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Rockfall failure mechanisms in Yosemite Valley, California (USA)

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Rockfall hazard is especially high in Yosemite Valley, with tens of rockfalls inventoried every year. A rockfall on 5 October 2013 from Ahwiyah Point consisted of a volume of 740 cubic meters and occurred within the perimeter of a larger event on 28 March 2009 that released 25’400 cubic meters of rock (Zimmer et al., 2012). In both events (2009 and 2013), the initial rockfall volumes dislodged a second one approximately equivalent in size by impacting the cliff below the source area during the fall. Rock fragments of up to several cubic meters were deposited on the talus slope, damaging a heavily used and recently reconstructed hiking path.

We performed extensive mapping of structural features for several cliffs of Yosemite Valley to improve the assessment of the most susceptible rockfall areas. In particular we mapped and characterized the main brittle structures, the exfoliation joints and the failure mechanisms of the past rockfalls. Several failure mechanisms exist in Yosemite including the propagation of brittle structures that may lead to tensile, planar sliding, wedge sliding or toppling failures. Frequently, topographically-parallel exfoliation joints and topographically-oblique discontinuities coexist, resulting in complex failures. We also developed a methodology to examine how the distribution of joints within the cliff faces of Yosemite Valley affects overall stability with respect to the identified failure mechanisms. For these analyses, we used terrestrial laser scanning (TLS) to collect high resolution point clouds of the vertical and overhanging rock faces throughout the Valley. This provided the necessary 3D data to identify the main joint sets, perform spacing and trace length measurements, and calculate volumes of previous and potential rockfalls. We integrated this information with stability calculations to identify the likely failure mechanisms for each area of cliff and to obtain the number of potential failures per square meter of cliff face. The areas of a cliff with the highest number of potential failures per cliff surface are considered to be the most susceptible to rockfalls. We then compared these areas to field observations displaying the most visually unstable compartments by considering the following factors: 1) the compartment’s degree of isolation due to bounding fractures, 2) the existence of basal steep, sliding prone discontinuities, 3) the opening of cracks, 4) the persistence of cracks, 5) the existence of overhangs, 6) the surrounding rockfall activity, 7) the water seepage along the limiting cracks, 8) the proximity to very fractured layers, 9) the proximity to geologic limits. Our preliminary results show a link between the type of failure mechanism, the persistence of discontinuities and the volume of analyzed rockfalls. Generally, planar or wedge sliding isolate larger unstable compartments compared to tensile failures along exfoliation joints.