Strong Basins and Weak Uplifts: Examples from the foreland of the Laramide (North America) and Himalayan (central Asia) orogenies

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Throughout the foreland of many orogenic belts, there is a observation of relatively undeformed basins surrounded by highly deformed uplifts. Faulting is generally concentrated in these uplifts, but is much less common in the basins away from the uplift edges. We apply an analog model for the strength of sedimentary basins to explain this pattern in both the Rocky Mountain foreland (Laramide) of North America and the Tarim and Jungar basins of China.

Strength of sedimentary basins has been investigated using simple physical models. In an important but not widely cited article Cobbold et al. (1993, Sed. Geol.), demonstrated a positive feedback loop in which erosion of uplifts and sedimentation in adjacent basins both enhances uplift and inhibits basin deformation. Erosion and sedimentation of an internally drained basin were simulated by removing material from the topographic highs and depositing sediments into the basins. The resulting basins often quickly buried the same thrust sheets that provided their earlier sedimentation, and new thrusts subsequently developed farther toward the interiors of the uplifts. The observation in the models is that deformation is increasingly concentrated in the uplifts and decreased in the basin. It is suggested that lithospheric strengthening is accomplished by thickening the upper crustal layer in sedimentary basins, and weakening is accomplished by thinning crust in uplifts.

In a more complex system, a thermal effect from the sedimentation in the basin could be expected to further increase their lithospheric strength, as rapid deposition of sediments causes the depression of isograds. Cooler basins are thus strengthened, and are less likely to deform further. Thus, sedimentation increases the lithospheric strength by creating a stronger upper crust, until a new thermal equilibrium is reached. Consequently, a positive feedback loop is expected between sedimentation and crustal strength.

The Rock Springs uplift (WY)/Douglas Creek arch (CO) are primarily Late Cretaceous (Laramide) uplifts developed in the Rocky Mountain foreland of North America. Of the Laramide uplifts, these are the closest to the Sevier thrust front, and differ significantly from uplifts farther into the foreland (e.g., Front Range uplift) in that they exhibit much lower amplitude antiformal arches in Paleozoic–Mesozoic strata and do not expose Precambrian crust at the surface. We attribute their comparatively undeformed nature to their position in the foredeep of the thin-skinned Sevier thrust front, and suggest that the thickened foredeep sedimentary basin fill apparently acted to dampen deformation. The multiphase Tarim and Jungar basins of China show similar patterns of resisting deformation. During the late Cenozoic Himalayan orogeny, these internally-drained basins received thick blankets of nonmarine clastic sediments, shed from the adjacent Kunlun Shan, Tian Shan, and Altay Shan mountain ranges. The interior of each basin contains major contractional to transpressional faults and folds inherited from late Paleozoic tectonic amalgamation of central Asia. Superjacent Mesozoic and Cenozoic successor strata overlap the late Paleozoic structures and continue across each basin. Unlike the highly deformed uplifts that bound these basins, Cenozoic strata in the basin interiors are almost entirely undisturbed by deformation related to the Himlayan orogeny.

Deformation of these sediments is limited to relatively basin-marginal fold and thrust belts, that appear to be genetically related to the shortening within the intervening mountain ranges. The superposition of undisturbed Cenozoic strata over previous zones of structural weakness therefore indicates that these basins have actually become stronger with time, coincident with rapid and sedimentation.