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The Influence of Climate and Micro-climate (aspect) on Soil Creep Efficiency: cinder cone morphology and evolution along the eastern Mediterranean Golan Heights

Matan Ben-Asher (1), Itai Haviv (1), Joshua. J Roering (2), and Onn Crouvi (3)

(1) Ben-Gurion University of the Negev, Geological & Environmental Sciences, Beer Sheva, Israel , (2) University of Oregon, Department of Geological Sciences, Eugene, Oregon, USA, (3) Geological Survey of Israel, Jerusalem, Israel

Although hillslope evolution has occupied geoscientists for over a century, the effect of climate on the morphology of soil-mantled hillslopes remained poorly-constrained. In this study we utilize numerical simulations of volcanic cinder cones in the Golan Heights (Eastern Mediterranean) to estimate soil creep efficiency across a strong north-to-south gradient in mean annual precipitation (1100-500 mm). Our model utilizes the initial cinder cone profile (constrained by the dip of the ash layers), the current hillslope profile (measured with cm scale accuracy) and the known eruption age (^{40}Ar-^{39}Ar constraints) to predict the best-fit value of the soil creep diffusion coefficient ('diffusivity').

Our results indicate that the best-fit diffusivity coefficient varies from 0.5 to 6 m^2/ka among the seven cinder cones we have analyzed. Soil diffusivity varies with both climate (precipitation) and aspect-related microclimate: diffusivity values are higher on south facing hillslopes, and decrease with mean annual precipitation. This climate dependency likely reflects an increase in the apparent soil cohesion (or resistance to disturbance-driven transport) at higher precipitation rates due to higher density of vegetation coverage (root network) which co-varies with rainfall and aspect. We demonstrate this significant co-variance utilizing the spatial distribution of NDVI vegetation index calculated from ASTER images and show that aspect-related hillslope asymmetry becomes established over time on cinder cones as well as in other landforms. In addition, our results show that 750-850 ka cinder cones display lower diffusivity values relative to late Pleistocene cinder cones (120-150 ka). This temporal variance in diffusivity may reflect either rapid transport associated with climatic conditions of the last glacial and inter-glacial period or time-dependent material properties that influence transport efficiency.

Analysis of previously studied cinder cones in the US extends our framework to arid climatic domains and suggests a humped relationship between soil diffusivity and mean annual precipitation with maximum diffusivity at annual precipitation of 400-600 mm.