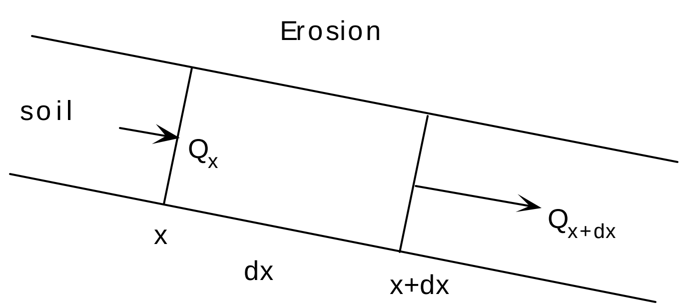
COMPUTER METHODS AND MODELING IN GEOLOGY
LANDSCAPE DIFFUSION LAB

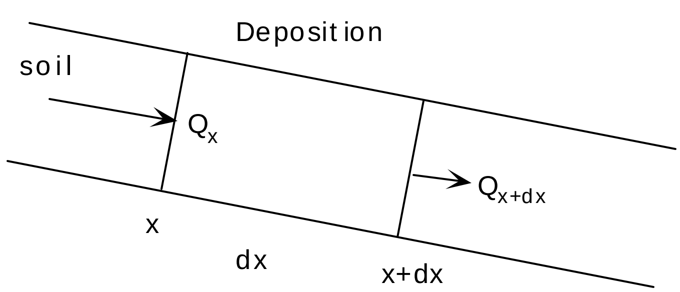
Landscapes evolve over time as natural processes work to smooth sharp corners and level uneven topography. Raindrop impacts, the annual cycle of freeze-thaw, and even ground squirrels act to move soils and sediments from topographic high points to low points. The rate at which material is moved, called the flux (Q), is directly proportional to the slope (dz / dx):

$$Q = -a * \frac{dz}{dx}$$

where α is a proportionality constant.

We can divide any hillslope into a number of small boxes.





As diffusive processes operate, material enters the upper side of each box and leaves along the lower side of the box. We'll call these fluxes Q_x and Q_{x+dx}. If $Q_x < Q_{x+dx}$, more material leaves the box than enters it, resulting in erosion. If $Q_x > Q_{x+dx}$, the opposite is true and deposition occurs. The change in the flux over the distance of any small hillslope box, therefore, causes a change in the elevation of the box over time (dz / dt), a relationship that can be written as follows:

$$\frac{dz}{dt} = -\frac{1}{1-p} * \frac{(Q_{x+dx} - Q_x)}{dx} = -\frac{1}{1-p} * \frac{dQ}{dx}$$

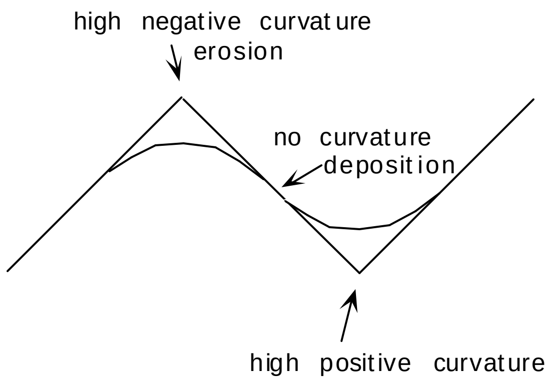
where p is the porosity of the sediment.

Differentiating the first equation and substituting it into the second gives:

$$\frac{dz}{dt} = k * \frac{d^2 z}{dx^2}$$

Where κ is $\alpha/(1\text{-}p)$ and is called the diffusivity.

The second derivative of z with respect to x is the curvature of the landscape, or change in slope with distance. This equation, called the "diffusion equation," says that the change in elevation of any hillslope element over time (dz/dt) depends on the curvature of the landscape (d^2z/dx^2). On the flanks of hills, where the slope is constant, no change in elevation occurs with time. At the crests of hills and in valleys, where the slope of the landscape changes from being positive to being negative, or vice versa, there will be change over time, either erosion or deposition.



Today we will create a model of two marine terrace platforms separated in elevation by a cliff. We will use the hillslope flux equation to simulate the change in the cliff face over time as it is torn down by diffusive processes.

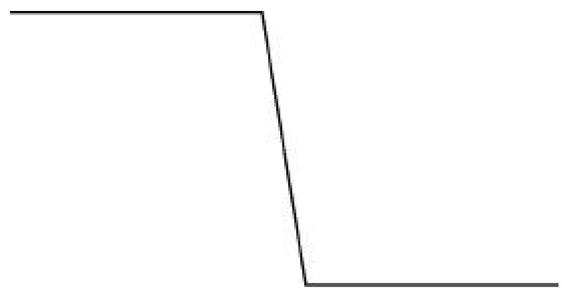
Readings

Anderson, R.S., and Humphrey, N.F., 1989, Interaction of weathering and transport processes in the evolution of arid landscapes, in Cross, T.A. (ed.), Quantitative Dynamic Stratigraphy, New York: Prentice Hall, p. 349-361.

Rosenbloom, N.A., and Anderson, R.S., 1994, Hillslope and channel evolution in a marine terraced landscape, Santa Cruz, California, Journal of Geophysical Research, v. 99, p. 14,013-14,029.

Exercises

Use whatever modeling tool you wish (i.e. Stella, Compaq Visual Fortran, or Fortran on the UNIX workstation) to create a model of a cliff separating 2 marine terrace platforms that evolve over time in response to erosion at the top of the cliff and deposition at the base. Your starting cliff should look something like this.



Assume that the landscape is easily erodible material. In other words, don't bother putting in routines to first weather the material and then erode it. Just assume that we're operating under Anderson and Humphrey's "transport limited" scenario.

Once your model is complete, think of 2 experiments to conduct. Explain what you were trying to discover, how you modified the model to conduct your experiment, and what your results were. Show me the plots that go with your experiments.