2003 Fall Meeting
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TI: Rheological Consequences of Rapid Erosion in Active Orogens

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AB: It has long been recognized that erosion can influence the geodynamics of an orogen by redistributing mass. However, only recently has it become appreciated that rapid exhumation can locally alter the three-dimensional thermal structure of the crust, profoundly changing its rheology and weakening portions of the crustal profile. This process in turn permits feedbacks between erosion, rheology, and deformation. Specifically, based on geological and geophysical observations at Nanga Parbat in the northwestern Himalaya, we have proposed the "tectonic aneurysm" model, in which significant erosion (at Nanga Parbat, along the large Indus River valley) is sufficient to weaken the crust and divert crustal flow into the region. This in turn facilitates coupled rock uplift and erosion, which further weaken the crust as the shallow thermal gradient steepens, localizing and enhancing deformation. Geological observations at the Nanga Parbat antiform in support of this model include a concentric distribution of metamorphic facies distribution with high-T/low-P granulites at the center, a bulls-eye distribution of very young cooling ages and Neogene decompression melts, and the prevalence of compressional deformation for all young and active structures (which young towards the interior of the antiform). Geophsyical data in the form of dense seismic tomography, distribution of microseismicity, and magnetotelluric measurements document a volume of warm, weak, and resistive crust localized beneath the antiform, none of which appears to be molten to any significant degree. Three-dimensional mechanical models of active incision into a lithosphere with thermally activated lower crust can initialize the

aneurysm behavior when fluvial incision occurs along a valley with approximately the same width as the thickness of the frictional upper crust. As the aneurysm grows through positive feedback of advective heating and thermal weakening, the rheological effect becomes dominant over the topographic effect of the incising valley and extreme topography can result. The implications of aneurysm behavior for the integrated strength of a lithosphere with a thermally activated lower crust arise from the sensitivity of integrated strength to the square of the thickness of the upper frictional layer. Aneurysm behavior observed in the Himalayan syntaxes imposes constraints on the rheology of the lower crust as well. In order to concentrate vertical displacement into the thermally weakening region, the lower crust must not be relatively weak, precluding a widespread zone of partial melt within the lower crust upstream of the aneurysm. In general, we hypothesize that the rheology and morphology of convergent plate boundaries will be strongly influenced by any mechanism of localized voracious erosion. In the somewhat different tectonic setting of the eastern Himalayan syntaxis, similar large-magnitude surface processes seem to be producing an antiformal structure localized at Namche Barwa near the dramatic knickpoint on the Tsangpo River. The presence of extreme topography at a plate corner, preliminary field observations, and geochronological measurements suggest development of aneurysm behavior is occurring here as well. The St. Elias Range in southeastern Alaska, developed in the presence of strong coupling between glacial erosion and local uplift related to oblique plate convergence, represents another case where we would predict such behavior.

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