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Paraglacial rock mass damage during repeat glacial cycles in preparing slope instabilities (Aletsch region, Switzerland)

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Glacier advance and retreat imposes mechanical stress cycles on underlying bedrock. Stress changes propagate rock mass damage and act as preparatory factors for slope instabilities, however, the mechanics of paraglacial rock slope damage remains poorly understood. In this study, we present results of detailed, conceptual numerical models, based on extensive field mapping and characterization at our Aletsch valley study site, Switzerland. We illustrate how simple stress changes associated with repeat glacial cycles can propagate fractures, enhance slip along discontinuities, and lead to failure of intact rock bridges, conditioning adjacent valley slopes for failure. We describe the timing and location of induced damage, stress redistribution, and displacement associated with Late Pleistocene and Holocene glacial cycles, and compare numerical predictions with the spatial and temporal distribution of landslides around the Great Aletsch Glacier. Our results help clarify mechanical linkages between glacial cycles and damage propagation in alpine valley rock slopes. In our simulations, most damage occurs during first deglaciation. This is in good agreement with the relative initiation timing (post-LGM / post-Egesen) for the majority of identified landslides at Aletsch. Large Holocene glacial cycles with high amplitude ice elevation changes in our models have a significant impact on displacement patterns in adjacent slopes. This correlates with a concentrated area of landslides located around the present-day glacier terminus, where the Great Aletsch Glacier fluctuated most during the Holocene. The kinematics and dimensions of an unstable rock slope produced in our models also generally resembles field observations of toppling-mode landslides on the eastern slope. No substantial displacement was generated on the western slope, although compound rock slides are observed on the western flank in the Aletsch.