How far can the plateau lower crust flow? Ask Ellipsis!

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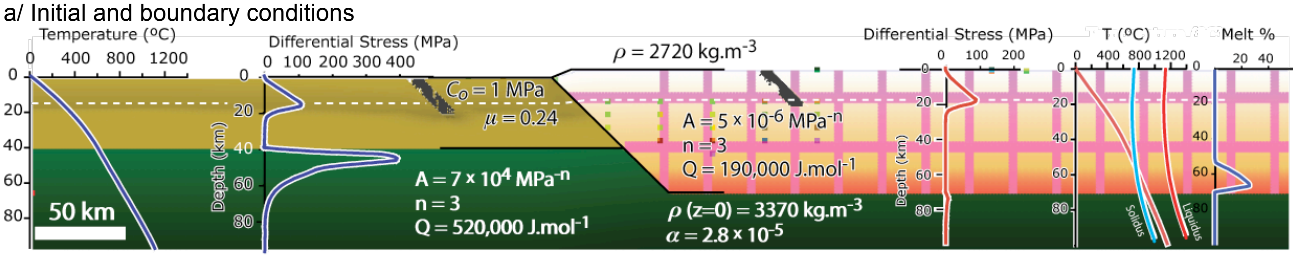
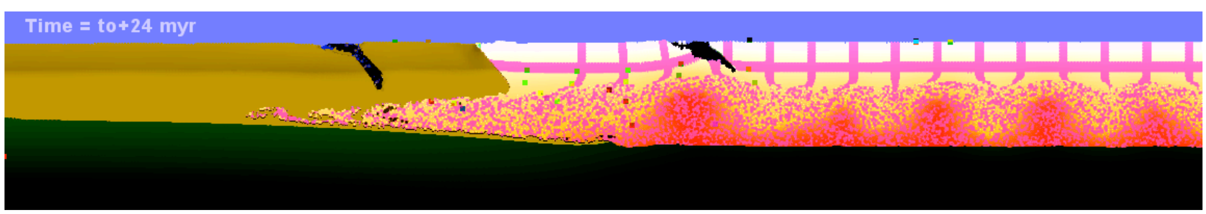
Gravitational potential energy stored in an orogenic plateau can be sufficiently strong to deform the surrounding region (foreland), hence contributing to both plateau growth and collapse. Gravity-driven channel flow from the plateau lower crust into the foreland lower crust, called channel extrusion, has been proposed as a main contributor to the eastward growth of the Tibetan plateau, possibly driving the lower crustal channel as far as 1000 km. On the basis of numerical modeling using temperature-dependent viscosities and densities, we investigate channel flow extrusion and its impact on the stability of orogenic plateau.
The 400 km wide plateau region is made of a 70 km thick crust, which stands 4500 m above the foreland region for which continental crust is 40 km thick. In both the foreland and the plateau, the strong upper crust is made locally weaker by introducing a fault-shaped rheological anomaly. Viscous creep is modeled assuming both dislocation creep and diffusion creep. The lower crust of the plateau region is partially molten, which makes it more buoyant.

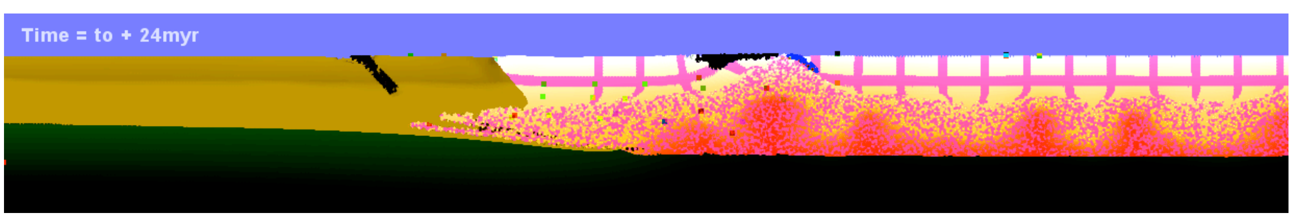
a/ Initial and boundary conditions



b/ Fixed boundary collapse: The velocity in the channel decreases from a few cm to a few mm per year in a few myr, due to cooling and crystallization of the channel as it travels through the cooler foreland. Soon after, the plateau channel starts to convect inhibiting further the laminar flow that was driven the plateau lower crust into the foreland. Under the gravitational push from the plateau, extension in the plateau focuses along a normal fault, which controls the exhumation of an incipient metamorphic dome. After 24 myr, the channel has traveled at most 150 km into the foreland.



c/ In this experiment, the foreland is moving to the left at 2.3 mm per year (strain rate 10^{-16} s^{-1}). It shows that a modest boundary-driven extension activates zones of weakness in the plateau region, promoting the development of Metamorphic Core Complexes (MCC). Surface extension in the plateau provides a shortcut to the surface for the weak plateau channel, which flows into the growing MCC, inhibiting the channel flow extrusion into the foreland. Vigorous erosion along the plateau margins would have the same inhibiting effect on channel flow extrusion. After 24 myr, the channel has traveled at most 75km into the foreland.



Within the limits of our model, the length scale of the extrusion channel is an order of magnitude less than what has been proposed for eastern Tibet (i.e. 100 km rather than 1000 km). Overall, our models cannot account for hundreds of km of channel flow extrusion as large magnitude channel flow extrusion is inhibited by any one of the following processes: cooling of the extrusion channel; convective motion in the plateau channel; and surface extension in the plateau providing a shortcut to the surface for the weak plateau channel. Results point also to a general incompatibility between coeval channel flow extrusion and the formation of metamorphic core complexes or aggressive localized erosion.

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