Landform analysis for recognizing tectonic and structural heterogeneity

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In the 1950s, John T. Hack conducted quantitative studies of several longitudinal river profiles. Beside his widely used power-law relationship between drainage area and river length, he also found a relationship between the slope S and the drainage area A: $S \sim A^{-\beta}$ where b is in the range between about 0.3 and 0.5. Comparing this empirical relationship with simple models of fluvial erosion suggests that Hack's findings reflect an equilibrium between uplift and erosion under homogeneous conditions, i.e., constant uplift rate and constant erodibility. Thus, deviations from the relationship should indicate tectonic or structural heterogeneity.

In this study, we extend this idea from the main rivers towards smaller ones and even towards slopes. The Mur basin serves as a test region. The data suggest that the relationship holds at least down to drainage areas of a single SRTM3 grid cell (< 0.01 km^2) where erosion is clearly not a result of permanent surface runoff. For the Mur basin, an exponent of $\beta \approx 0.3$ is obtained. In order to detect tectonic or structural heterogeneity, the product $S \cdot A^{\beta}$ is plotted in a map. Upward deviations of the product point towards high uplift rates, low erodibility or non-equilibrium between uplift and erosion and vice versa. Many peculiarities found in the map can be directly attributed to lithologic structures, but there are also regions such as the area between Raab and Mur where the origin of several remarkably asymmetric valleys cannot be uniquely determined.