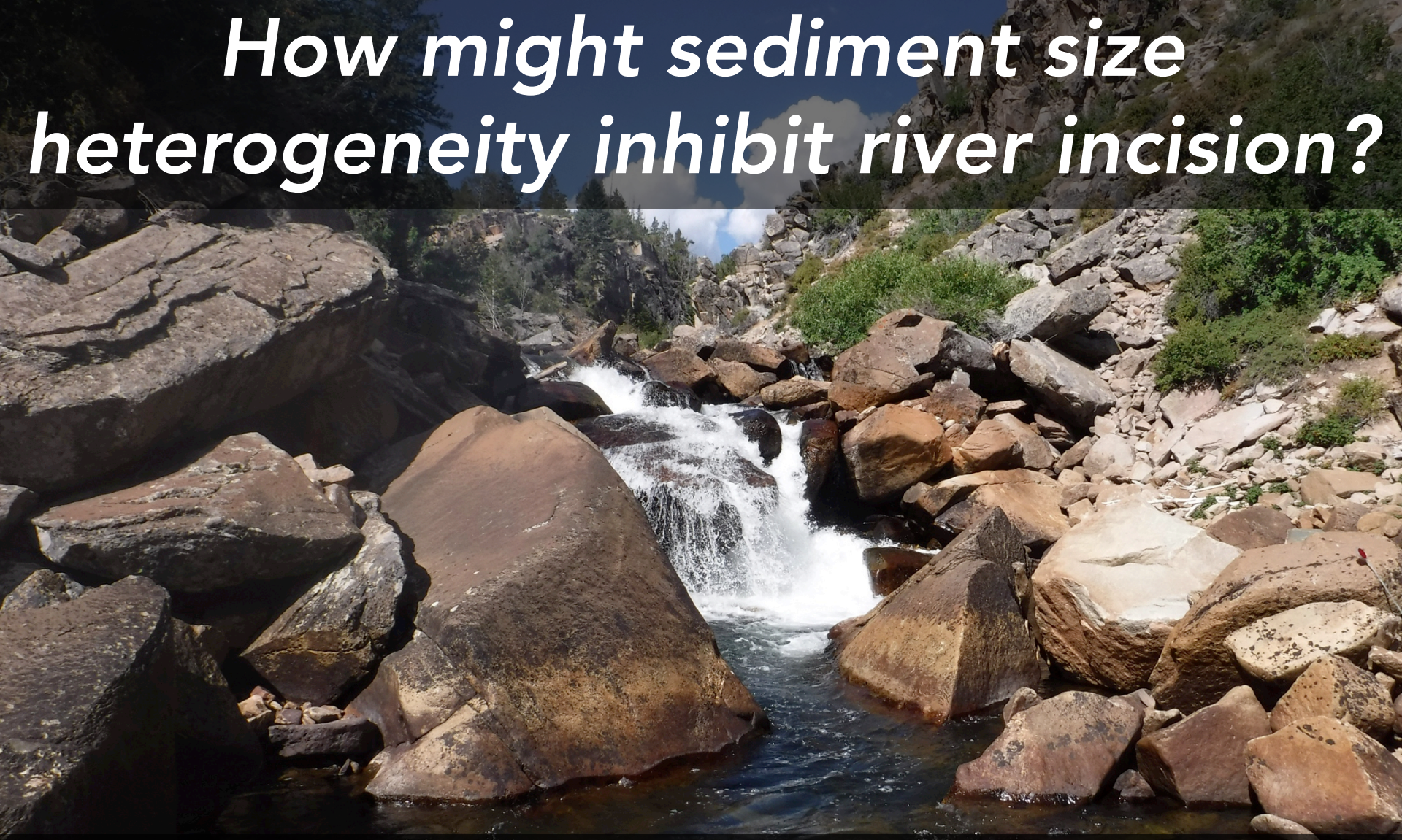
How might sediment size heterogeneity inhibit river incision?



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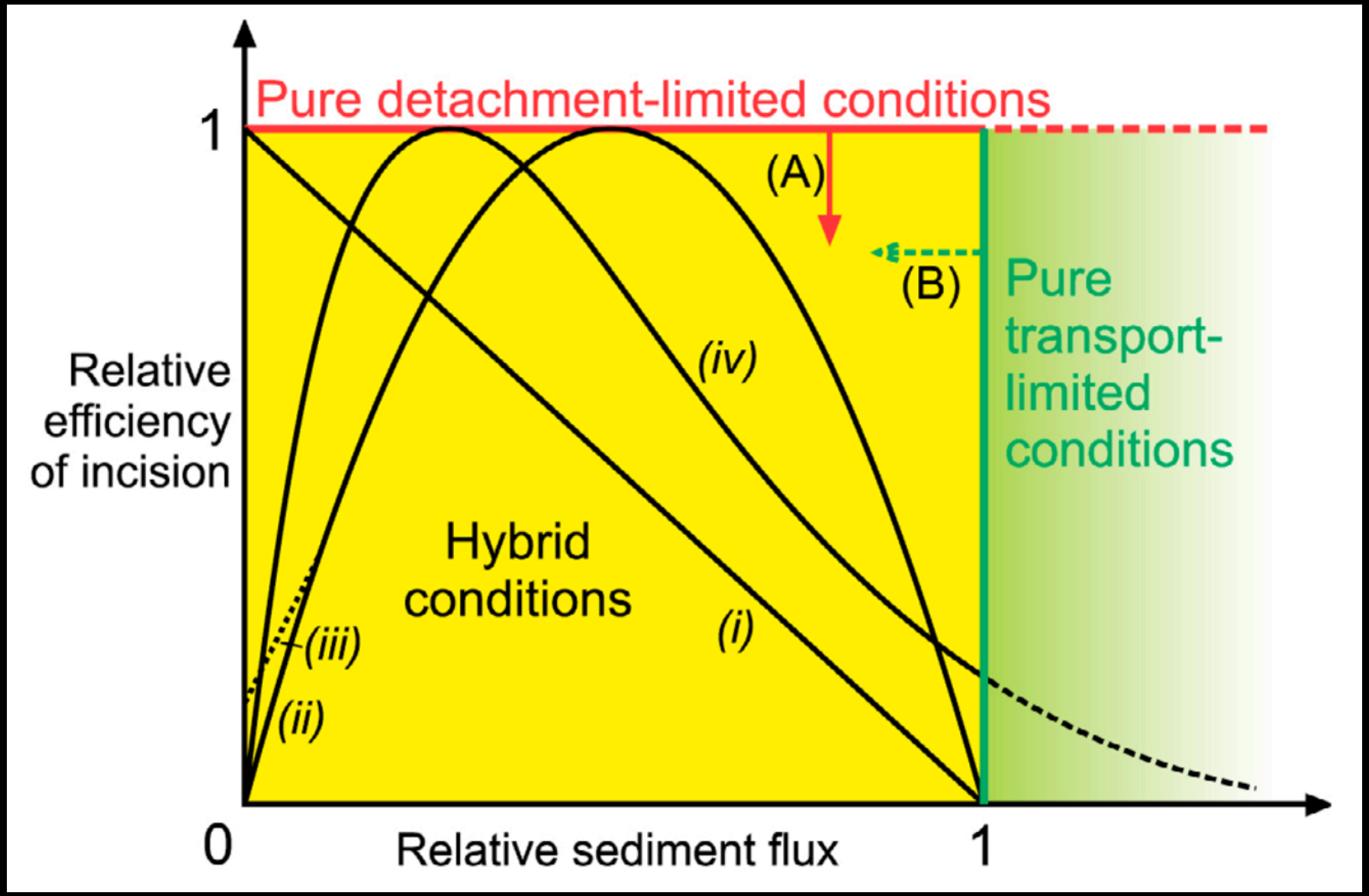
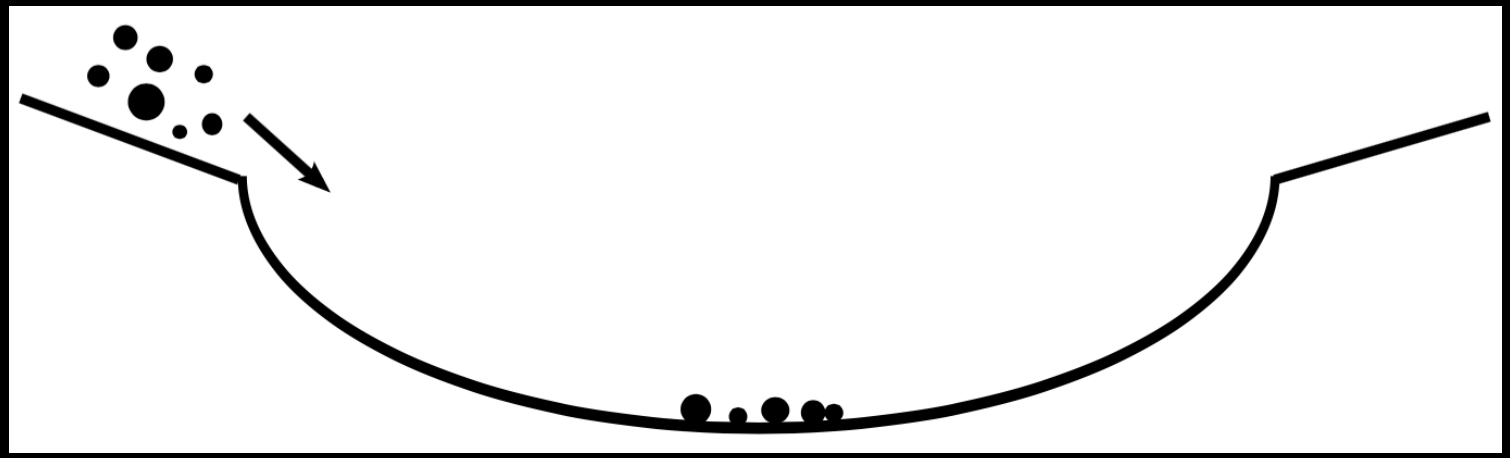
University of Colorado, Boulder



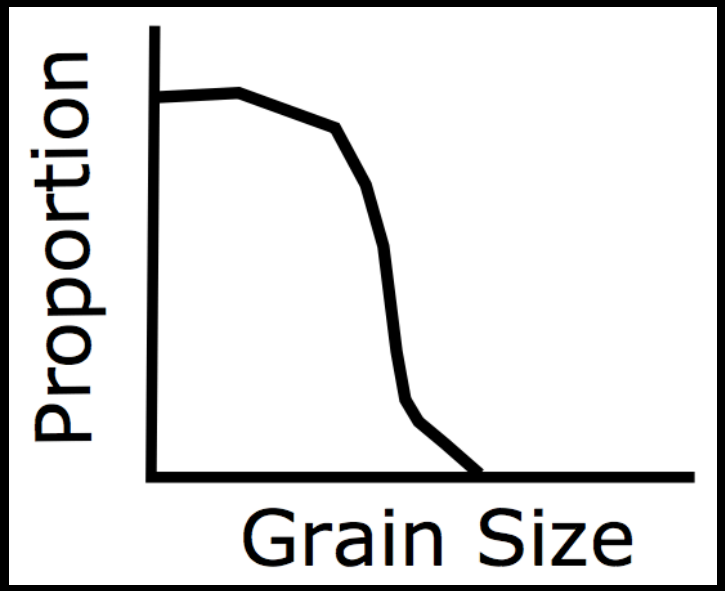
Hobley et al., 2011; Beaumont et al., 1992; Sklar and Dietrich, 2004; Gasparini et al., 2006; Turowski et al., 2007

Hypothesis: Incision-driven changes in sediment size distribution can retard river incision

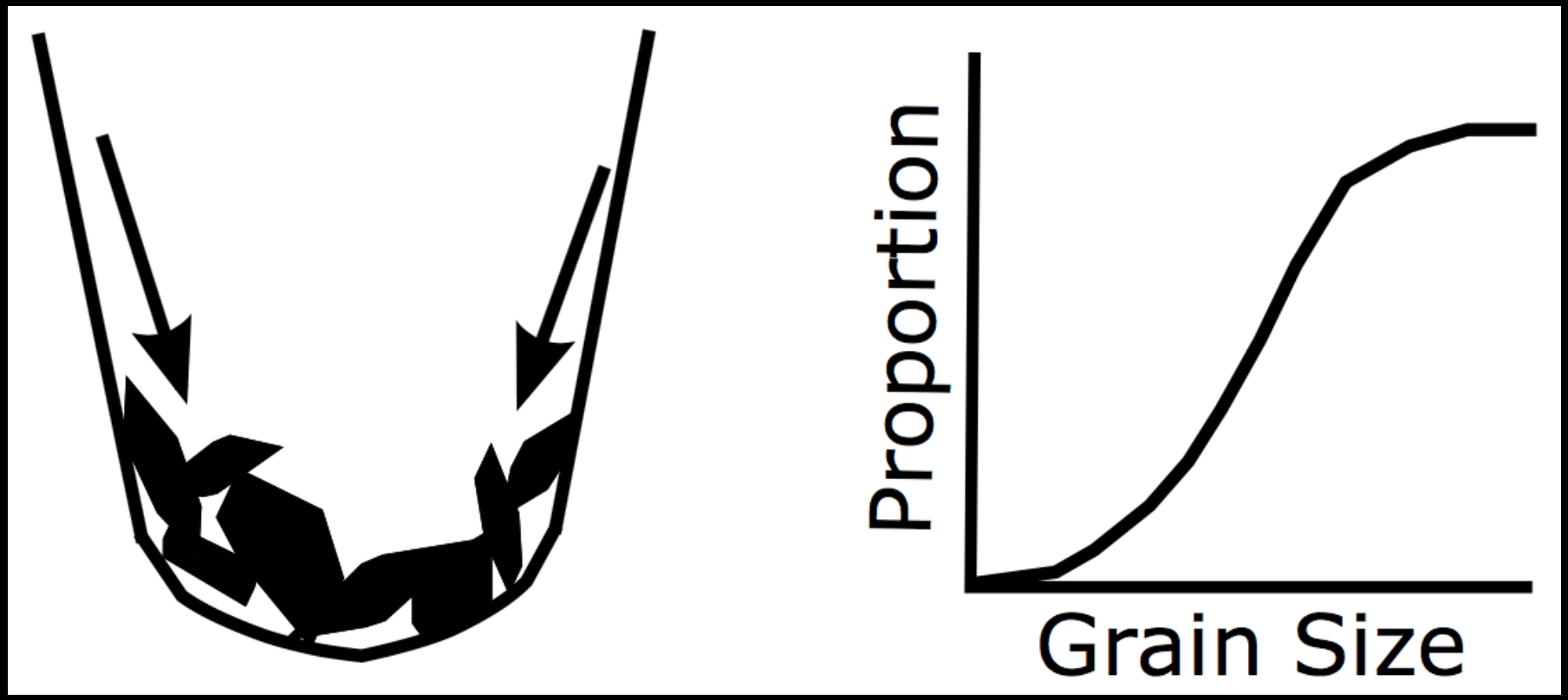
Conceptual model: slow incision



- low erosion rate
- low angle hillslopes
- small sediment
- no bed cover by immobile grains



Conceptual model: Rapid incision



- Rapid incision steepens hillslopes, resulting in influx of large, immobile sediment that armors the bed

Model setup: Fluvial erosion

- One-dimensional channel reach
- Shear stress bedrock erosion
- Erosion is modulated by bed armoring by large, infrequently mobile grains.

$$E = k_e(\tau - \tau_c)^a(1 - f_c)$$

Model setup: Sediment supply

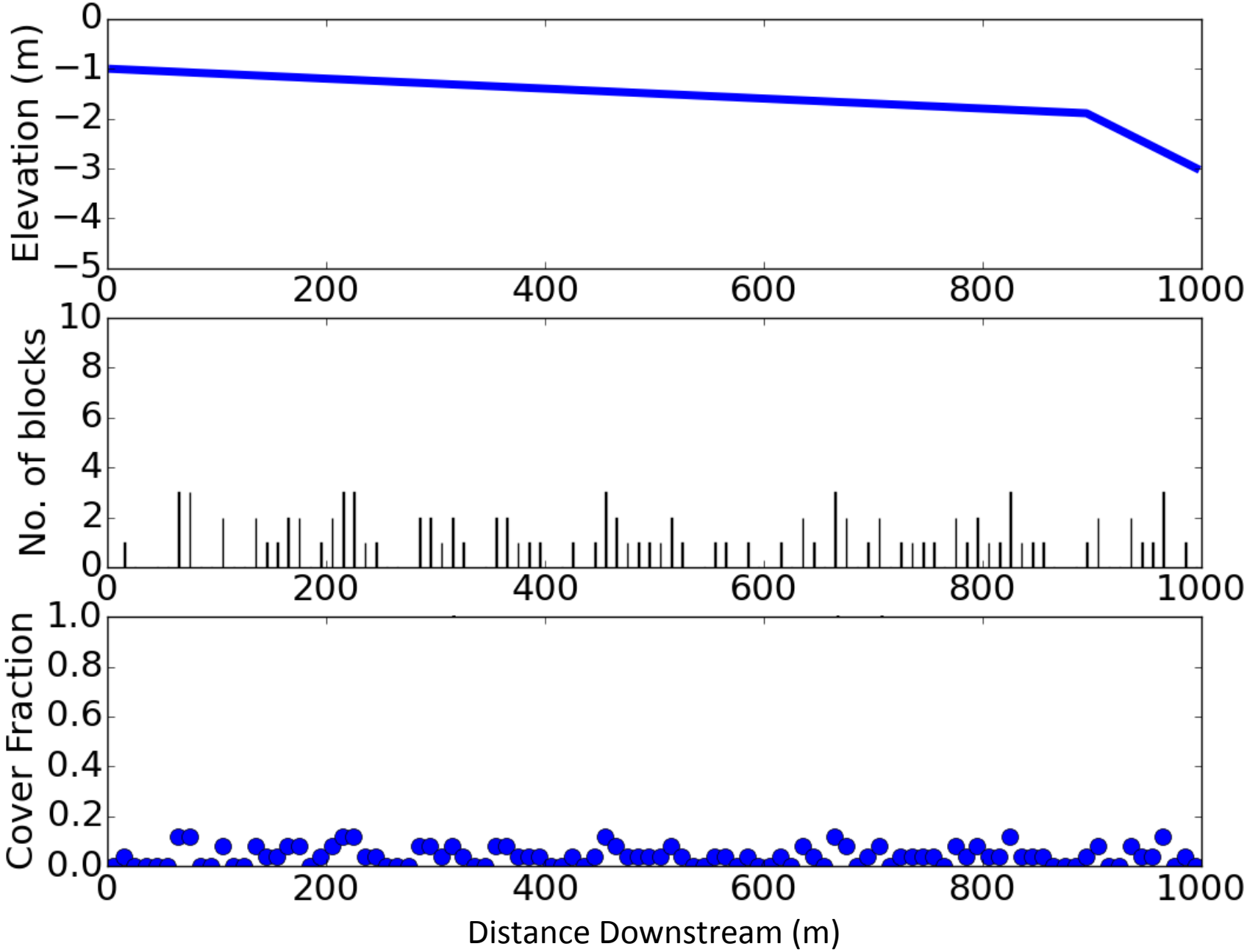
- Channel lowering → Hillslope steepening → More rapid influx of large grains

- Influx of large grains is treated as a Poisson process dependent on channel erosion rate

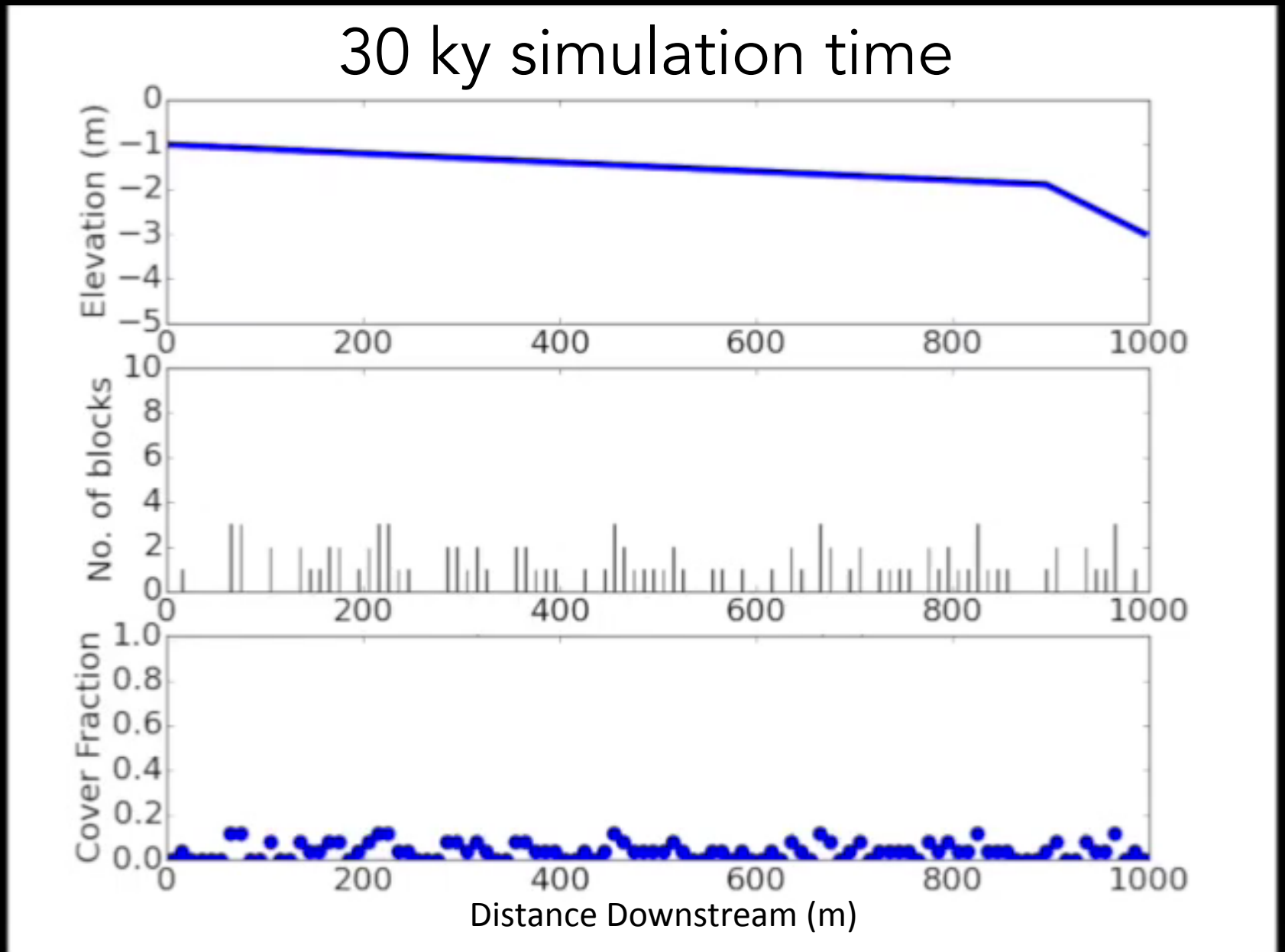
- Large grains abrade with time in the channel, becoming more frequently mobile

$$\frac{dV}{dt} = -\alpha V$$

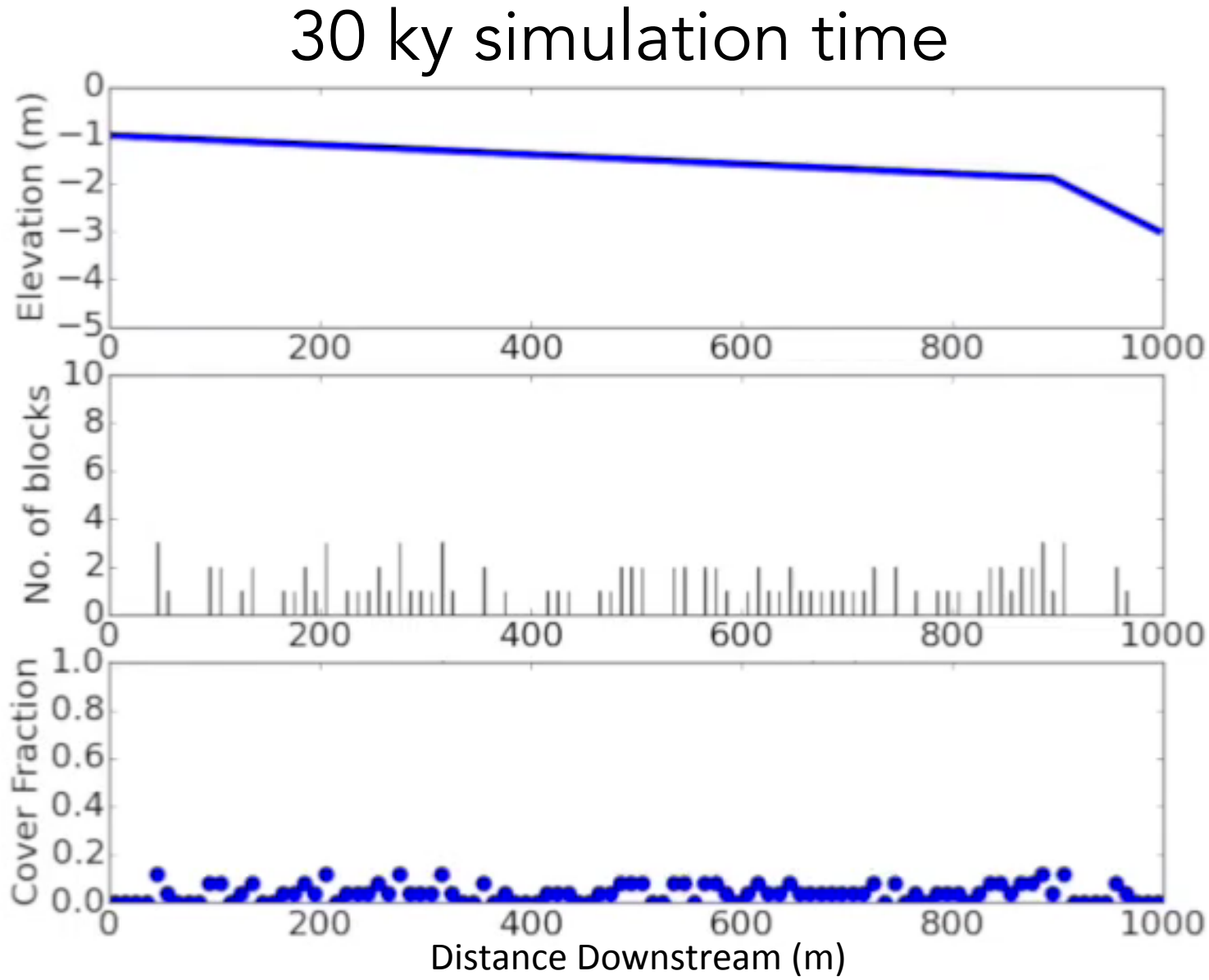
Initial conditions (t = 0)



No large grain flux from hillslopes



Fully responsive hillslopes

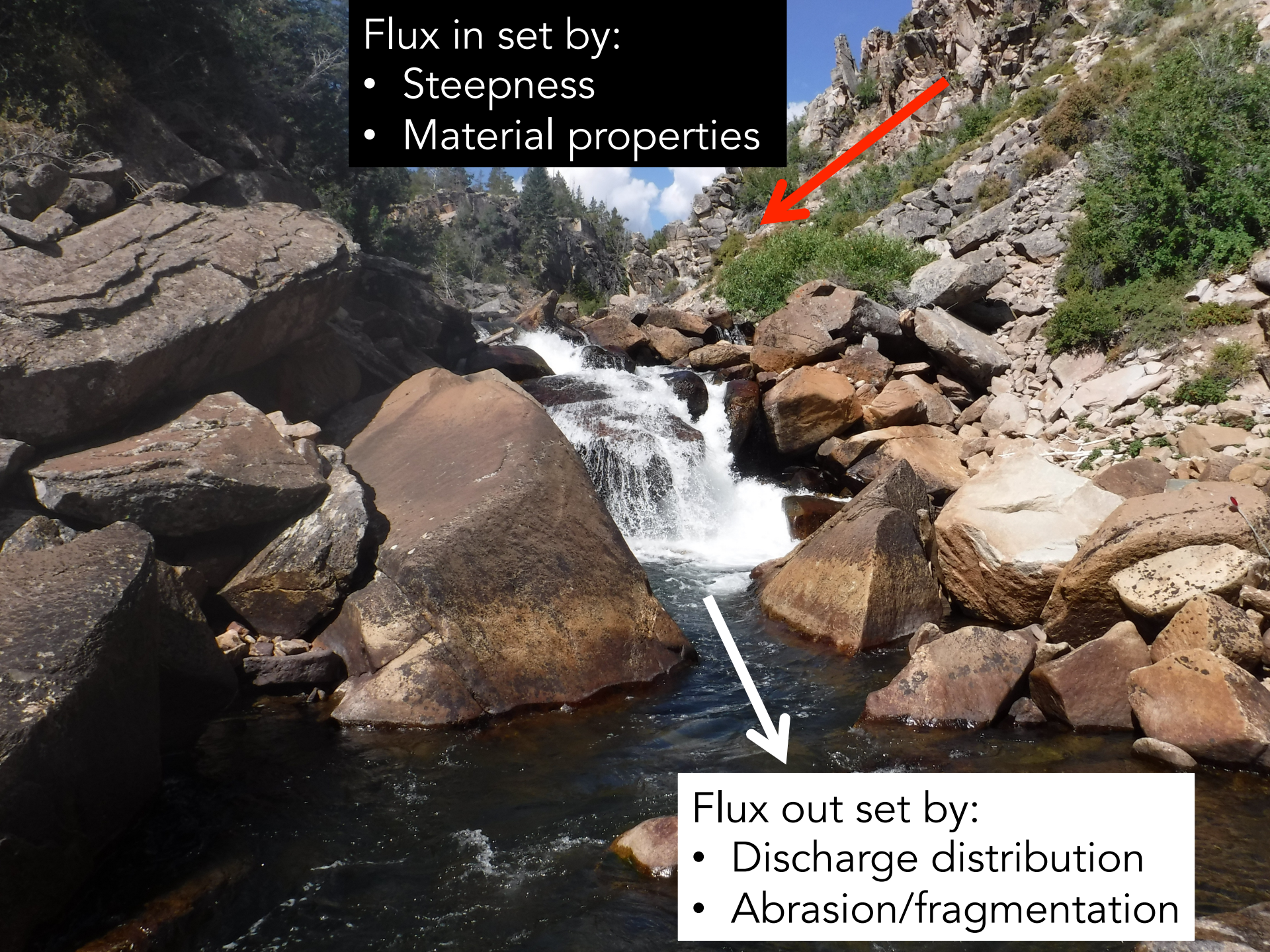


Model Predictions

- Rapid large grain flux from hillslopes can stall channel evolution, alter knickpoint distribution and form

- Matches field observations of clusters of large grains within and below knickzones

- Magnitude of effect set by competition between influx rate, degradation processes


Flux in set by:
• Steepness
• Material properties
Flux out set by:
• Discharge distribution
• Abrasion/fragmentation

Applicable in landscapes that have access to large, potentially immobile grains.

e.g. where bedrock is jointed on sub-m to several m scale.

Not here →

Middle Fork Popo Agie River, WY

Boulder Creek, CO

Grand Canyon from Jumpup Point, AZ

Scott Run near Great Falls, VA
TOPCON

Conclusions

- Rivers may inhibit their own erosion through channel-hillslope sediment size feedbacks

- May help explain variability in knickzone form, evolution timescales

- Significant implications for stream profile analysis– consider hillslope characteristics