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Effects of subducting plate geometry and erosion on overriding plate deformation at plate corners (syntaxes)

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Regions of rapid and focused exhumation have drawn wide scientific interest over the years. Most notable are the Himalayan syntaxes, Namche Barwa and Nanga Parbat, as well as the St. Elias region (Alaska), where sustained exhumation rates exceeding 5 km/Myr have been measured. These regions lie above plate corners, where changes in the subducting plate geometry create a short, convex bend. This unique 3D geometry and associated flexural stiffening of the subducting plate have been discussed as possible drivers for such high erosion rates in previous studies. However, other similar plate corners show no signs of rapid exhumation (e.g., Arica Bend (Peru/Chile)). Another proposed mechanism at plate corners is crustal weakening initiated by focused (climate driven) erosion. To resolve this apparent discrepancy in tectonic versus climate-induced rapid exhumation we evaluate both effects using numerical models.

In this study, we use a fully coupled thermo-mechanical numerical model (DOUAR) to investigate deformation rates, the pattern of upper plate deformation and predicted thermochronometric cooling ages under changing boundary conditions and erosion scenarios. Our model is characterized by a central indenter in the rigid subducting plate, which approximates the flexural stiffening caused by the 3D geometry at plate corners. The effect of this feature on deformation rates and overriding plate deformation is investigated by varying the tectonic boundary conditions, specifically the rates of slab advance and subduction. In order to identify the effects of erosion, models with flat and more realistic fluvial erosion are compared.

We find that the forward-bulging indenter causes a change in strain localization in its vicinity and facilitates the formation of a crustal-scale basal detachment, as long as subduction of the down-going plate is active. This structure leads to localized and rapid upper plate uplift above the indenter apex, with focused uplift occurring over a 100x300 km elliptical region. Fluvial erosion modulates uplift rates by the creation of additional lithostatic overpressure as the orogen grows. In areas where tectonic forcing coincides with high erosion potential, deep-seated and rapid rock uplift is focused on an even smaller scale (<100 km). We conclude that a combination of both localized, subduction geometry driven, uplift and rapid erosion are necessary to create the areas of focused uplift observed in nature.