Structures and properties of Tibetan lithosphere control the India-Asian collision and plateau evolution: Numerical modeling

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Lithosphere delamination is believed to have played a major role in mountain building and also in the Tibetan plateau evolution; however, the styles and dynamics of delamination remain poorly understood. Using high-resolution thermo-mechanical models, we systematically investigated the conditions for the initiation of lithosphere delamination during orogenesis of continental collision and explored the key factors that control the various modes of delamination. Our results indicate that the negative buoyancy from lithosphere thickening during orogenesis could cause delamination, when the reference density of the lithospheric mantle is not lower than that of the asthenosphere. In these cases, compositional rejuvenation of depleted continental lithosphere by magmatic/metasomatic plume- and/or subduction-induced processes may play crucial roles for subsequent lithosphere delamination. If the reference density of the lithospheric mantle is less than that of the asthenosphere, additional promoting factors such as lower crustal eclogitization are required for delamination to occur. Based on systematic numerical simulations, three basic modes of lithosphere delamination are predicted: pro-plate delamination, retro-plate delamination, and a transitional double-plates (both pro- and retro-plate) delamination. Pro-plate delamination is favored by low convergence rates, high lithospheric density and a relatively strong retro-plate, whereas retro-plate delamination requires a weak retro-plate. The Central-Northern Tibetan plateau is a possible geological analogue for the retro-plate delamination modes. Our model also shows significant impact of delamination on the topographic evolution of orogens. Large-scale lithosphere delamination in continental collision zones would lead to wide and flat plateaus, whereas relatively narrow and steep mountain belts are predicted in orogens without major delamination.

In the previous study, the Tibetan plate is generally considered as a homogeneous block. However, the Tibetan plateau is also manifested by contrasting along-strike lithospheric structures, the formation mechanism of which and its relationship with the heterogeneous multi-terrane structure of the Tibetan plate is a challenging problem. Here, we further conducted systematic numerical models to explore the role of geometric width, density and rheological properties of the multi-terranes in the lithospheric evolution of Tibetan plateau, which reveal two distinct collision modes. In Mode-I, the lithospheric mantles of both the strong and weak terranes in the Tibetan plate are completely delaminated, followed by the underthrusting of Indian lithosphere beneath the whole plateau. Alternatively, Mode-II is characterized by full delamination of the weak terrane, but (partial) residue of the strong terrane during collision. Both contrasting modes, broadly consistent with the deep structures of western and central–eastern Tibetan plateau, respectively, are strongly dependent on the along-strike changing width of the strong Lhasa–Qiangtang terranes.

Based on these systematic numerical models, many geodynamic problems related to the India-Asian collision and Tibetan plateau evolution are discussed and systematically compared with the widely geological and geophysical observations.