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Geodynamic models of mature continental collision: Evolution of an orogen from lithospheric subduction to continental retreat/delamination

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The behavior of deep lithospheric processes in continental collision are frequently speculated on, but poorly understood. In this study we build on previous work to explore the styles of continental lithosphere deformation during mature collision where 1800 km of convergence has been accommodated by horizontal shortening. We conducted a suite of geodynamic experiments that test the sensitivity of mature continent collision to varying mantle lithosphere density, mantle lithosphere yield stress and to the presence of phase change-related density changes in the lower crust (i.e., eclogitization of mafic lower crust). The models suggest that the early stages of collision are accommodated by subduction of lower crust and mantle lithosphere along a discrete shear zone beneath the overriding plate. Following this initial stage of subduction, the subducting lower crust and mantle lithosphere can retreat from the collision zone, permitting the sub-lithospheric mantle to upwell and intrude the overriding plate. As a result, the lower crust and mantle lithosphere of the overriding plate delaminate from the overlying crus. With isostatic compensation, subduction- and delamination-driven crustal processes plateau-like uplift occurs. The sub-crustal evolution also causes bands of syn-convergent crustal extension to develop. In models with a rheologically weaker lower crust, surface crustal response to the deep lithosphere dynamics becomes more diffuse. As an example, the numerical experiments satisfy a number of surface observables of the Himalayan-Tibetan orogen, namely: 1) the current general mantle lithosphere architecture as defined by seismic analyses; 2) the long-wavelength plateau uplift of the western Tibetan Plateau; 3) the surface heat flow measurements in India, the Tethyan Himalaya, Qiangtang and in Qaidam basin; and 4) the anomalous syn-convergent extension in the southern portion of the orogen.