



Putting weathering into a landscape context: Variations in exhumation rates across the Colorado Front Range

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Erosion rates are expected vary with lithology, climate, and topographic slope, yet assembling these variations for an entire landscape is rarely done. The Front Range of the southern Rocky Mountains in Colorado, USA, exhibits contrasts in all three parameters. The range comprises ~2300 m in relief from the Plains to the crags of the Continental Divide. Its abrupt mountain front coincides closely with the boundary between marine sedimentary rocks to the east and Proterozoic crystalline rocks (primarily granodiorite and gneiss) to the west. Mean annual temperature declines and mean annual precipitation increases with elevation, from ~11°C/490 mm at the western edge of the Plains to -3.7°C/930 mm on Niwot Ridge near the range crest. The range contains regions of low relief with rolling topography, in which slopes rarely exceed 20°, as well as deeply incised glacial valleys and fluvial canyons lined by steep slopes (>25°).

Cosmogenic ¹⁰Be based erosion rates vary by a factor of ~5 within crystalline rock across the range. The lowest rates (5-10 mm/ka) are found on low relief summit tors in the alpine, where temperatures are low and precipitation is high. Slightly higher erosion rates (20-30 mm/ka) are found in low relief crystalline rock areas with montane forest cover. Taken together, these rates suggest that on low slopes, rock-weathering rates (which place a fundamental limit on erosion rates) are lower in cold alpine settings. Over the 40-150 ka averaging time of ¹⁰Be erosion rates, lower rates are found where periglacial/tundra conditions have prevailed, while moderate rates occur where conditions have varied from periglacial/tundra in the past to frigid regime/montane forest in the Holocene.

Higher basin-averaged erosion rates of 40-60 mm/ka are reported for “canyon edge” basins (Dethier et al., 2014, *Geology*), which are small, steep basins responding to fluvial bedrock incision that formed the canyons in the late Cenozoic. Are higher erosion rates in canyon-edge basins evidence that topographic slope affects weathering rates? We argue that it is more likely that these high erosion rates reflect faster weathering in areas with thinner soil cover. A recent major storm unleashed landslides and debris flows from ~10% of these canyon-edge basins. On average, the volume of material evacuated in these basins was equivalent to ~300 years of soil production by weathering at these rates, approximately the recurrence interval of the storm. The conceptual model that emerges is that agents that cut into rock (bedrock rivers, glaciers) set the pace for exhumation. Adjoining hillslopes erode at a pace set by weathering in the prevailing climate/vegetation regime, conditioned by the ability of sediment transport processes to limit soil thickness on the slopes.