

# Modeling blocky hillslopes in layered landscapes

Rachel Glade



Photo: Bob Anderson



Geological Sciences  
UNIVERSITY OF COLORADO BOULDER





Photo: Bob Anderson

Fort Collins, Colorado





Fort Collins, Colorado





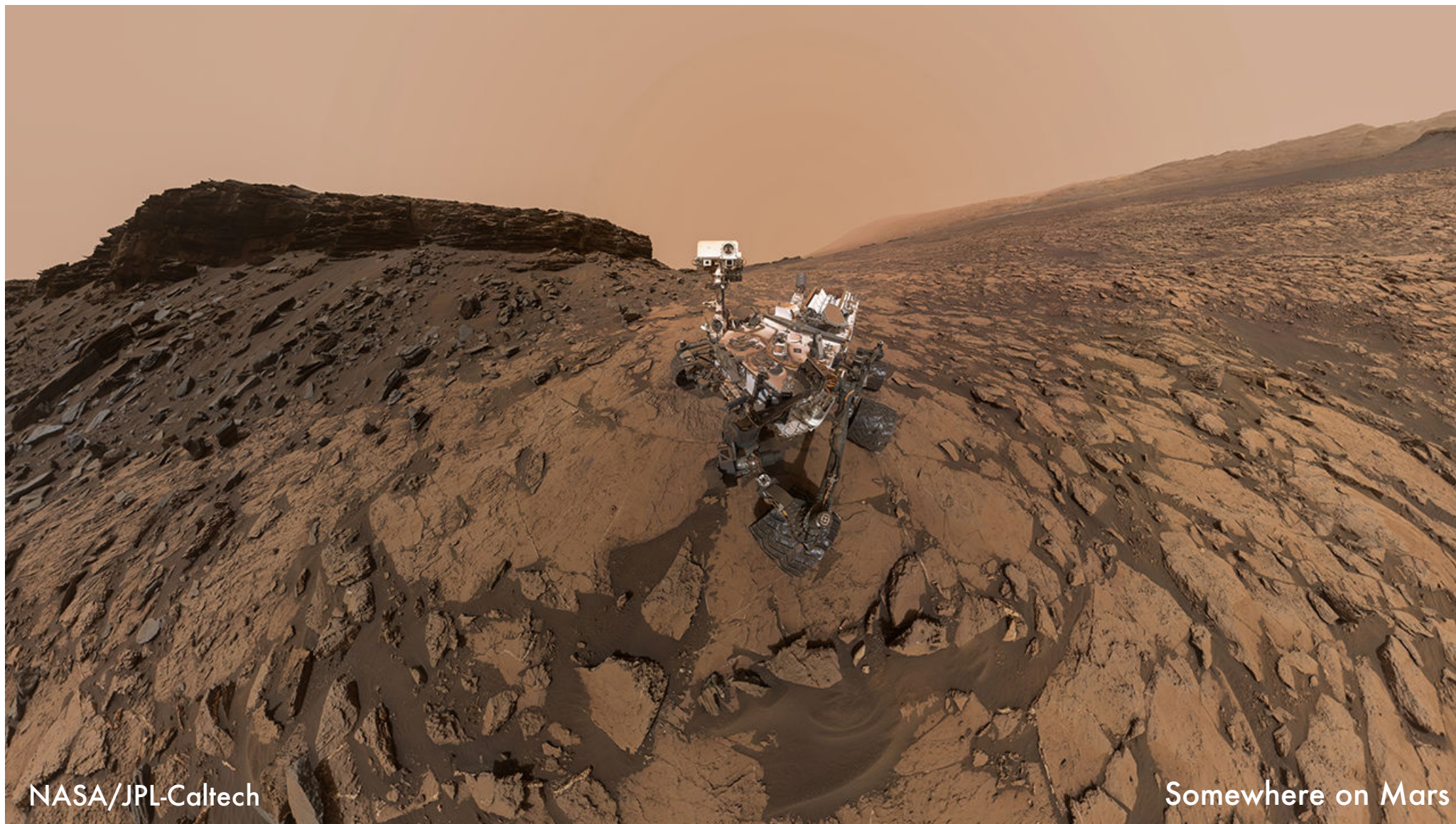
Moab, Utah





Shiprock, New Mexico





NASA/JPL-Caltech

Somewhere on Mars



# Layered landforms

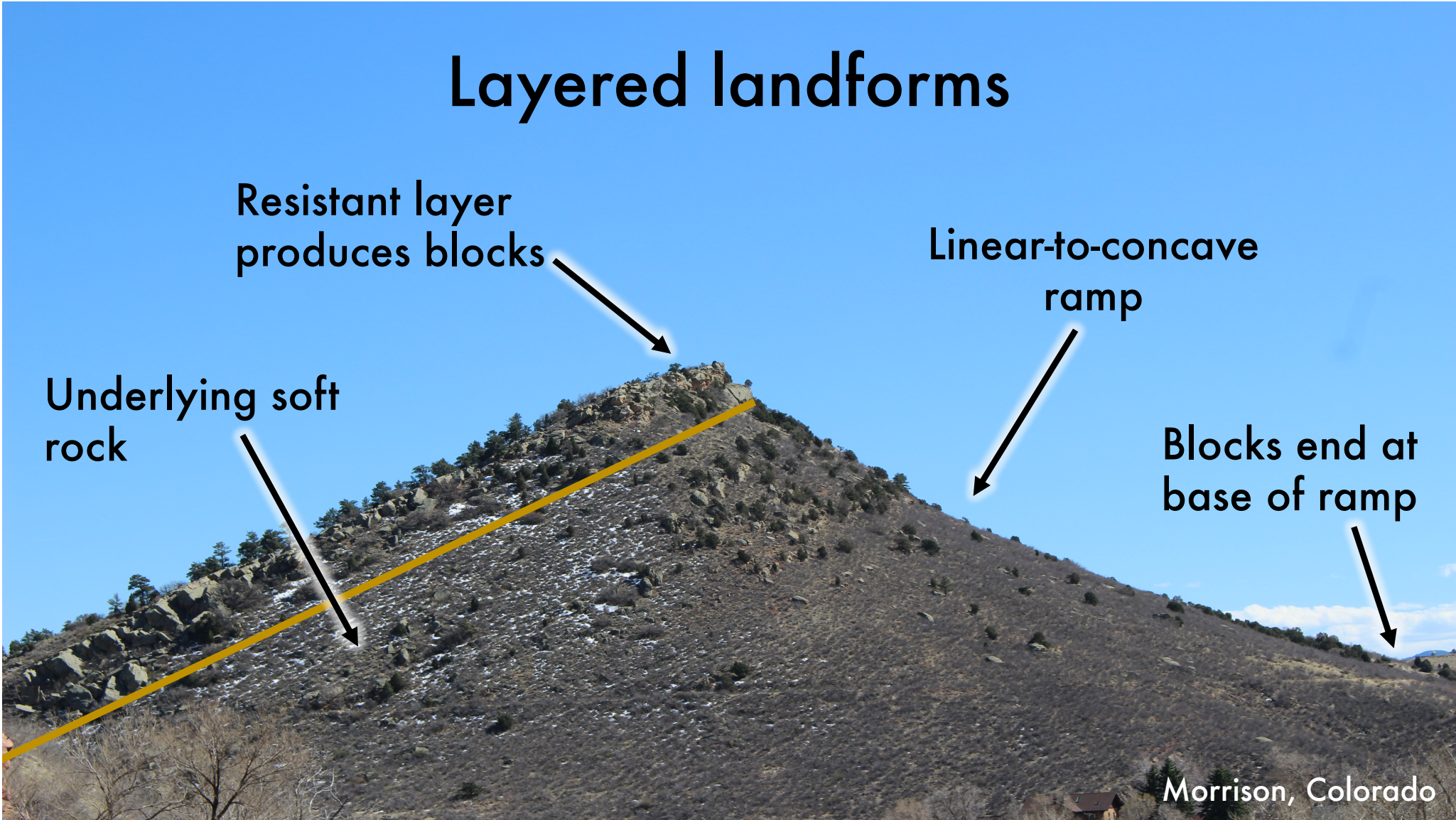
Resistant layer  
produces blocks

Linear-to-concave  
ramp

Underlying soft  
rock

Blocks end at  
base of ramp

Morrison, Colorado



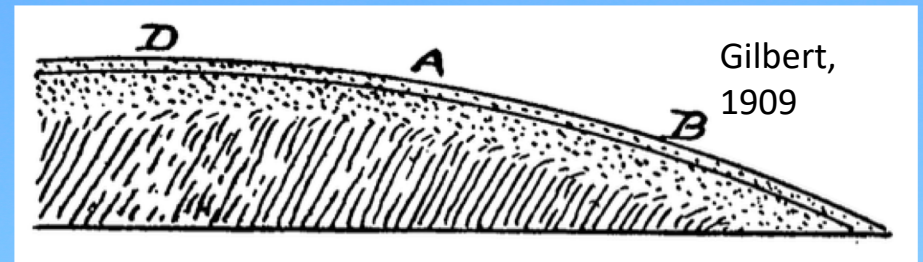


# Layered landforms

Resistant layer  
produces blocks

Underlying soft  
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Blocks end at  
base of ramp



Morrison, Colorado



**How do layered  
landforms evolve?**

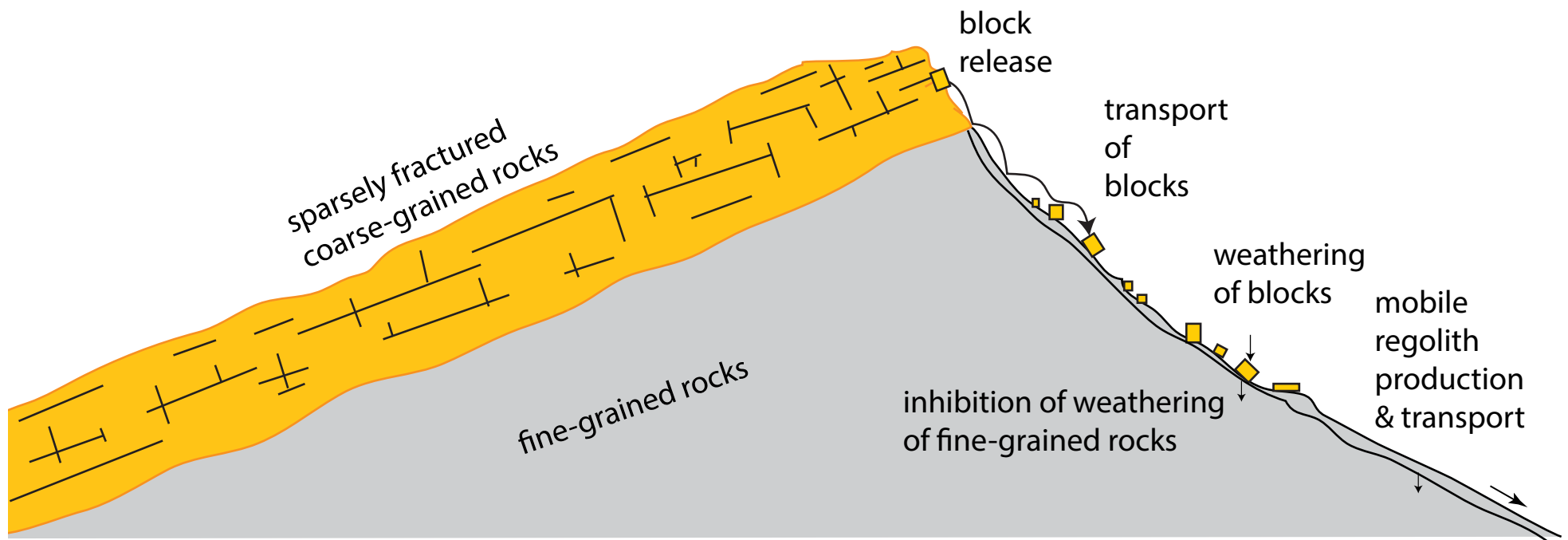
**What is the role  
of blocks?**



Morrison, Colorado



# Conceptual model

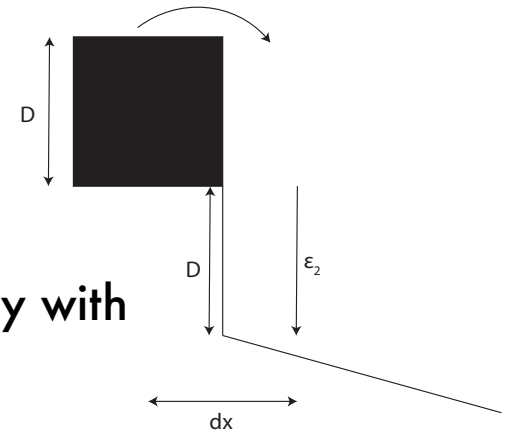


Glade et al., 2017, *Geology*

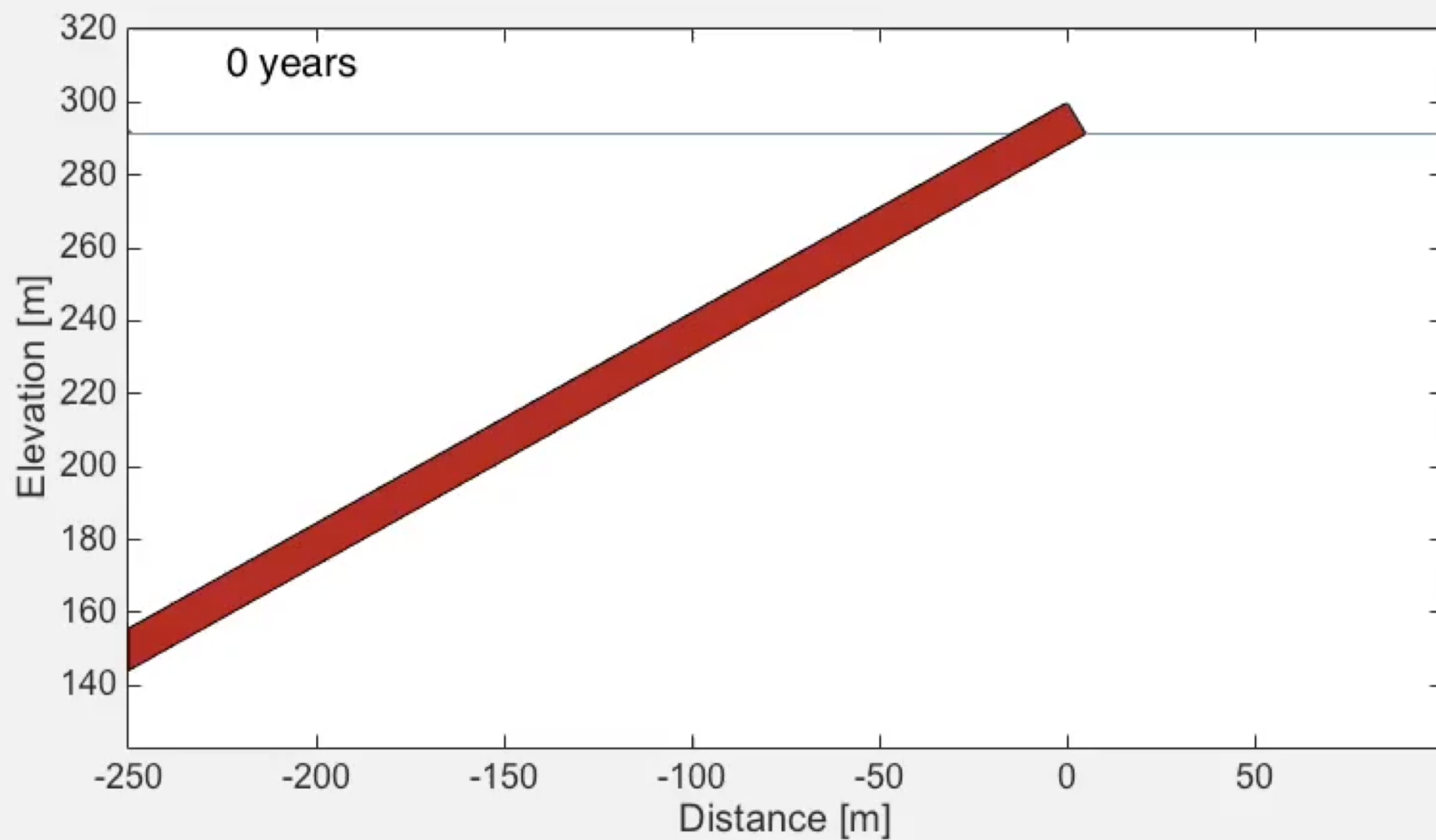


# Numerical Model

- Depth-dependent soil transport:  $q = -kS(1 - e^{-H/h_t})$ 
  - Johnstone and Hilley, 2014
- Depth-dependent soil production:  $w = w_0 e^{-H/h_w}$ 
  - Ahnert, 1977; Heimsath et al., 1997
- Block weathering: constant rate
- Discrete Block transport
  - With these rules, block size should exponentially decay with distance from crest

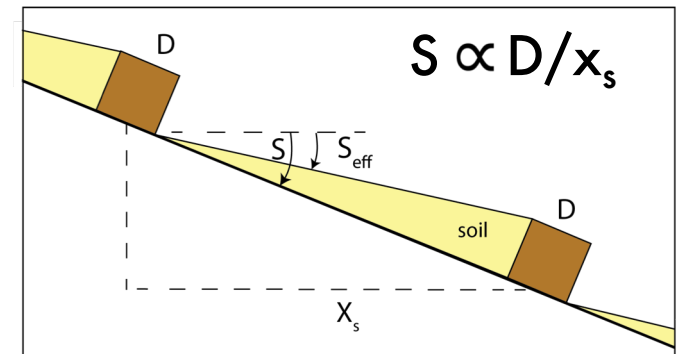
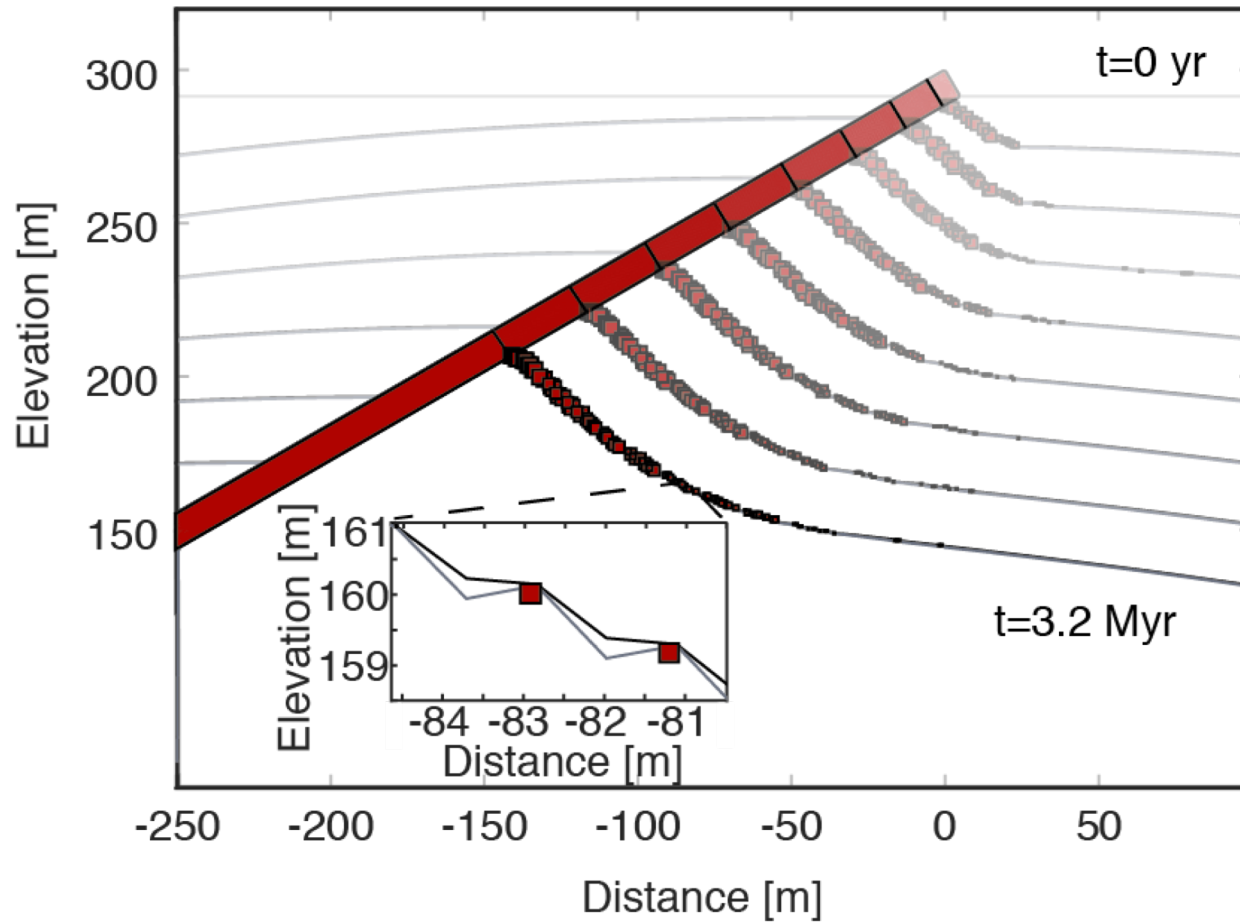








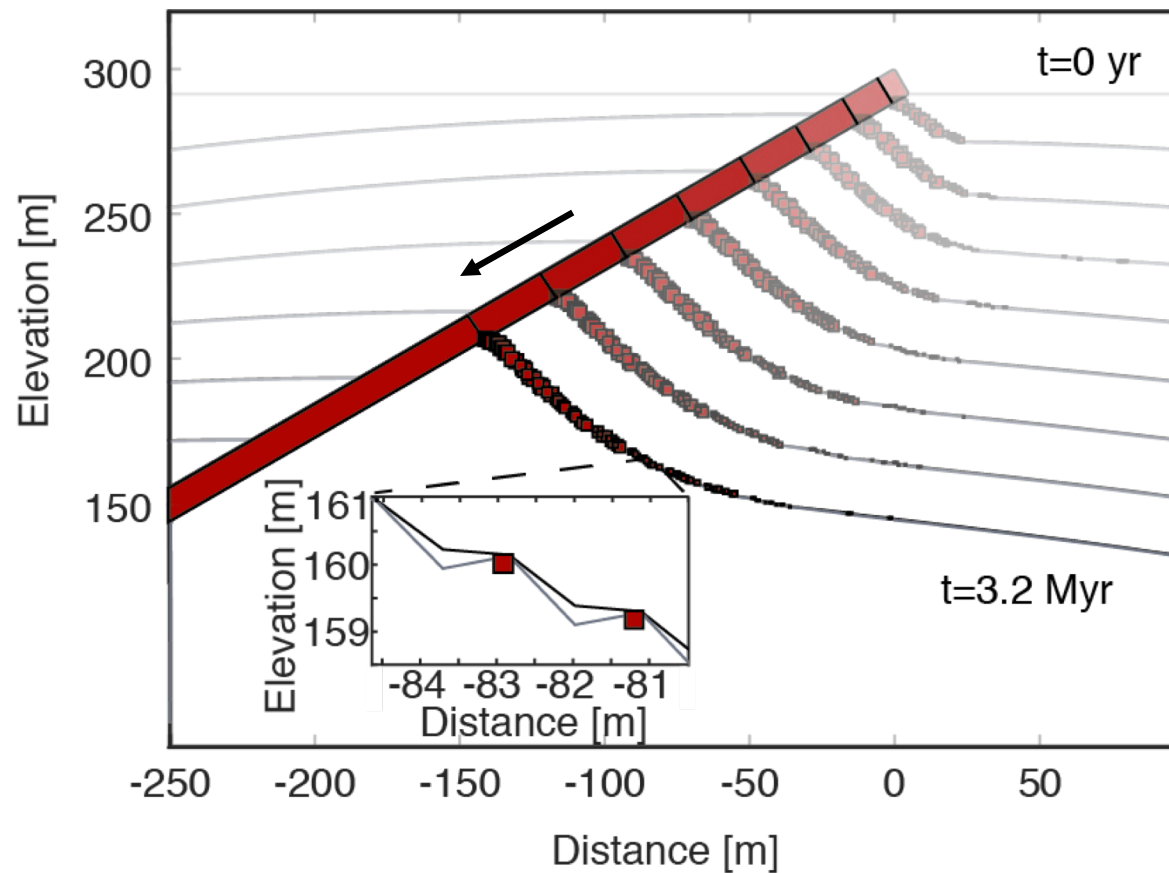
# Block Dams



Glade et al., 2017, *Geology*

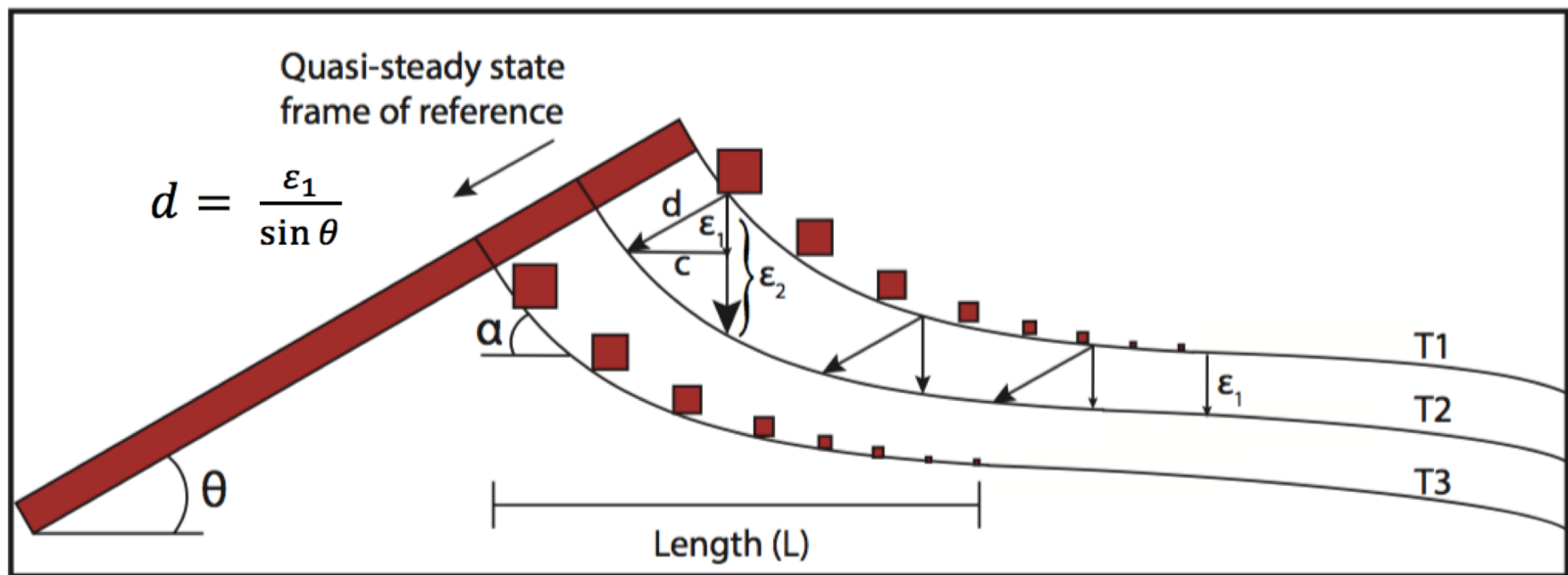


# How does the model reach quasi-steady state?





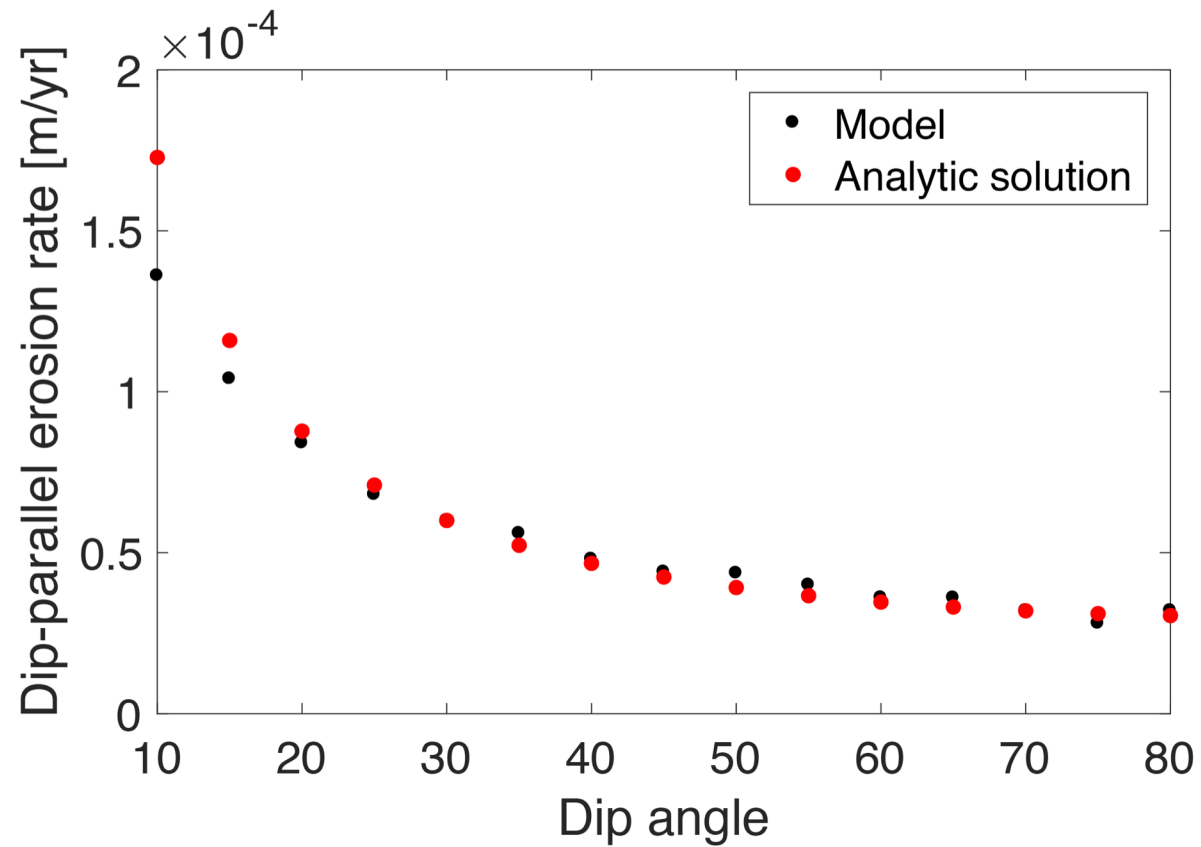
# Geometric analysis



Glade and Anderson, 2018, *JGR Earth Surface*

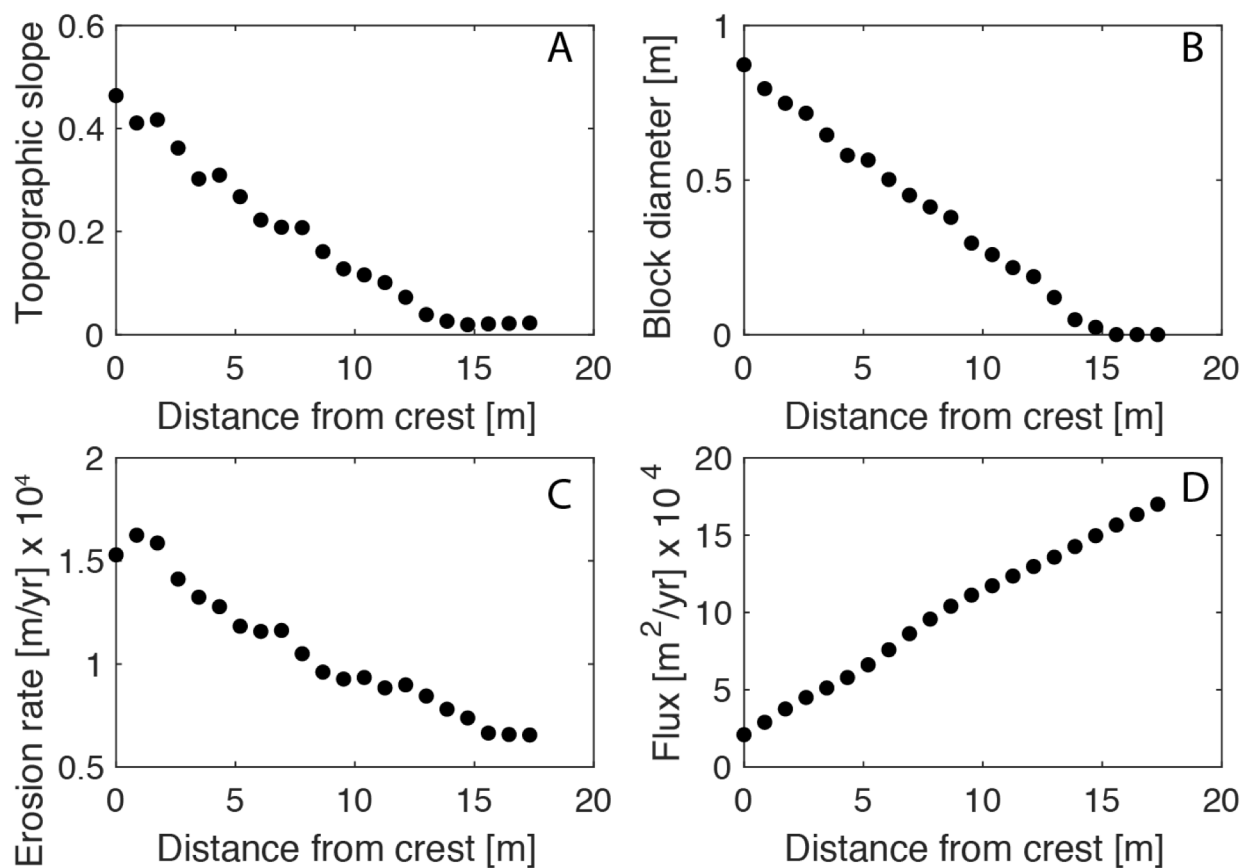


# Numerical vs. Analytical



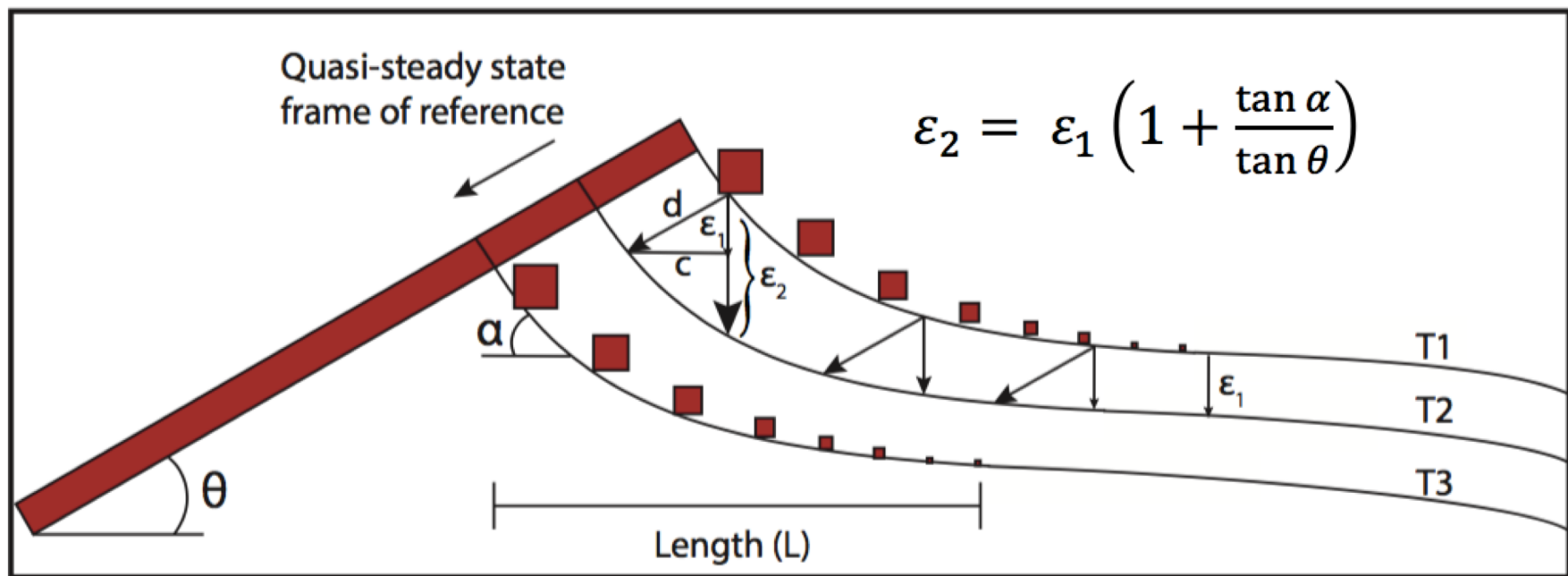


# Steady trends: Why so... linear?





# Geometric analysis





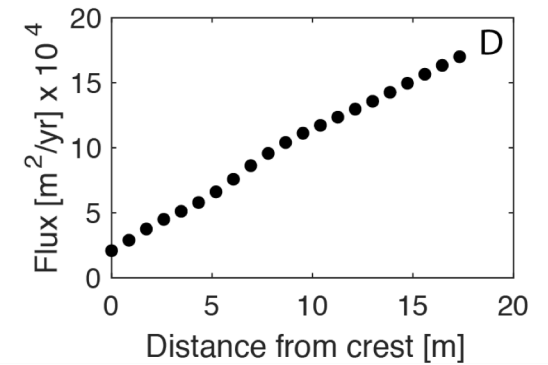
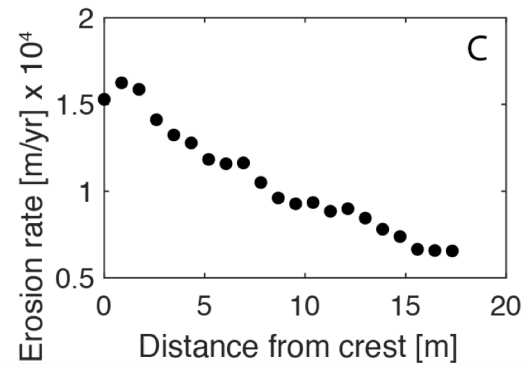
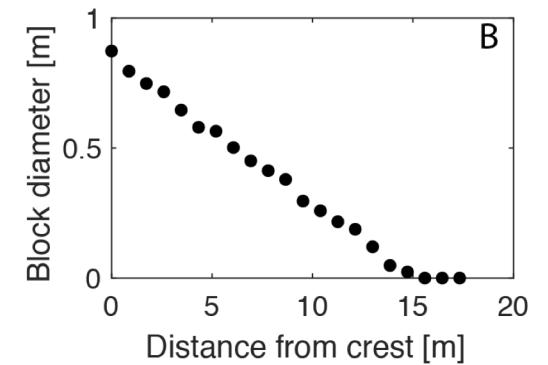
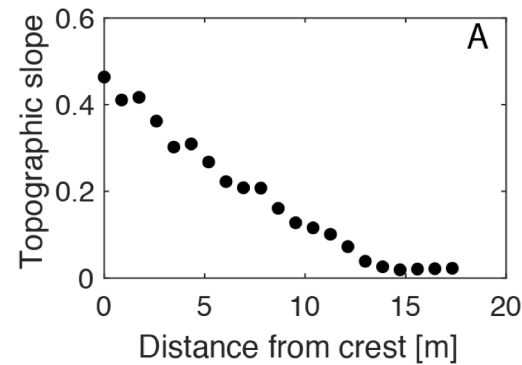
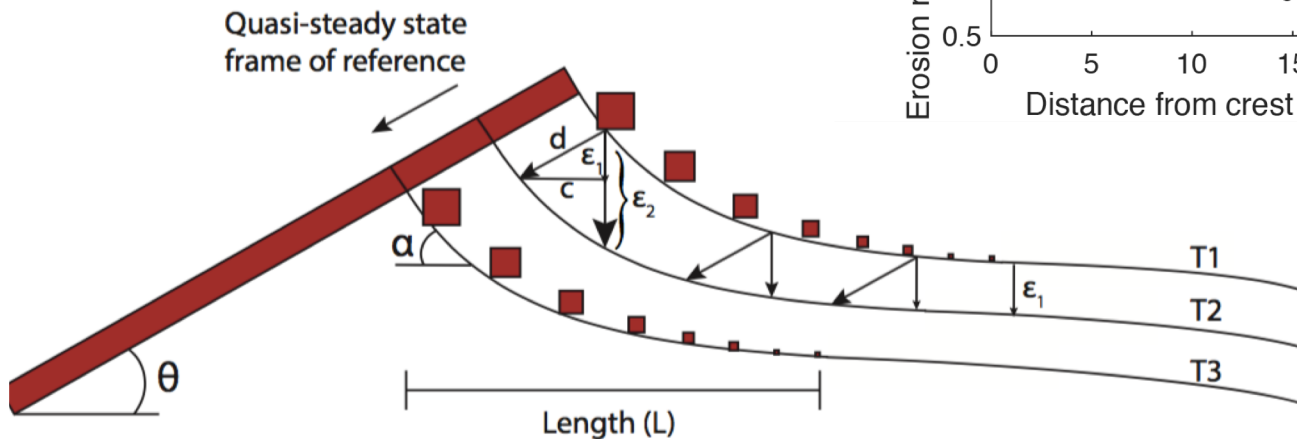
# Self-organization

↓ Block size (constant weathering rate)

↓ Slope ( $S \propto D$ )

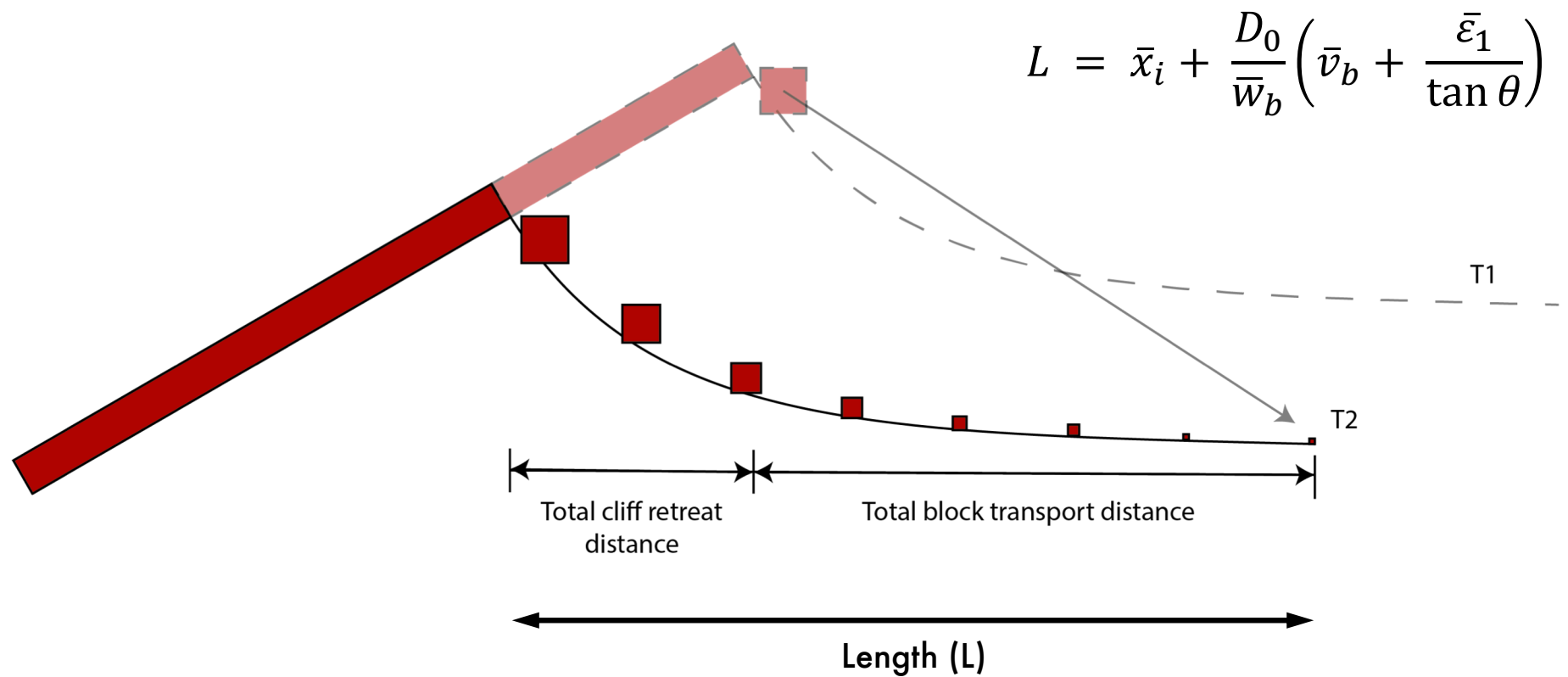
↓ Vertical erosion/soil production rate

$$\text{Constant block velocity } v_b = \frac{\varepsilon_2 dx}{D}$$



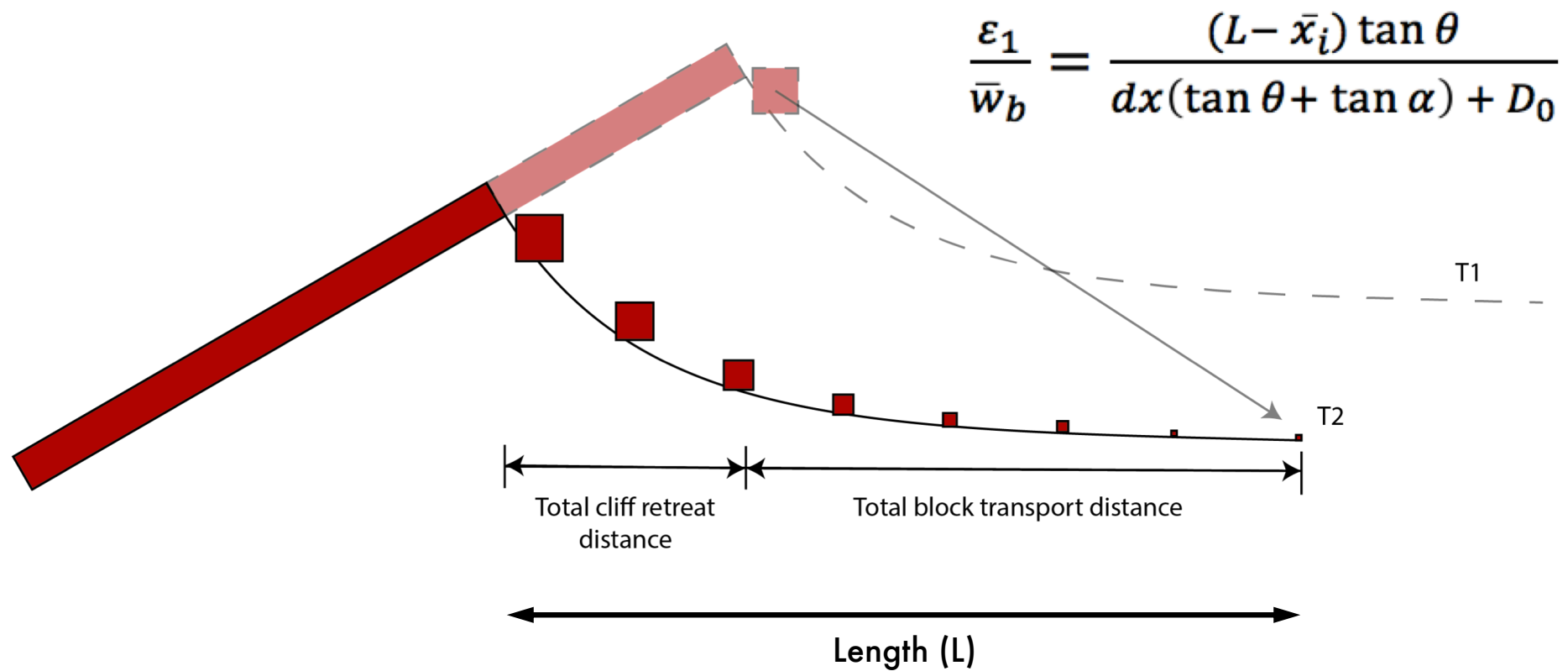
Importance of depth dependence

# What sets the ramp length?

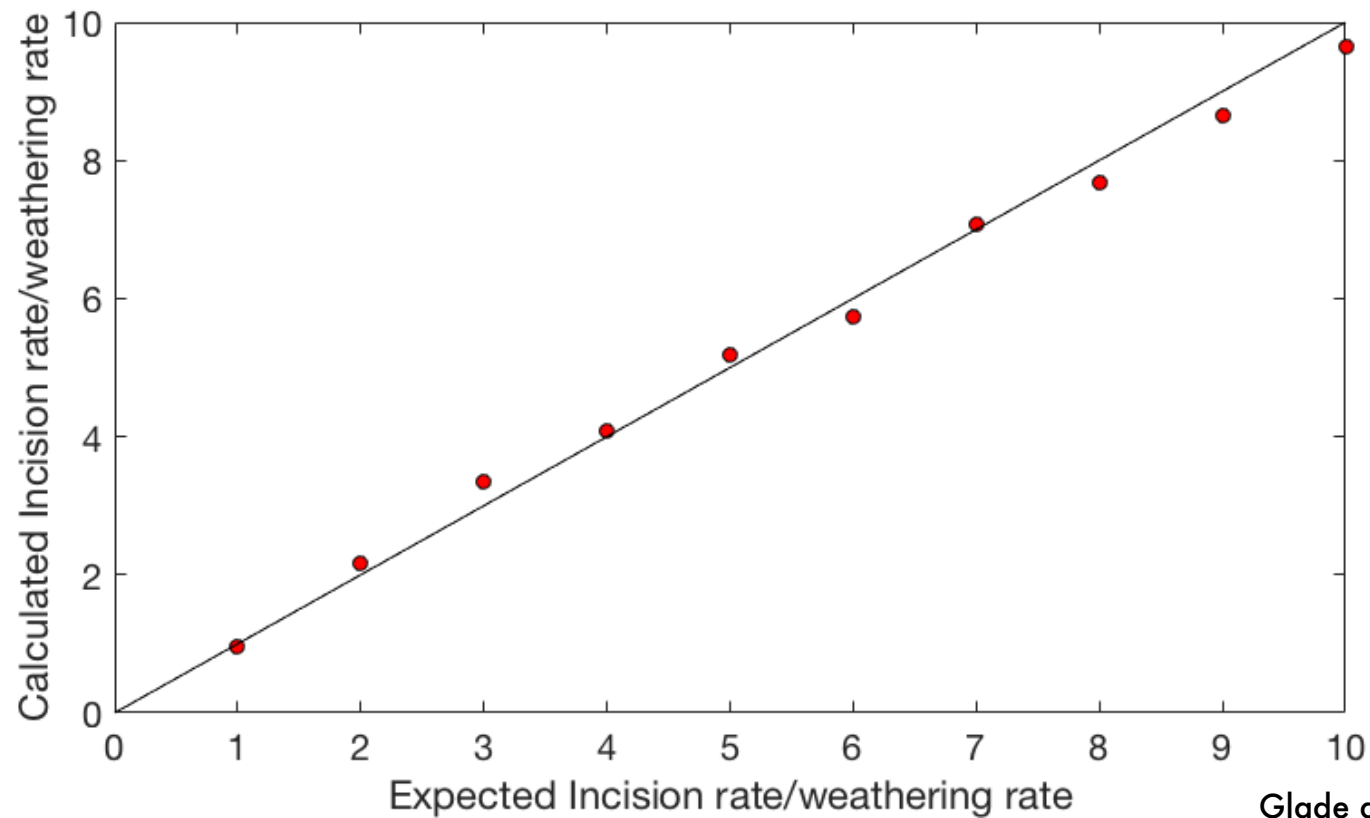




# What sets the ramp length?



# Numerical vs. Analytical



Glade and Anderson, 2018,  
*JGR Earth Surface*

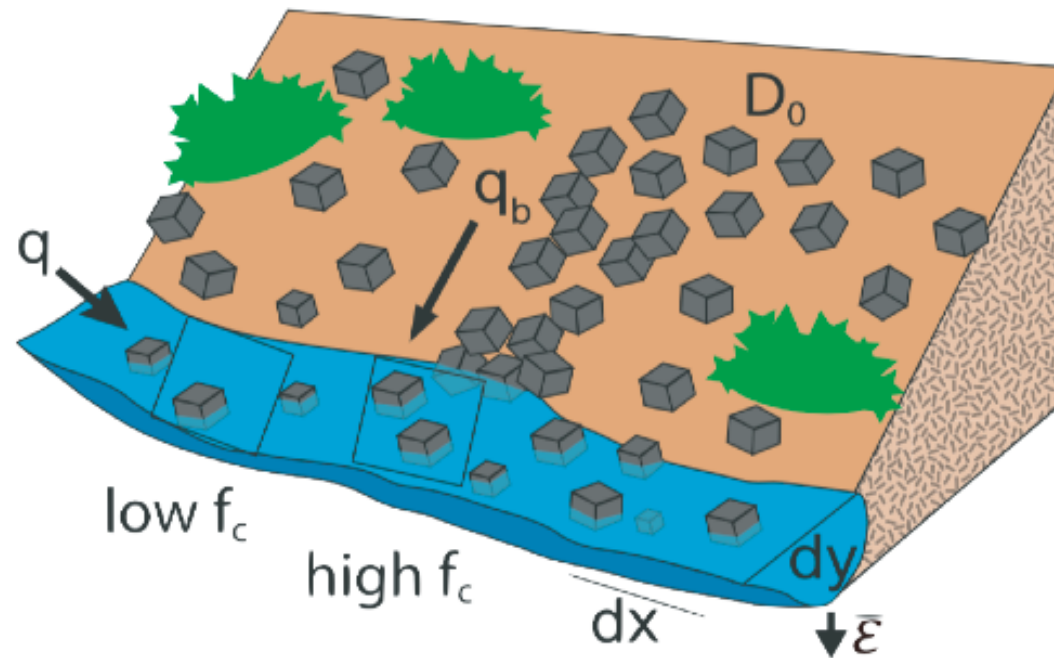


# BlockLab



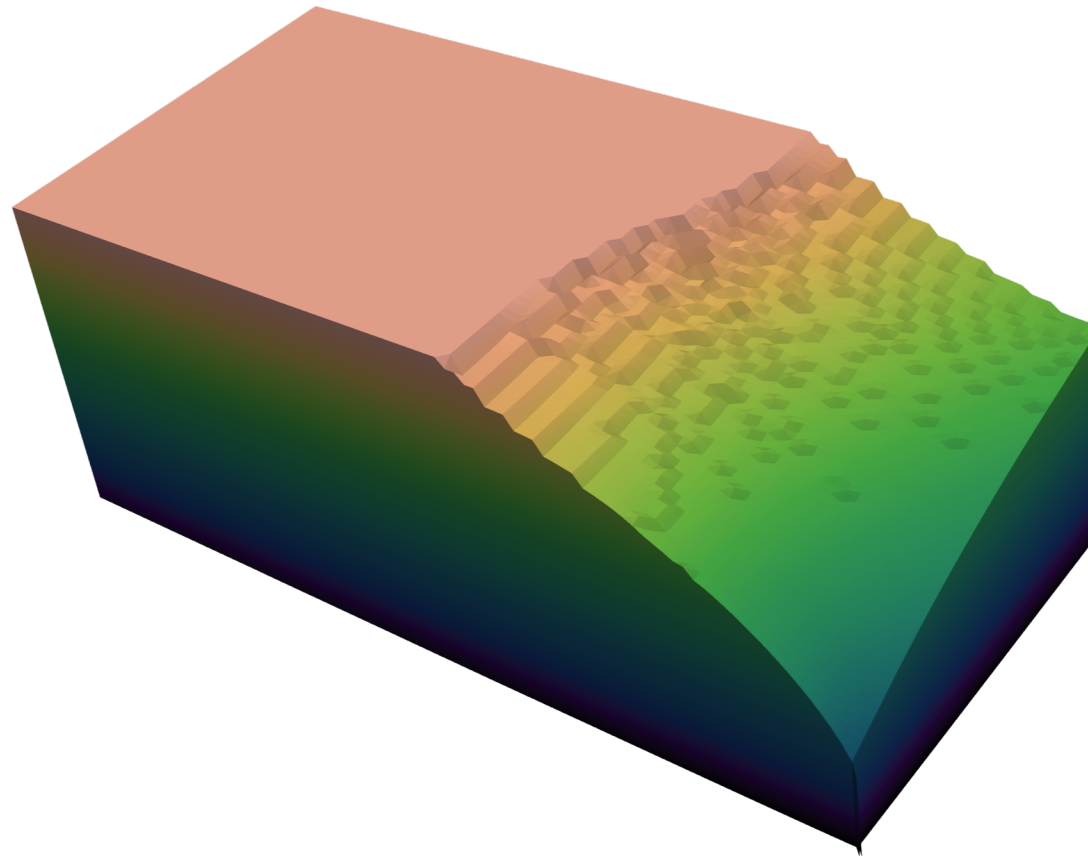
## Coupled channel-hillslope evolution model in LandLab

- 2-D implementation of hillslope model and river incision model in the presence of blocks



Shobe et al., 2016, GRL

# BlockLab



Glade and Shobe, 2018? *in prep*



An aerial photograph of a landscape featuring a prominent, winding river or channel that cuts through a series of terraced or layered hills. The terrain is a mix of brownish and greenish hues, suggesting different soil types or vegetation. In the upper right, there are patches of green, possibly agricultural fields. The overall scene illustrates the concept of 'layered landscape evolution' mentioned in the text.

# Conclusions

\*Dual  
posters  
tomorrow

Block dynamics control layered landscape evolution

Numerical/analytical approach leads to field-testable predictions

Links between large scale morphology, patterns and processes