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Assessment of rock mechanical properties and seismic slope stability in variably weathered layered basalts

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A field and laboratory experimental study was conducted to assess the influence of weathering on the mechanical properties of basalts in the region of the Kohala volcano on the island of Hawaii. Through the systematic characterization of the weathering profiles developed in different precipitation regimes, we aim to explain the regional pattern of stability of slopes in layered basalts that were observed during the 2006 Mw 6.7 Kiholo Bay earthquake. While deeper weathering profiles on the wet side of the island might be expected to promote more and larger landslides, the distribution of landslides during the Kiholo Bay earthquake did not follow this anticipated trend. Landslide frequency (defined as number of landslides divided by total area) was similar on the steepest slopes (> 50-60 [U+F0B0]) for both the dry and the wet side of the study area suggesting relatively strong ground materials irrespective of weathering. The study location is ideally suited to investigate the role of precipitation, and more broadly of climate, on the mechanical properties of the local rock units because the presence of the Kohala volcano produces a significant precipitation gradient on what are essentially identical basaltic flows. Mean annual precipitation (MAP) varies by more than an order of magnitude, from 200 mm/year on the western side of the volcano to 4000 mm/year in the eastern side. We will present results of measured shear wave velocities using a seismic surface wave methodology. These results were paired with laboratory testing on selected basalt specimens that document the sample-scale shear wave velocity and unconfined compressive strength of the basaltic rocks. Shear wave velocity and unconfined strength of the rocks are correlated and are both significantly lower in weathered rocks near the ground surface than at depth. This weathering-related reduction in shear wave velocity extends to greater depths in areas of high precipitation compared to areas of lower precipitation, as expected, with a pronounced transition occurring at about 1000 mm/yr MAP. We speculate that relatively stiff, sub-horizontal layers that are interbedded with weathered material, may explain the discrepancy between both lower seismic velocities (in the field and the laboratory) and lower unconfined compressive strength, and the interpreted high strength exhibited by the seismic slope response during the Kiholo Bay earthquake. This observation has important consequences on the type of landslides observed in the 2006 earthquake, as well as the landslides that can be expected in future earthquakes.