Isolating lithologic controls on landscape morphology in the Guadalupe Mountains, Texas, USA

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Qualitatively, lithologic control on topography is apparent in many landscapes. This is perhaps most notably evident in dryland settings with horizontal stratigraphy, where the contrasting geomorphic expression of “cliff formers” and “slope formers” is common. However, in many geomorphic studies, lithologic contrasts are often acknowledged as important, but are otherwise ignored in attempts to determine tectonic forcing or climatic control. Tectonic inactivity and relatively little spatial variability in climate make the Guadalupe Mountains of Texas and New Mexico an ideal site to investigate the effects of lithology on topography. To determine the effects of lithology, we compared topographic metrics including topographic relief, slope and channel steepness index in different mapped lithologic units across the region. Steepness indices were calculated for approximately 1,050 channels in the Guadalupe Mountains and surrounding area using elevation data extracted from USGS 10m Digital Elevation Models. Individual steepness indices were fitted for distinctive segments along each longitudinal stream profile in order to capture the variability as streams cross potential lithologic contacts. These indices were then grouped per 23 discrete lithologic units, including abundant limestone and dolomite with some evaporites, sandstone, and shale.

We first compared the datasets using the Kruskal-Wallis method for hypothesis testing and found that significant differences exist between the lithologic groups, suggesting potential correlation among channel steepness and lithology. To better evaluate the different rock units, we used published unit descriptions to develop a simple and a semi-quantitative ranking of relative rock erodibility. This ranking system assumes units with evaporates are softer and units limestone and dolomite are harder, with other units, including sandstone and shale in between. This ranking system also accounts for other factors such as relative bed thicknesses, as well as spatial heterogeneity and variety of rock type within a given unit. These objective ranks were correlated with average steepness indices for each of the 23 lithologic units, giving an R^2 value of approximately 0.44, suggesting that steepness provides some predictive ability in determining rock properties. Finally, we show that some of the variability in the relation between steepness and relative erodibility can be explained by effects of stratigraphic order.

Keywords: Geomorphology, Channel Steepness, Lithology, Digital Elevation Model, Topographic Relief, Rock Erodibility

