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Numerical models of Indian plate underthrusting after slab break-off: controls on Himalayan-Tibetan tectonics

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Tomographic images show that the Indian lithosphere lies sub-horizontally beneath the southern part of the Tibetan Plateau. However, the evolution of the India-Eurasia collisional system that formed the present-day crustal and lithospheric structure is unclear. We used three-dimensional numerical models of continental collision to investigate the dynamics of underthrusting of the Indian lithosphere and what consequences this might have on the topographic, structural and thermal evolution of the broad collision zone. Moreover, we performed a parametric study varying initial plate geometry and rheology to study the viability of underthrusting in different collision setting scenarios.

Our modelling results show that initially the Indian continental plate subducts at $\sim$45 degree dip, and that after oceanic slab break-off occurs (at least 10 Myr after initial collision), it may rise back towards the surface and underthrust the Eurasian plate. This process can result in the formation of a thick horizontal layer of continental crust that extends for about $\sim$300 km from the suture zone under the overriding Eurasian plate. This scenario fits very well with the proposed deep structure of the area inferred from geophysical observations. Interestingly, we find that this process of underplating after slab break-off happens only if an external force pushes the subducting plate towards the overriding plate, consistent with a far field driver from the Réunion plume or ridge push.

We observe a sharp peak in the effect on overriding plate topography right after the occurrence of slab break-off. Afterwards, during underplating, the maximum topographic effect is lower, but the area with high topography is much larger (up to 200 km across). Precise contributions to elevation are parameter-sensitive, but this pattern of a northwards-migration of the topographic effect seems robust. As the Indian continental lithosphere rises, its temperature decreases at the top of 100 – 250ºC through time. At the same time, however, the deepest part of the subducted continental crust gets hotter reaching temperatures of $\sim$900ºC. Moreover, the overriding mantle wedge progressively migrates northwards away from the trench and eventually disappears. This pattern matches the observed northward migration of volcanism.