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Assessing slope stability in three dimensions throughout a landscape: Stratovolcanoes, coastal bluffs, and submarine slopes

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Variations in topography, strength, and pore-fluid pressures strongly control the three-dimensional (3D) stability of potential landslides. We developed a 3D slope-stability program, Scoops3D, which efficiently and thoroughly assesses slope stability throughout a digital landscape [1]. We then used this software to evaluate 3D effects in diverse settings. Our analysis of stratovolcano edifices, including Mount St. Helens (USA), Mount Rainier (USA), Volcan Casita (Nicaragua), and Augustine Volcano (USA), demonstrated that deformation from shallow magma intrusion and/or subsurface distributions of weak hydrothermally altered rock control the locations of potential future failures (Fig. 1) in the cases examined. We also combined Scoops3D with a 3D groundwater flow model to evaluate coastal bluff stability in Seattle, Washington (USA). Here, 3D groundwater flow localized potential instability where groundwater perched on relatively low-permeability stratigraphic layers or concentrated in topographic re-entrants. Additional studies showed that 3D groundwater flow and instability are sensitive to the spacing of coastal re-entrants. Analysis of submarine slopes offshore southern California (USA) revealed bathymetric controls on instability.

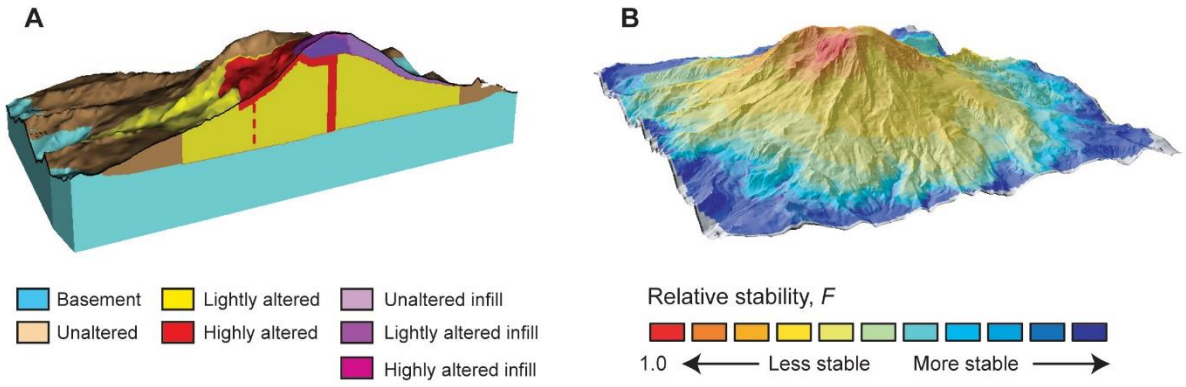

Figure 1: A. 3D subsurface distribution of weak hydrothermally altered rocks within Mount Rainier (USA) [2]*. B. Computed relative stability, F, of the entire edifice given rock distribution shown in A.*

Scoops3D functions by computing the stability of millions of potential spherical failure surfaces of different sizes and depths affecting all parts of a digital elevation model (DEM). Slope stability is determined using Bishop's simplified or the Ordinary method of limit-equilibrium analysis. Scoops3D can incorporate layered or fully 3D variations in material strengths, saturated pore-fluid pressures, or unsaturated effects, as well as static earthquake loading. Results provide the minimum factor of safety, *F*, for all examined failure surfaces affecting each DEM cell in the landscape, as well as the volumes and/or areas associated with these potential failures. We designed Scoops3D to aid regional

assessments of landslide susceptibility; it can also be used as a screening tool to identify areas of low stability that may warrant more detailed analyses. Scoops3D and its user interface (Scoops3D-i) are publicly available with easy-to-use installation packages for Windows or Macintosh operating systems (http://landslides.usgs.gov/research/software.php).

References:

[1] Reid ME et al. (2015) USGS Techniques and Methods, 14(A1): http://dx.doi.org/10.3133/tm14A1

[2] Reid ME, Sisson TW and Brien DL (2001) Geology 29(9): 779-782