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Dynamic coupling among channel flow, plateau growth, foreland shortening, and the formation of metamorphic core complexes: Application to the Tibetan plateau

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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, or channel extrusion, has been proposed as a main contributor to the eastward growth of the Tibetan plateau, possibly driving the lower crust channel as far as 1000 km beneath the foreland (eg. Royden et al., 2008). On the basis of numerical modeling using temperature-dependent viscosities and densities, we show that four processes impose severe limitations to channel extrusion: (1) cooling of the extruded channel, (2) convective motion in the plateau channel, (3) surface extension of the plateau, and (4) erosion of the plateau edge.

Model results show that peak velocities in the extrusion channel drop rapidly (in less than a few My) from ca. 5 cm/year to less than 1 cm/year, owing to the rapid cooling in the channel from 750-850ºC to 650-550ºC as it travels into the foreland region. Channel flow extrusion is further slowed when convective flow initiates in the plateau channel as a result of only a few percent drop in density. This convection inhibits laminar flow in the channel, reduces the peak horizontal velocity in the channel to a few mm, and even drives a counter flow at the base of the channel, preventing its propagation toward the foreland. If the foreland is actively pulled away from the plateau (extending boundaries), the plateau upper crust undergoes extension and the lower crust moves up efficiently into a metamorphic core complex, which inhibits flow of the channel away from the plateau and even generates a counter flow from the foreland to the metamorphic core complex. If the foreland is fixed, the same phenomenon occurs as long as the foreland upper crust undergoes shortening (likely weakened by high pore fluid pressure), which enhances extension of the plateau and upward flow of the channel. Previous studies (eg. Beaumont et al, 2001) have already emphasized the importance of aggressive erosion of the plateau edge as a process able to remove a section of the plateau upper crust, providing space for the plateau lower crust to flow into. Together, these numerical experiments demonstrate the dynamic link that exists between plateau and foreland through the behavior of a low-viscosity channel. For the cases studied, the length scale of channel extrusion is 100 km in the most favorable conditions, and not 1000 km as previously suggested.

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