Chemical heterogeneities transported by mantle plumes

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Geochemical and petrological observations indicate that recycled oceanic crust is carried to the surface by mantle plumes. Here we present laboratory experiments and numerical simulations that explore how mantle plumes transport, deform and stir compositionally denser, or more viscous, heterogeneities. We address the following questions: (1) How do active heterogeneities modify the axially symmetric velocity field of the plume conduit? (2) Under which conditions the azimuthal zonation of the source region is no longer preserved in the plume stem? (3) How do heterogeneities deform during upwelling and what is their shape once at sublithospheric depths? Our laboratory experiments use Particle Image Velocimetry to calculate velocities, and liquid crystals to calculate the temperature field, whereas the 3D simulations use millions of active tracers to keep track of the heterogeneous fluid. For compositionally denser heterogeneities we span a range of buoyancy ratios (B) and show that for increasing B the heterogeneity tends to spread at the base of the plume stem and to upwell as a tendril close to the axis, so that the initial zonation may be poorly preserved. For intrinsically more viscous heterogeneities we span a range of viscosity ratios (λ), and find that for increasing λ the shape of the heterogeneity transitions from filament-like to blob-like. Finally, we calculate the transit time of heterogeneous material within the plume melting zone and discuss the applicability of our results to a variety of hotspots, both in the Pacific and in the South Atlantic, where geochemical zonation is observed.