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The roles of glaciers and rivers in Late Cenozoic increase of relief in the Colorado Front Range and the Sierra Nevadas

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The most obvious regional to global change in the late Cenozoic has been the occupation of the surface of the earth by major glaciers, both in the form of alpine glaciers, and ice sheets. We therefore seek to know how these might drive changes in the detailed topography of mountain ranges, and changes in the rock uplift rates within them.

Because glaciers are efficient engines of erosion, late Cenozoic glaciers have left a strong signal in the headwaters of many mountain ranges. The erosional products of glaciers have been passed downstream to the fluvial system, influencing the erosion of bedrock channels in several ways. In addition, the inevitable isostatic response to erosional unloading of the headwaters can incite tilting of the channels even well outboard of the range margins, aiding in the exhumation of adjacent basins. While other geophysical mechanisms can incite rock uplift patterns, the erosionally driven signal can and should be quantified. I focus on examples from Colorado's Front Range and the southern Sierra Nevadas, the former most certainly tectonically dead, the latter perhaps experiencing rejuvenation associated with delamination of a dense lower crustal root.

The first order signature of glacial occupation of an alpine landscape is the flattening and widening of valley floors upstream of the glacial limit. This is most easily explained as reflecting the longitudinal pattern of ice discharge in the valley, which vanishes at headwall and terminus, and reaches a maximum at the ELA. The detailed erosion pattern is dictated by the topology of the system. As this is inherited from the fluvial drainage pattern, and is therefore branching in nature, the pattern of ice discharge per unit valley width shows a strong maximum below the major confluences.

This causes a broad step in a typical valley profile and separates more or less rolling bedrock morphology from the classic U-shaped trough.

In both the Sierras and several of the Laramide Ranges of the American West, convexities in the longitudinal profiles reveal that many streams within the ranges are in a transient state of adjustment to both the glaciations in the headwaters (their upper boundary condition), and to alteration of the master streams to which these are tributary (their lower boundary condition). Lowering of the base level in the master stream, for whatever reason, sends a wave of incision up the tributaries, its progress denoted by the location of the convexity. The low susceptibility to erosion in these crystalline rocks dictates that the rate of progress is slow; the response time to changes in boundary conditions is millions of years. This has also left unaffected major swaths of topography on the interfluves. In these tectonically quiescent ranges, these broad rolling interfluves dominate the topography.

The influence on the fluvial system of glacial cycling in the headwaters is severalfold, and complex. While glacial health is promoted by high precipitation, and a glacierized catchment should therefore produce peaks in discharge that roughly coincide with glacial maxima, the high erosional output of glacial sediment may be sufficient to aggrade the channel and prevent erosion at the very time that stream power reaches a maximum. Some alluvial terraces appear to document this negative feedback. Our two-dimensional planview modeling of alpine valley glaciation, however, suggests that there are times when the fluvial system should be subjected to frequent outburst floods from glacially-dammed tributaries. As the discharge from these events can greatly exceed discharge from meteorologically driven events, significant channel change could be incited.