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Plume-ridge interaction with nonlinear rheology: Formation of narrow(er) plume-ridge channels

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Substantial geophysical and geochemical evidence suggests that mantle plumes can interact with mid-ocean ridges up to 1000 km away via a connecting channel. Here we use asymptotic lubrication-theory and 3-D thermomechanical models to test the hypothesis that channeling is favored by non-Newtonian shear-thinning rheology, which inhibits lateral spreading of buoyant plume material at its edges where the strain rate is low. In our models a plume with buoyancy $g\Delta\rho$ and volume flux Q rises and spreads to form a thin pool in a background flow generated by a ridge with half-spreading rate U and migrating with speed U_m. The viscosity of the plume fluid is $\eta = BI^{(1/n)-1}$, where B is the stiffness, I is the second invariant of the strain rate tensor, and n is the power-law index. Scaling analysis of the lubrication equation shows that the width of the plume pool scales as $W \sim Q^{2/3}\left(\sigma/U^{2n+3}\right)^{1/(3n+3)}$, where $\sigma = (g\Delta\rho/B)^n/(n+2)(n+3)$ is the 'spreadability'. Numerical solutions of the lubrication-theory and 3-D thermomechanical equations shows that plume pools are 35-40% narrower for non-Newtonian rheology with $n = 3.5$ than for Newtonian rheology ($n = 1$). We will present a comparison of our model predictions with recent seismic inferences of a channel connecting the Réunion hotspot with the Central Indian Ridge.