Geophysical Research Abstracts,
Vol. 10, EGU2008-A-06704, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-06704
EGU General Assembly 2008

The use of a cellular automaton model to investigate variation in bedrock channel exposure with sediment transport rate

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The incision of bedrock rivers is a key component of landscape evolution. Simple 1D models of bedrock erosion are routinely used to predict spatial and temporal changes in bedrock river profiles, the simplest of which are of the form $E = KA^mS^n$ (where E is the local erosion rate, A is upstream basin area, S is local channel slope, K is an erosional co-efficient, and m and n are constants, the values of which are debated). However, the use of such models is limited by their extreme simplification of erosion processes, so that improved models, which are likely to have a physical basis, are needed.

The development of a single physically-based model is complicated by the range of erosive processes in bedrock channels, including abrasion, plucking and cavitation. Sklar and Dietrich (2004, 2006) modelled the abrasion of bedrock by saltating grains as $E = V_iI_rF_e$, where I_r is the rate of grain impacts per unit area per unit time, V_i is the average volume of rock detached per grain impact, and F_e is the fraction of the bedrock surface that is exposed (i.e. not covered with sediment), and deduced mathematical formulations for all three components.

This research is concerned with refining the third component, F_e. Sklar and Dietrich modelled F_e as a linear function of the sediment transport rate (Q_s), with F_e being 1 when Q_s is 0, and and F_e being 0 when Q_s is at capacity. Recently, Turowski *et al.* (2007) suggested that F_e is a negative-exponential function of Q_s. However, neither has considered the grain-scale dynamics of sediment transport.

A cellular automaton (CA) model has been used to reproduce the movement of individual uniform grains through a domain representing a patch of bedrock channel, allowing the variation of F_e with Q_s to be modelled. Simulations in which all grains are equally likely to move in each time step display the negative-exponential function for F_e hypothesised by Turowski *et al*. However, as widely noted in alluvial entrainment studies, grain entrainment is a function of the surrounding bed geometry, with isolated grains being more likely to move than grains surrounded by other grains. This is expressed in the CA model by altering the probability of movement of each grain in a time step as a binary function of the number of surrounding grains. The resulting simulations display a sigmoidal relationship between F_e and Q_s, with a rapid drop in F_e above a critical value of Q_s. This suggests a refined formulation of the Sklar and Dietrich model. We remain to investigate the behaviour of grain-size mixtures, and are designing field experiments to validate these results.