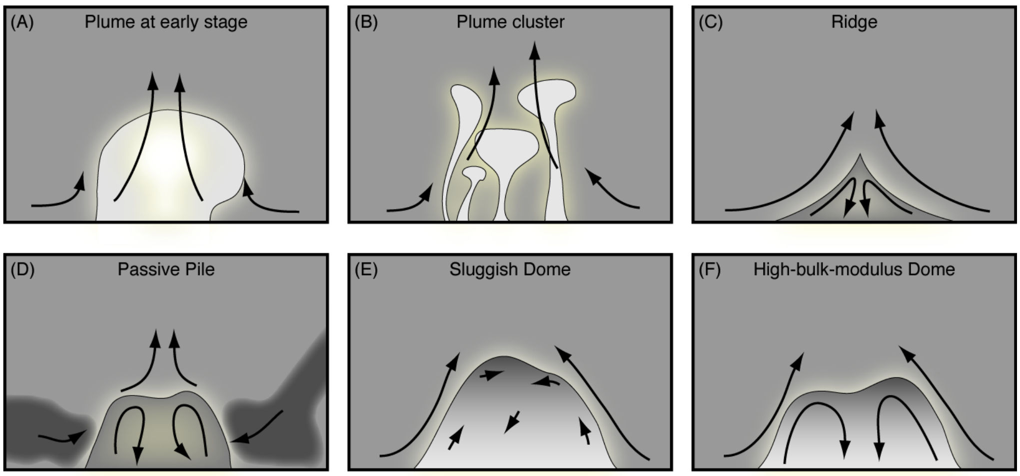

Figure 1: Various dynamic scenarios for the African low V_S structure. The gray scale indicates the density anomaly. Darker is denser. The arrows indicate the direction and speed of the flow. (A) A large, buoyant plume at early stage, (B) a cluster of small plumes merging together, (C) a stable ridge-shaped chemical structure, (D) a stable chemical pile passively displaced by dense slabs, (E) a stable chemical dome made of high-bulk-modulus material, and (F) a stable chemical dome made of high-viscosity material.