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The Influence of Glacial-Interglacial Cycles on the Erosion of Orogens

Brian Yanites (1,2) and Todd Ehlers (2)

(1) University of Michigan, Geological Sciences, Ann Arbor, United States (yanites@umich.edu), (2) Institut fuer Geowissenschaften, Universitaet Tuebingen, Germany

The evolution of mountain topography and sediment flux to adjacent basins is dictated by variations in the rates of rock-uplift, climate, lithology, and vegetation. Currently, many mountainous settings are in a state of a 'glacial hangover' whereby Quaternary glaciation has dramatically altered catchment morphology and produced non-equilibrium conditions with respect to the environmental conditions preceding this major climatic transition. In this study, we investigate transients in mountain erosion and morphology due to glacial-interglacial cycles imposed on landscapes previously dominated by fluvial and hillslope processes. In our approach, we use a surface process model to produce an equilibrium fluvial landscape for rock uplift rates between 0.25-1.0 mm/yr. The landscapes are then subjected to repeated glacial cycles of different periodicity and intensity. Variations in predicted glacial basal sliding velocity, erosion, topography and sediment flux are tracked. Results indicate that glacial processes increase rates of valley bottom erosion by one to two orders of magnitude higher than fluvial processes, a result consistent with low-temperature thermochronological data from a number of glaciated catchments worldwide. Increased rates of hillslope and ridgetop erosion occur in response to increased glacial erosion and lag behind the onset of glaciation, thereby producing a complicated history of local relief. The timescale of this lag can vary by orders of magnitude and depends on model parametrization. We also find that two broad effects compete to control the evolution of sediment leaving such an orogen: 1) the topographic disequilibrium with glacial processes acts to initially increase sediment production, but as the topography readjusts, the disequilibrium wanes; 2) the initial geometry of the drainage basin is inefficient at providing ice to the sliding portions of the glaciers, thus impeding erosion early on, but as the topography becomes more 'glacial'-like, down valley glaciers are readily fed sufficient ice to slide and erode. Model predictions for glacial erosion rates and magnitudes are consistent with observations of glaciated landscapes in western British Columbia and California.