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Regimes of plume-slab interaction and consequences for hotspot volcanism

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"Hotspot" volcanism is generally attributed to upwelling of anomalously warm mantle plumes, the intra-plate Hawaiian island chain and its simple age progression serving as an archetypal example. However, interactions of such plumes with plate margins, and in particular with subduction zones, is likely to have been a common occurrence and leads to more complicated geological records. Here we present results from a series of complementary, three-dimensional numerical and laboratory experiments that examine the dynamic interaction between negatively buoyant subducting slabs and positively buoyant mantle plumes. Slab-driven flow is shown to significantly influence the evolution and morphology of nearby plumes, which leads to a range of deformation regimes of the plume head and conduit. The success or failure of an ascending plume head to reach the lithosphere depends on the combination of plume buoyancy and position within the subduction system, where the mantle flow owing to downdip and rollback components of slab motion entrain plume material both vertically and laterally. Plumes rising within the sub-slab region tend to be suppressed by the surrounding flow field, while wedge-side plumes experience a slight enhancement before ultimately being entrained by subduction. Hotspot motion is more complex than that expected at intraplate settings and is primarily controlled by position alone. Regimes include severely deflected conduits as well as retrograde (corkscrew) motion from rollback-driven flow, often with weak and variable age-progression. The interaction styles and surface manifestations of plumes can be predicted from these models, and the results have important implications for potential hotspot evolution near convergent margins.