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Factors promoting rock falls along sheeting joints

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Yosemite National Park is a glaciated granitic landscape dominated by sheeting (exfoliation) joints, opening-mode rock factures that form (sub)parallel to topographic surfaces. Recent work indicates that tensile stresses perpendicular to the topographic surface are necessary for sheeting joints to form and grow, and that topographic curvature plays a critical role in this process. Numerous rock falls from the walls of Yosemite Valley detach along sheeting joints. Analyses of recent rock falls using terrestrial laser scanning data indicate that interactions between evolving topography, rock erosion, and local and regional stress fields are primary factors promoting these failures.

Researchers have hypothesized that rock falls stemming from sheeting failures occur in response to stress relief following deglaciation. Yosemite Valley provides an ideal setting to test this hypothesis, as deglaciation following the Last Glacial Maximum (LGM) essentially reset the talus record of rock falls. Precise measurements of talus volumes beneath the major cliffs show that these volumes, normalized by their respective contributing cliff areas, are greater beneath cliffs that were not extensively glaciated during the LGM than beneath cliffs that were extensively glaciated. The widespread presence of intact glacial polish below glacial trimlines indicates that postglacial rock falls have been most common from near the valley rim, where local curvatures, joint apertures, and degree of weathering are greatest. Both sets of observations indicate that glacial debuttressing probably is not a significant driver of sheeting failures in Yosemite Valley. Thus, the failures that continue to occur must result primarily from other processes.

Many sheeting-failure rock falls occur in response to precipitation and freezing events, but many others do not, hinting at more subtle triggers. Such triggers can include chemical weathering of crack tips, failure of rock bridges, and sub-critical crack growth. Our monitoring of a rock flake partially detached along a sheeting joint demonstrates that thermal stresses may also be important. The instrumented flake deforms on both diurnal and annual timescales in response to changes in temperature and solar radiation. Cyclic deformation may induce cracking and crack propagation at the margins of sheeting joints, progressively destabilizing partially detached flakes to the point of failure.

Sheeting-failure rock falls in Yosemite Valley commonly are time-dependent. A fifteen-month-long series of rock falls from the Rhombus Wall in 2009-2010 involved at least fifteen distinct but spatially clustered rock falls that radiated outward on the cliff face from an initial failure point. The progressive nature of these failures likely involved stress redistributions accompanying propagation of sheeting joints behind the cliff face. Mechanical analyses indicate first that tensile stresses should occur perpendicular to the cliff face and open sheeting joints, and second that sheeting joints should propagate parallel to a cliff face from areas of stress concentrations such as overhangs. Thus, as a region of failure spreads across a cliff face, stress concentrations along its margin will spread with it, promoting further crack propagation and rock falls. This process, along with specific environmental triggers, drives sheeting-failure rock falls long after glacial erosion sets the modern topography and associated stress fields.