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Simulating fault scarp degradation in jointed bedrock

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Fault scarps in bedrock are common in regions of active crustal extension where basaltic volcanism and extensional faulting are broadly synchronous. Determination of the ages of scarps can make important contributions to long-term seismic hazard evaluation and to estimating tectonic strain rates. Relative or absolute morphologic ages of bedrock fault scarps are difficult to determine, because the degradation of these scarps is substantially controlled by pre-existing discontinuities in the rock and cannot be modeled by simple continuum diffusion processes. This challenge is somewhat reduced in jointed basalt relative to other rock masses, because the orientation of the major discontinuities can be anticipated (perpendicular to flow boundaries), and the spacing of the discontinuities is easily measured and extrapolated to three dimensions (diameter of the joint-bounded columns).

A three-dimensional, quasi-static, stochastic model for fault scarp degradation in jointed basalt is presented. In the model, toppling of joint-bound columns is the primary degradation mechanism, and is assumed to operate at a rate much faster than regolith production (weathering of the basalt) or talus-slope processes. A toppled column in the model is instantaneously converted to talus and deposited at the base of the scarp at the angle of repose. In natural examples, talus protects the base of the scarp from subsequent undercutting or toppling. The interconnected joints provide high permeability; thus fluid pressure and freeze-thaw are unlikely to be effective in toppling columns. Strong ground motion is the most likely column-toppling mechanism. The ground acceleration required to topple a column is a function of the column diameter-to-height ratio, the convexity or concavity of the base of the column, and the resistance provided by neighboring columns. The likelihood that a model column will topple during any given ground-motion event is given by the following: 1) the ground

acceleration, which must exceed the static toppling acceleration of the column, determined by its width and exposed height; 2) the shape of the base of the column, assigned stochastically; and 3) the influence of neighboring columns given their relative positions, determined by calibration against observations of the shape of observed scarps along strike. The scarp profile evolves by parallel retreat of the free face and aggradation of the talus slope, until the exposed free-face height is approximately equivalent to the width of the column. After this, required toppling accelerations are very high, and other processes must take over.

It is possible to exploit the connection between ground motion and earthquakes to estimate rates of degradation. By generating a synthetic earthquake catalog with observed magnitude-frequency characteristics, spatial distribution and event rate, along with published empirical relationships between earthquake magnitudes and ground motion, the model generates stochastic ground motion forcing to drive model scarp degradation through time. This technique is used to evaluate the persistence of bedrock fault scarps in the seismically active high lava plains of the northeastern Basin and Range province of western North America.