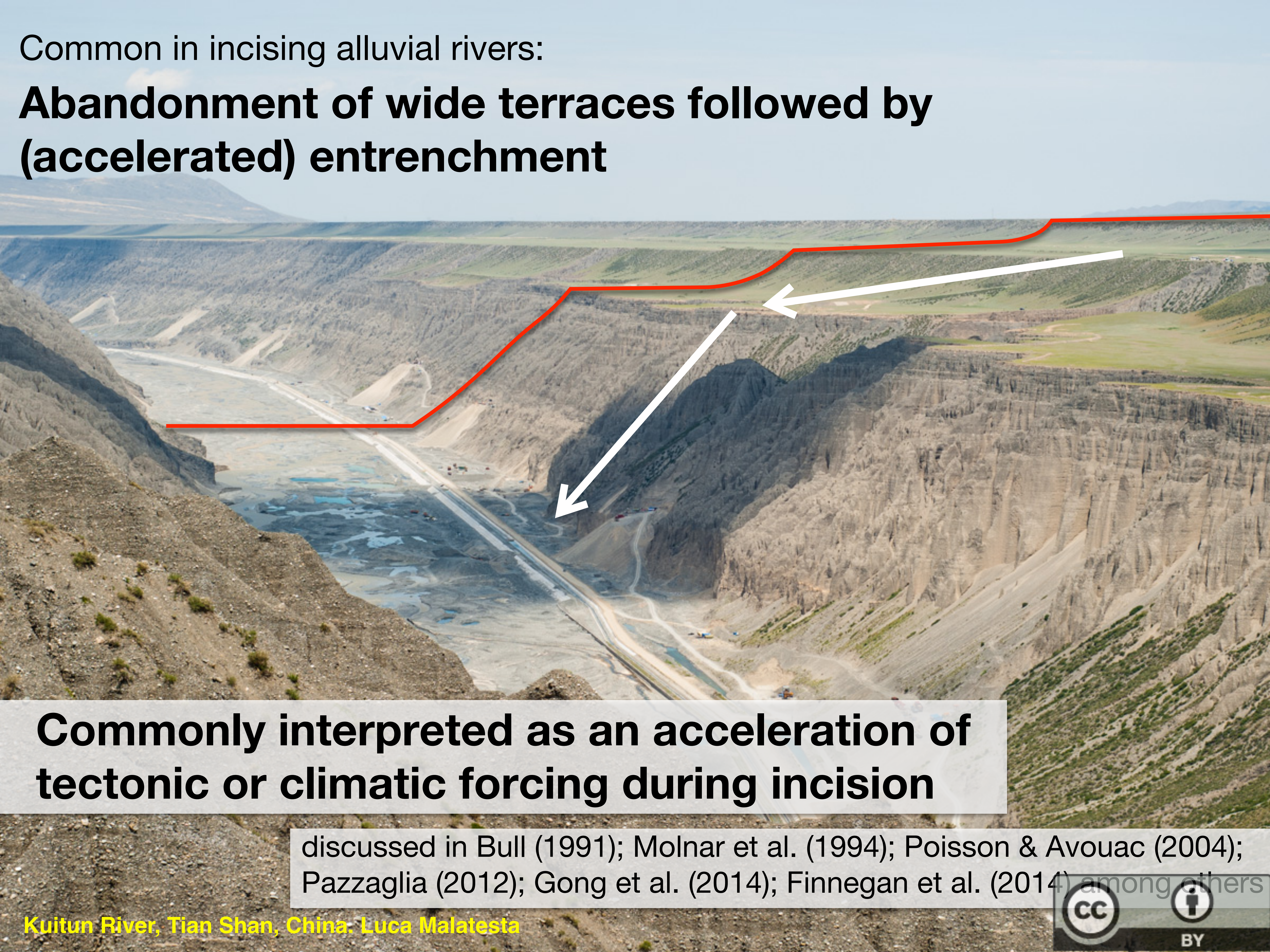
Autogenic terraces and non-linear river incision rates under steady external forcing

Luca C Malatesta[1], Jeffrey P Prancevic[1], Jean-Philippe Avouac[1,2]
California Institute of Technology, University of Cambridge

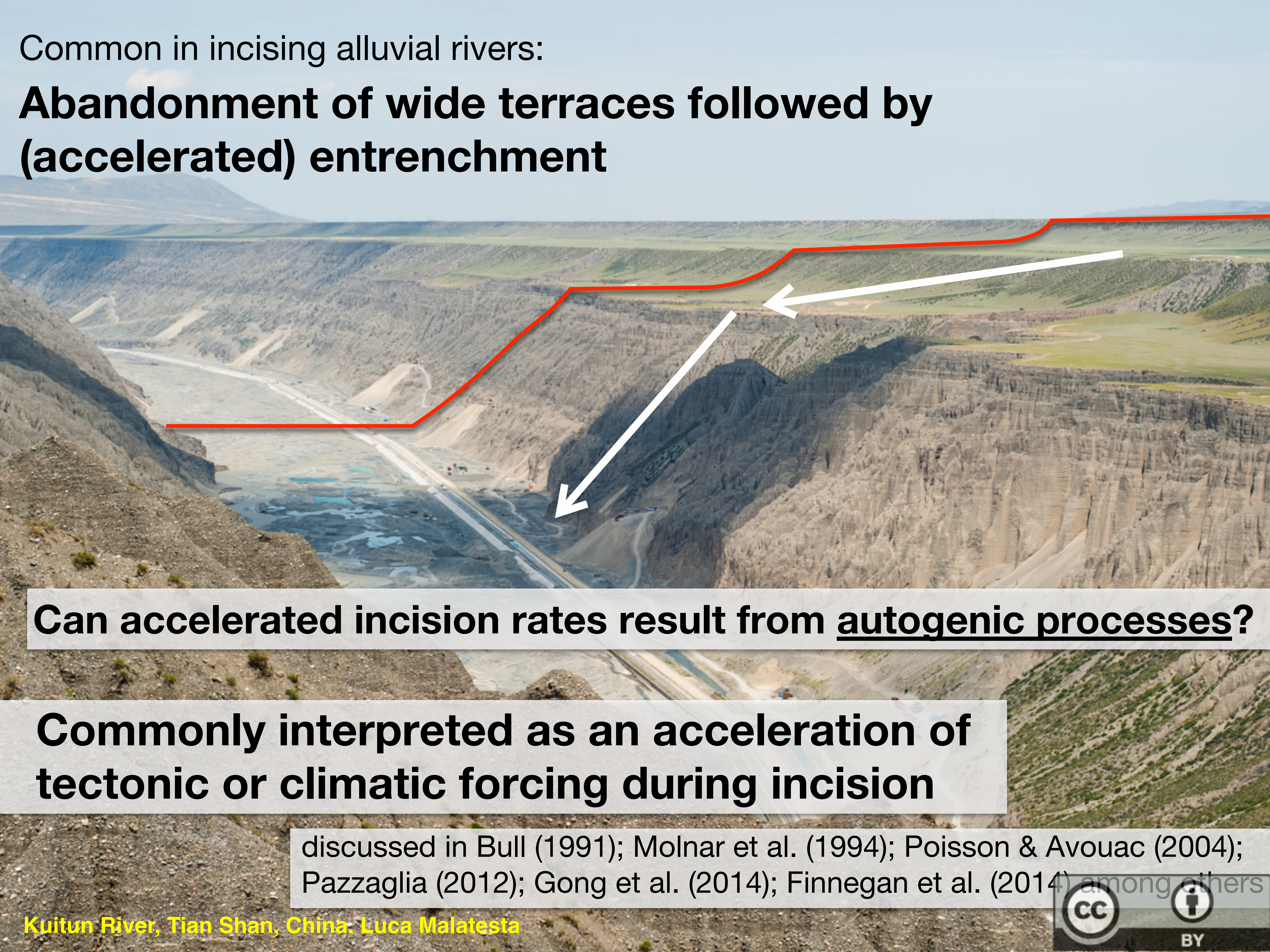
Tectonics Observatory
California Institute of Technology
GORDON AND BETTY MOORE FOUNDATION
ACS PRF

California Institute of Technology · Geological and Planetary Sciences · Labor Bonus et Multus


Common in incising alluvial rivers:
Abandonment of wide terraces followed by (accelerated) entrenchment
Commonly interpreted as an acceleration of tectonic or climatic forcing during incision
discussed in Bull (1991); Molnar et al. (1994); Poisson & Avouac (2004); Pazzaglia (2012); Gong et al. (2014); Finnegan et al. (2014) among others
Kuitun River, Tian Shan, China: Luca Malatesta
BY

Common in incising alluvial rivers:

Abandonment of wide terraces followed by (accelerated) entrenchment



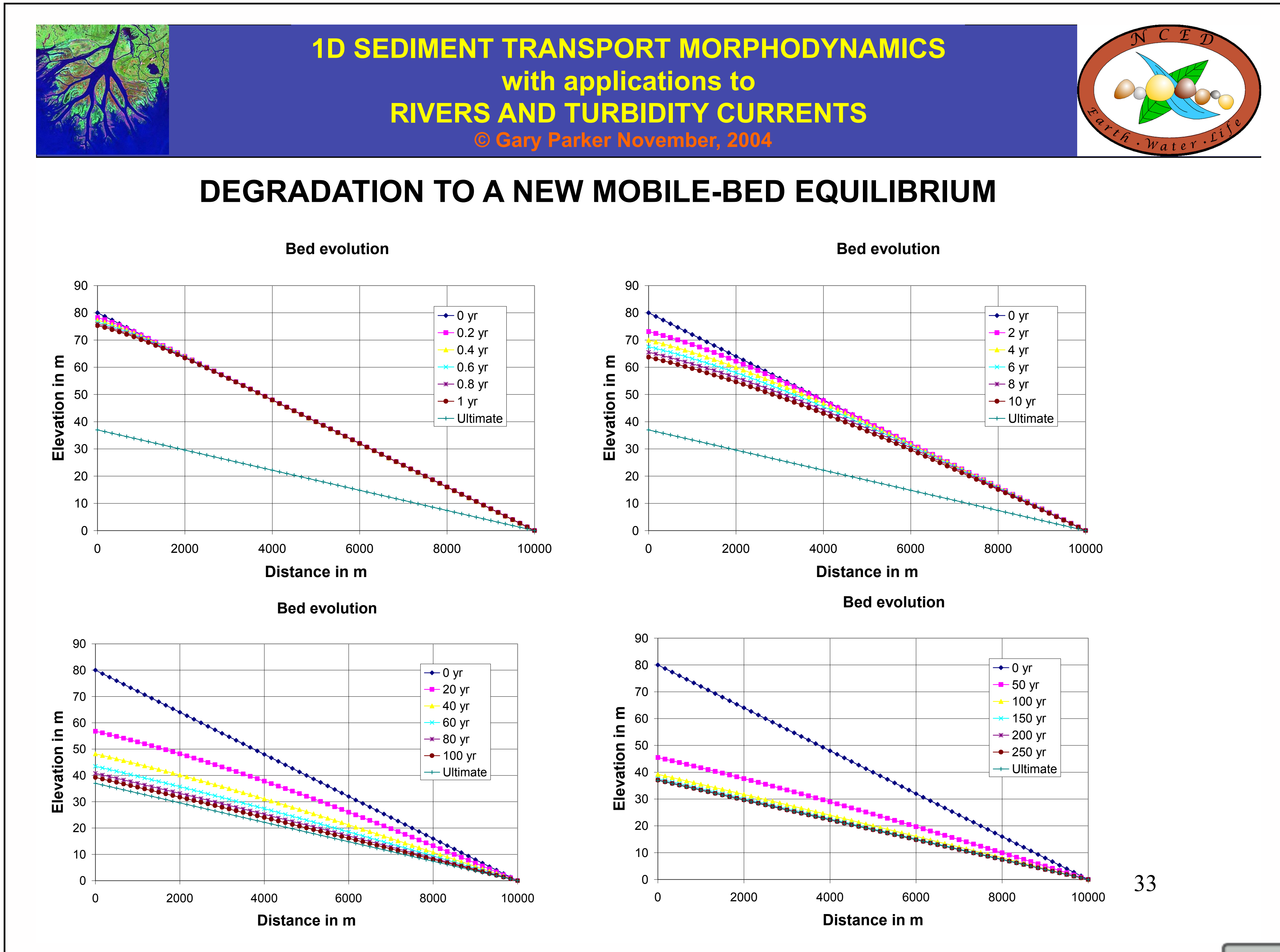
Can accelerated incision rates result from <u>autogenic processes</u>?

Commonly interpreted as an acceleration of tectonic or climatic forcing during incision

discussed in Bull (1991); Molnar et al. (1994); Poisson & Avouac (2004); Pazzaglia (2012); Gong et al. (2014); Finnegan et al. (2014) among others

Kuitun River, Tian Shan, China: Luca Malatesta

Our understanding of incision in transport-limited rivers is rooted in 1D



Gary Parker's morphodynamics e-book available online

We propose to test two autogenic processes that enhance vertical incision as entrenchment proceeds.

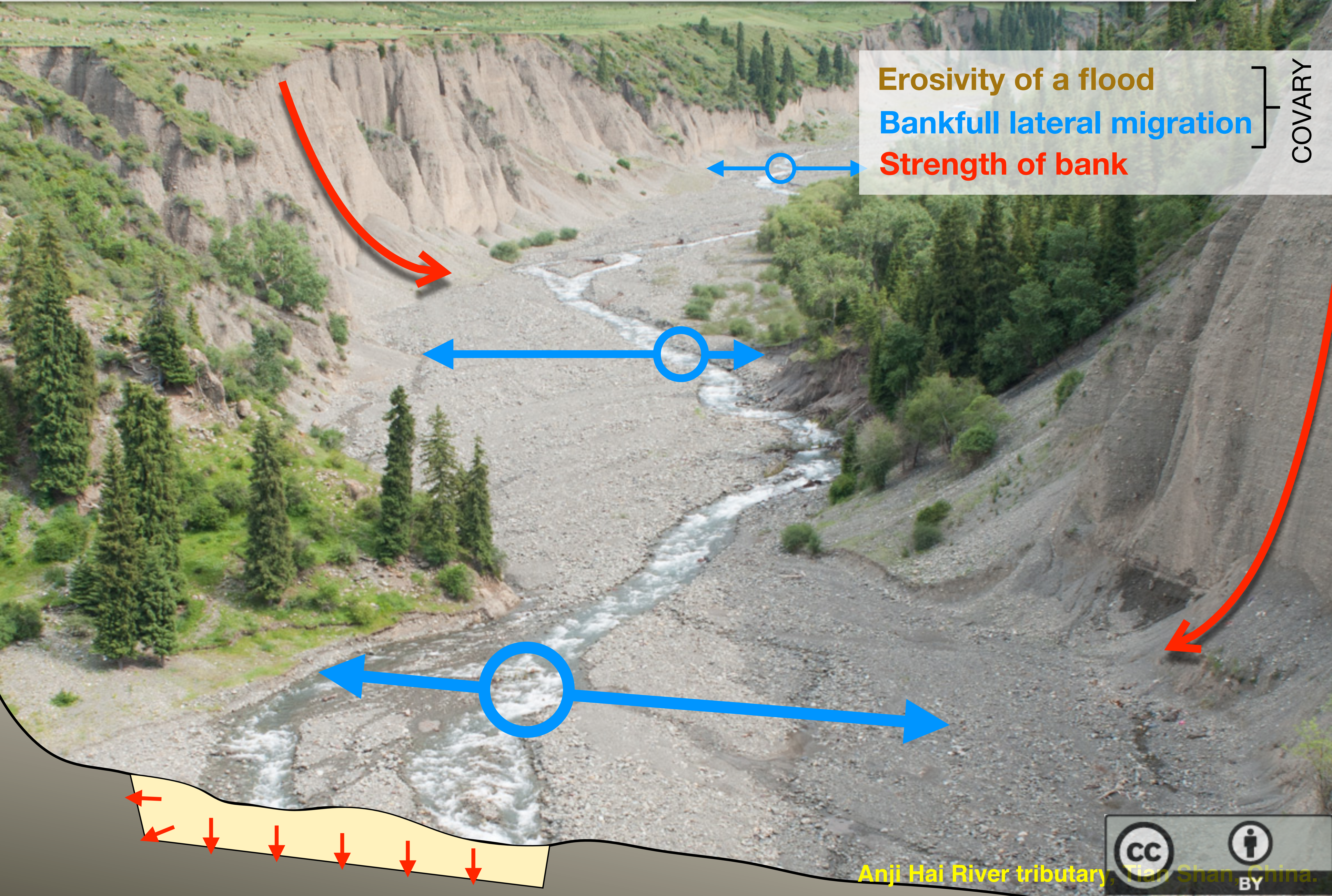
1. high banks reduce the channel lateral migration rate, vertical incision happens over the same area and is enhanced

2. large cliff collapse cannot be immediately removed by the river, creating a talus that shields the bank from erosion while vertical incision continues.

mentioned in Hancock and Anderson, 2002; Nicholas and Quine, 2007a,b; Clarke et al., 2010; Nicholas et al., 2009

Anji Hai River tributary, Tian Shan, China.

Model for cross-section evolution of entrenchment



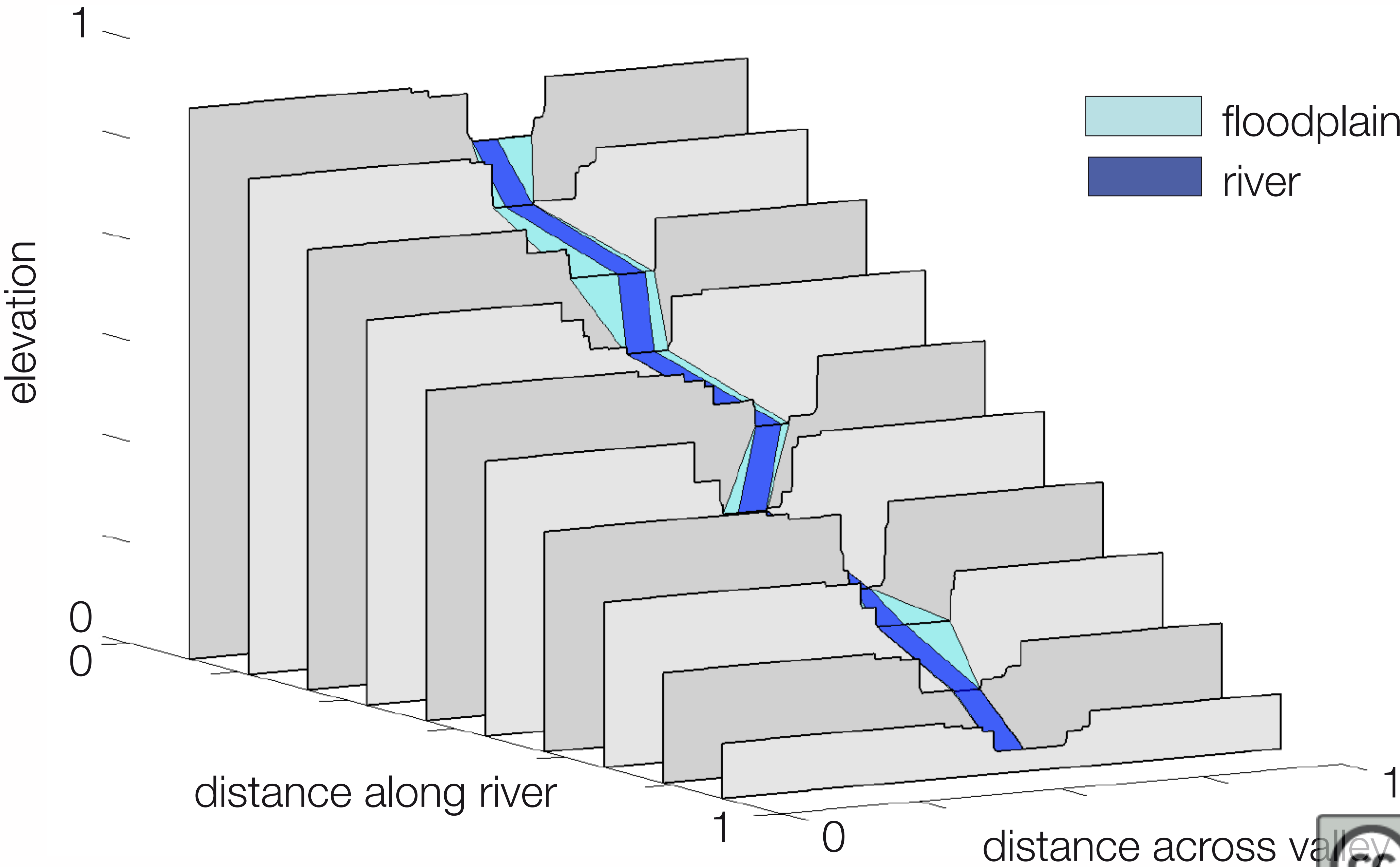
The geometric model is made of a series of independent cross-sections

Sediment flux in each cross-section depends on channel **slope**, **width** and **water discharge**

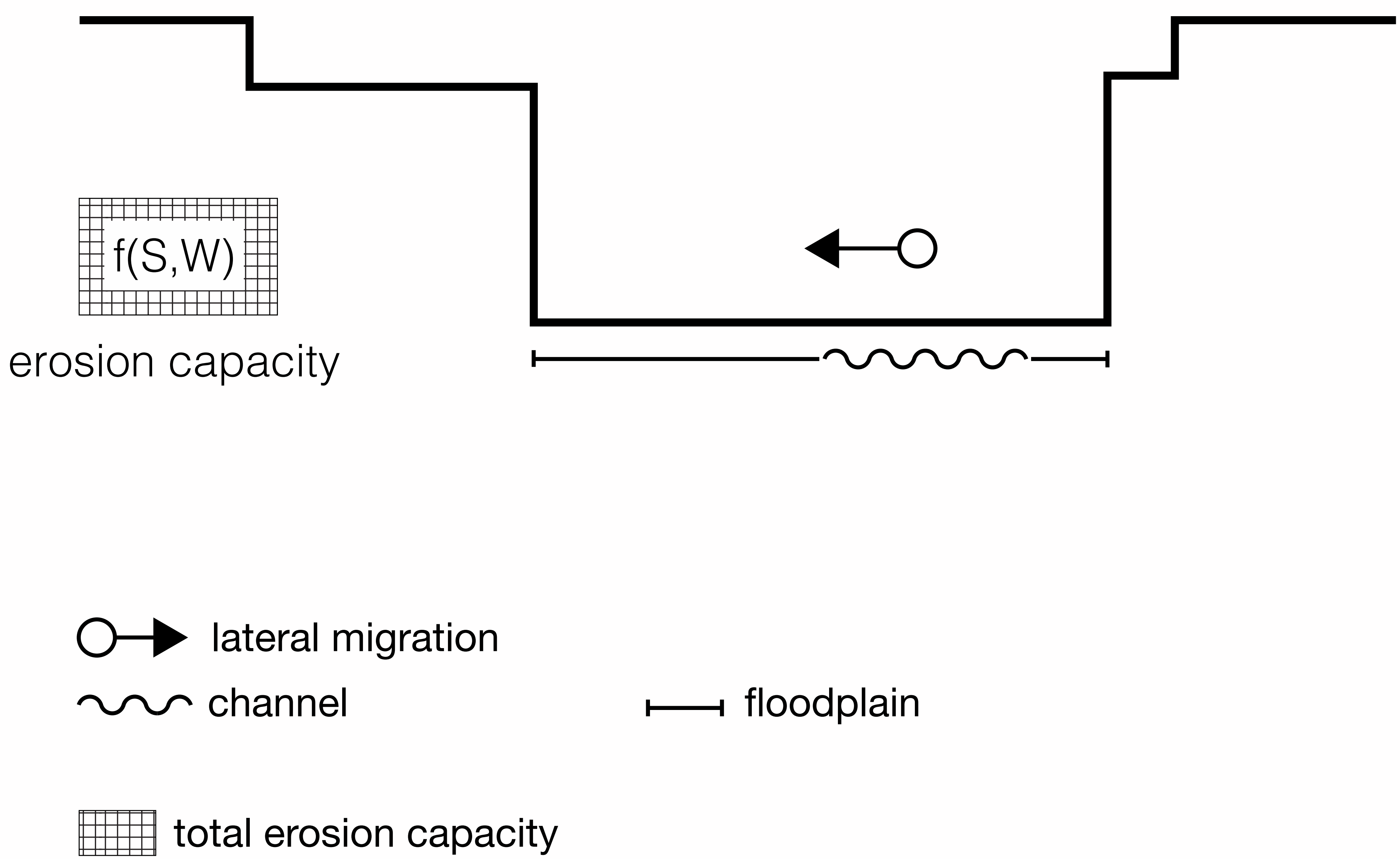
Erosion is defined by the **divergence of sediment flux** between the profiles (Exner)

In each cross-section erosion is partitioned between **bed erosion and lateral erosion**

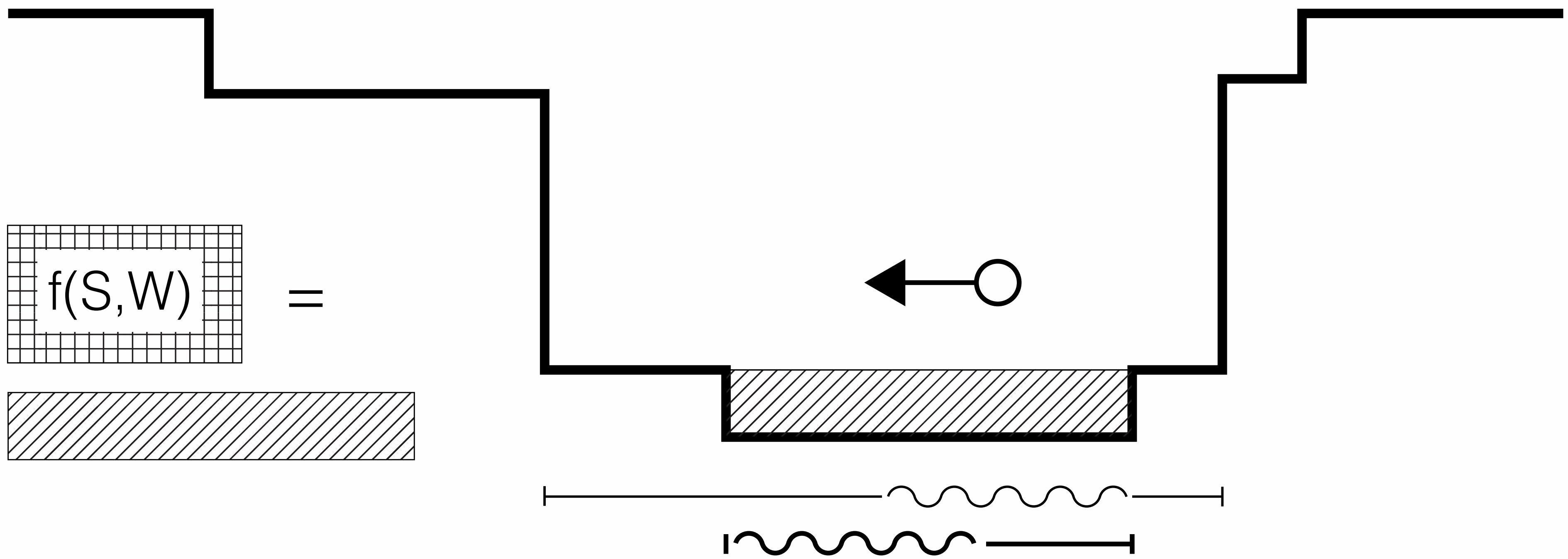
Lateral migration is **independently picked** in each cross-section following a **random walk**



the geometric model reflects the main processes: starting with a random migration to erode a set area

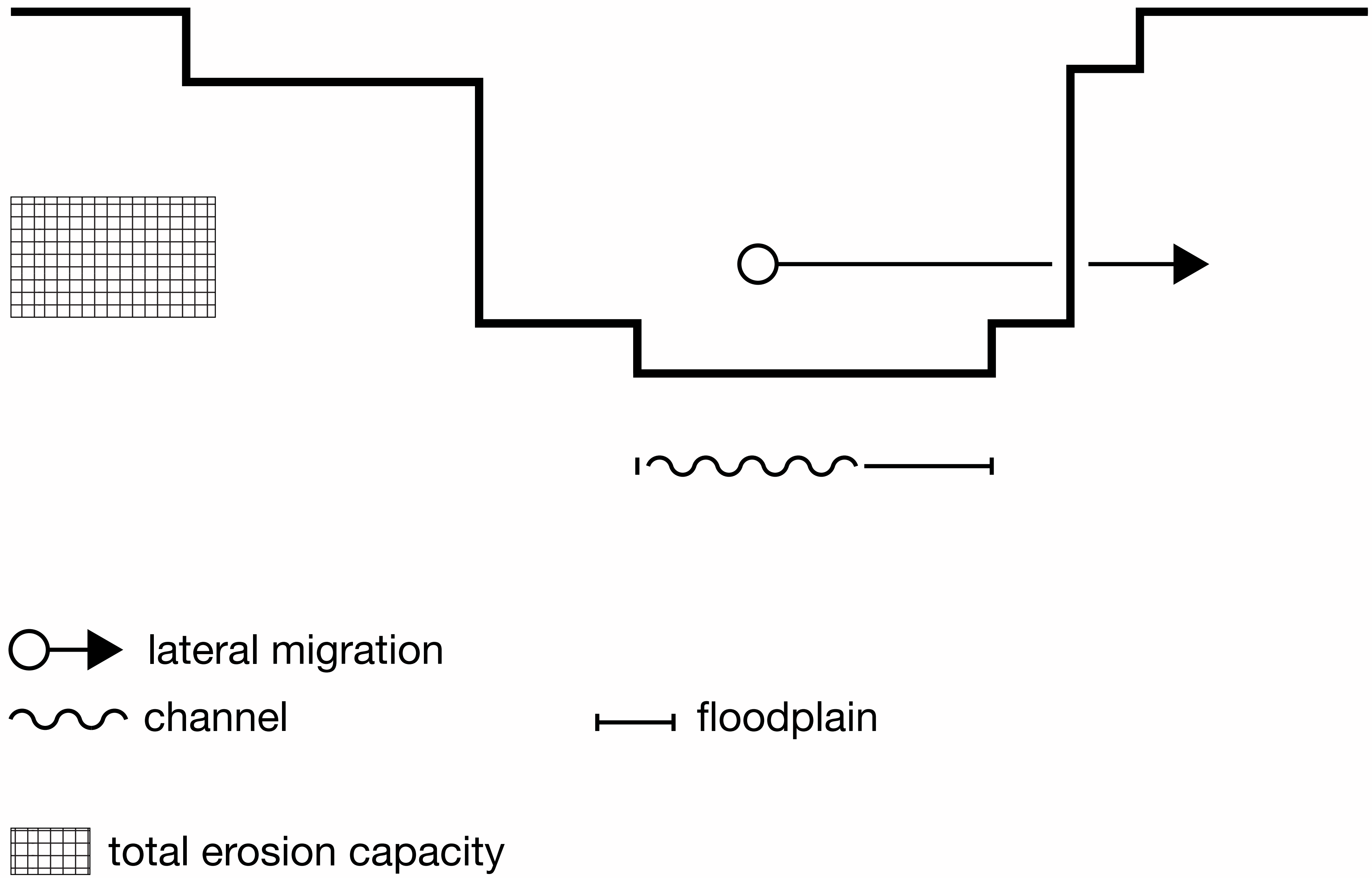


the geometric model reflects the main processes:
migration and erosion within the floodplain

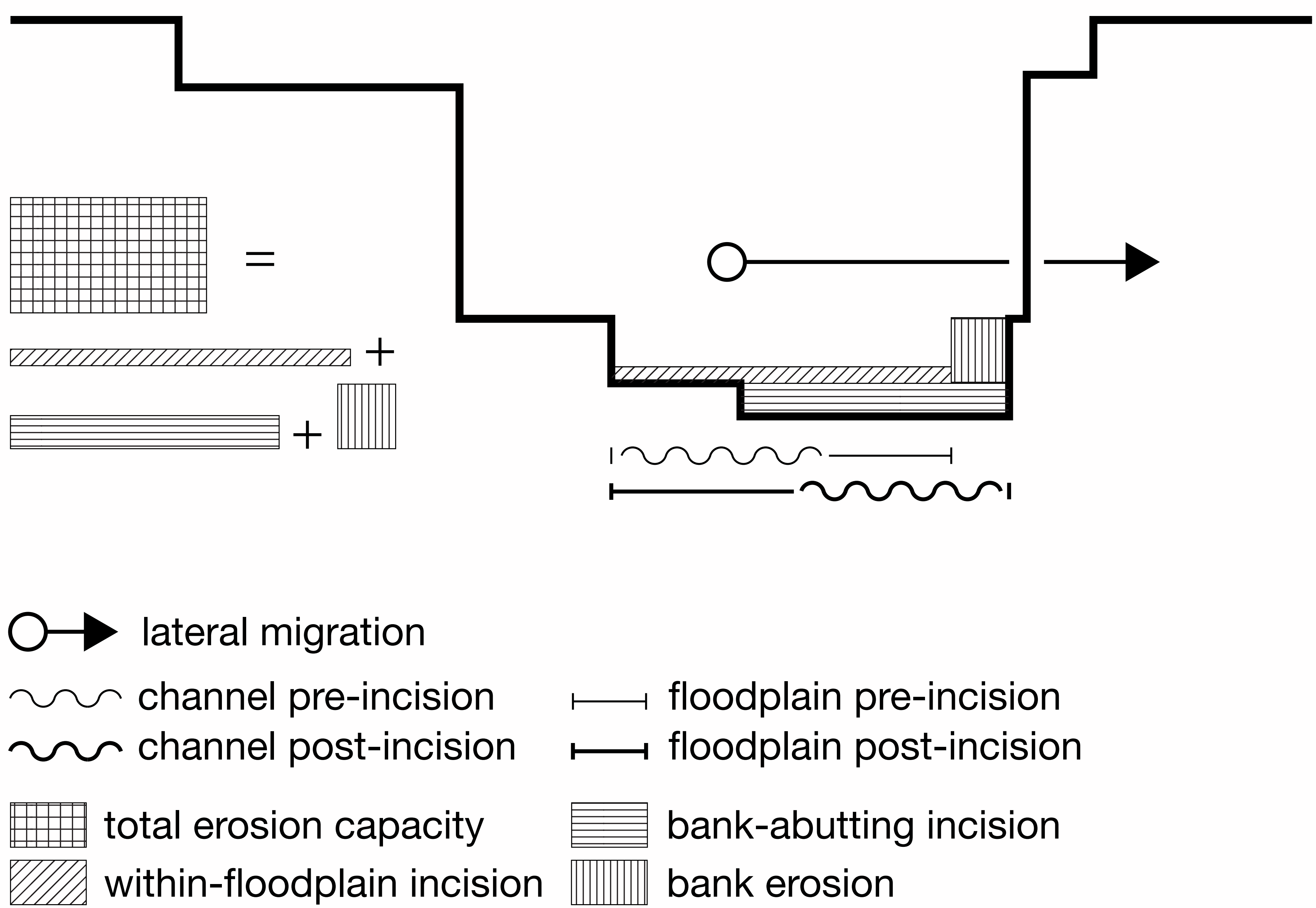


lateral migration
channel pre-incision
channel post-incision
floodplain pre-incision
floodplain post-incision
total erosion capacity
within-floodplain incision

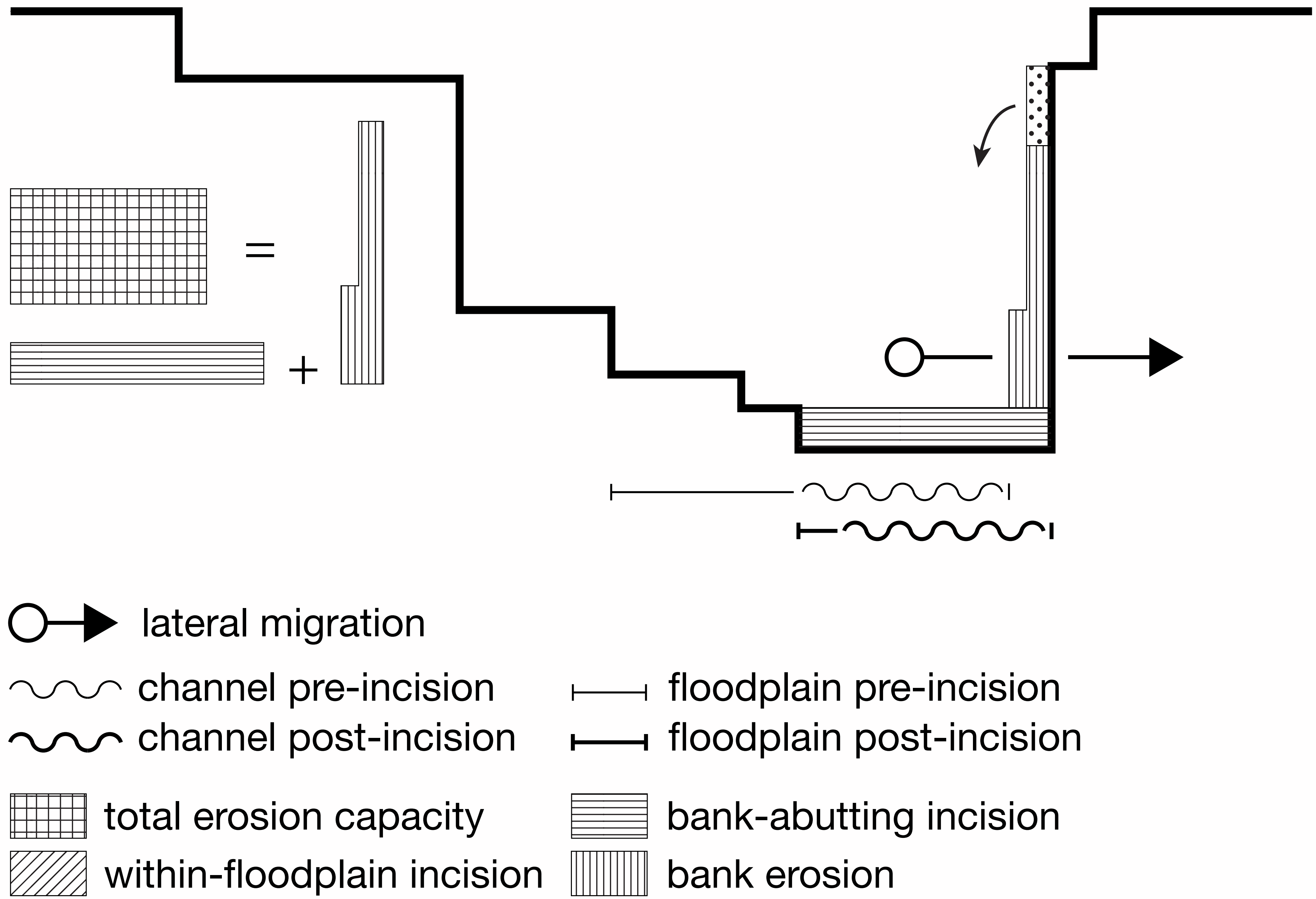
the geometric model reflects the main processes:
migration against a short bank



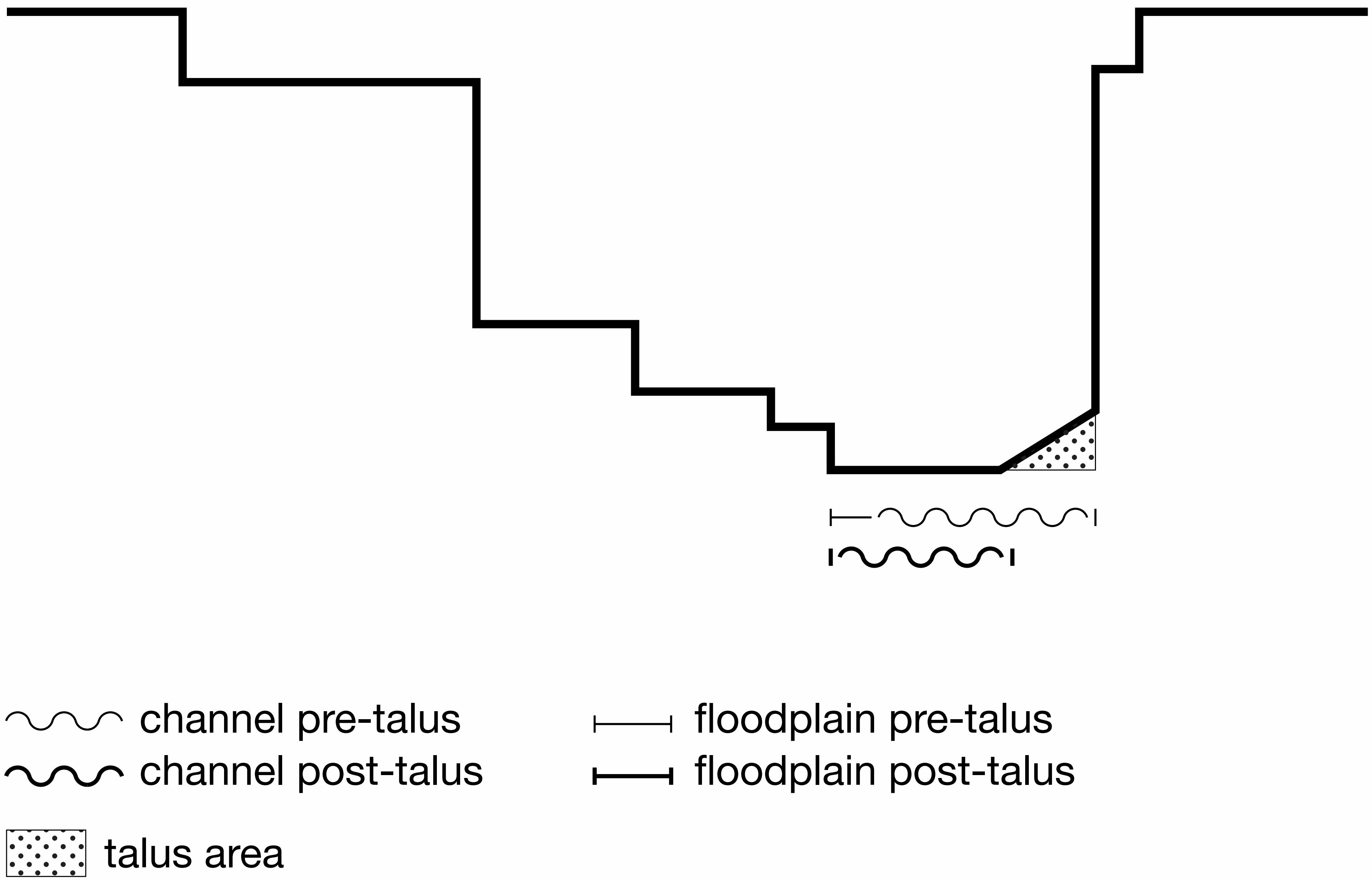
the geometric model reflects the main processes:
results in floodplain and bank erosion



the geometric model reflects the main processes:
against a tall bank (cliff), excess material is



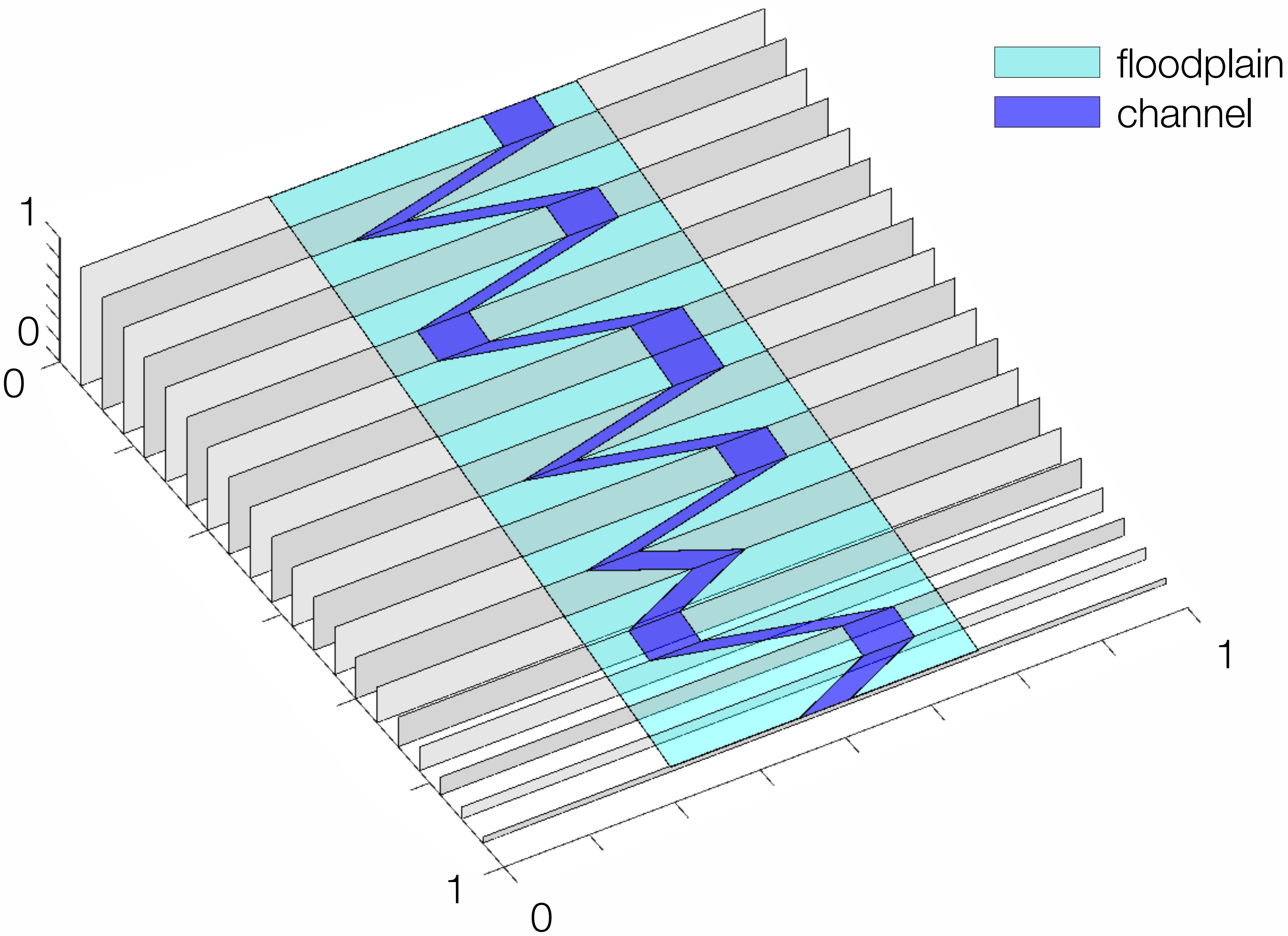
the geometric model reflects the main processes:
deposited as a talus and constrains the channel



180 runs to test parameters

Erosion capacity captures variability of entrenchment dynamics best

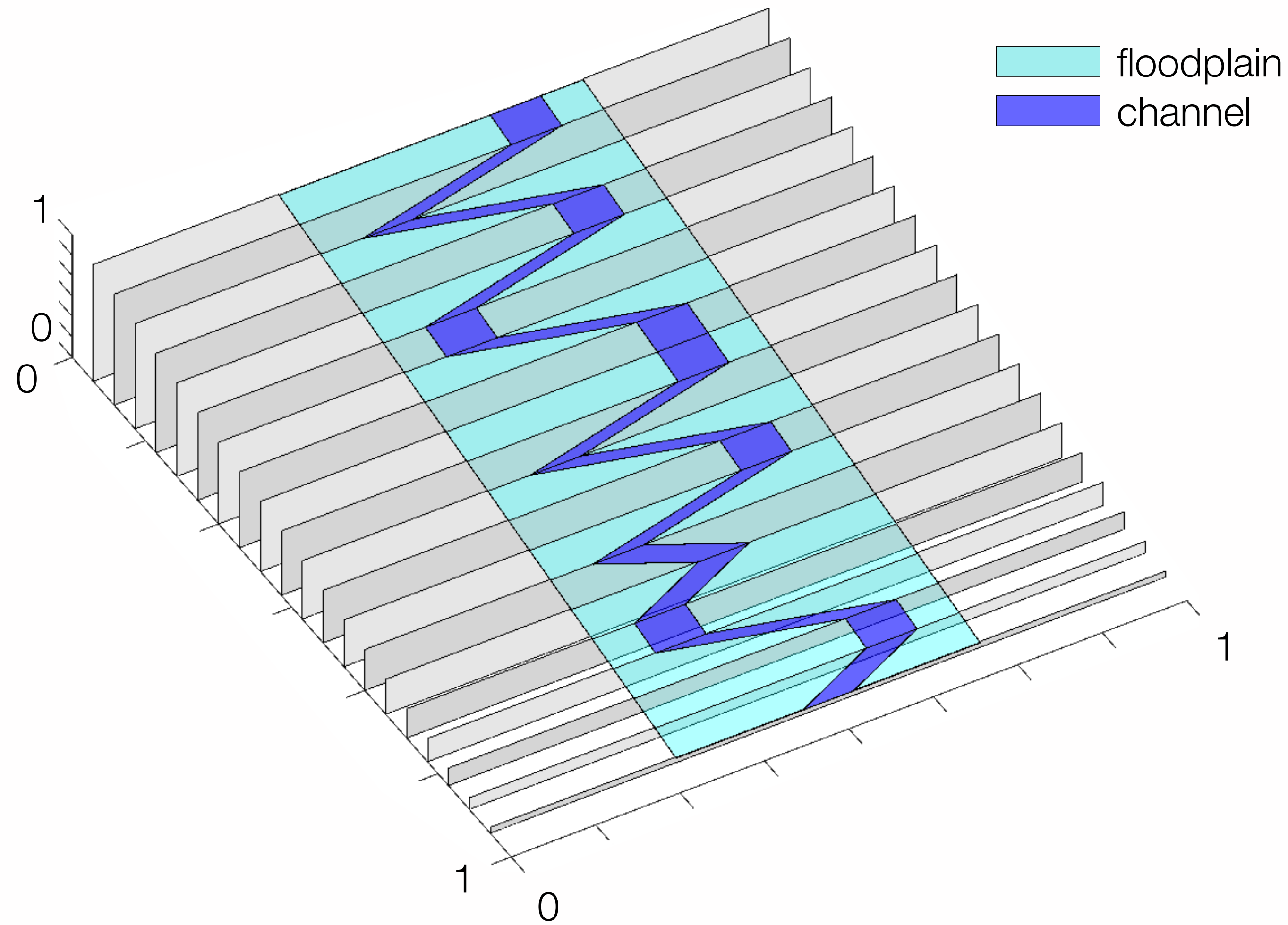
High erosion capacity result in deep rectangular canyons



Limited terrace record

Moderate channel narrowing

Low erosion capacity result in funnel-shaped canyons



Extensive terrace record

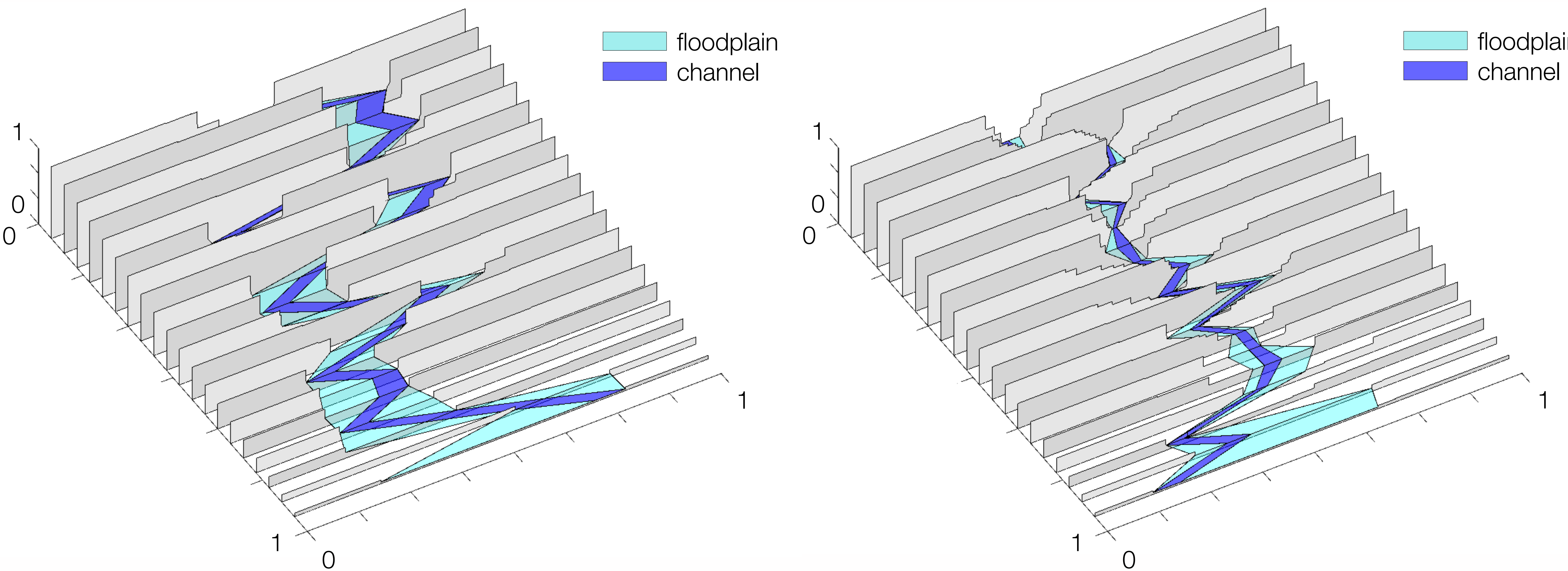
Important channel narrowing

180 runs to test parameters

Erosion capacity captures variability of entrenchment dynamics best

High erosion capacity result in deep rectangular canyons

Low erosion capacity result in funnel-shaped canyons



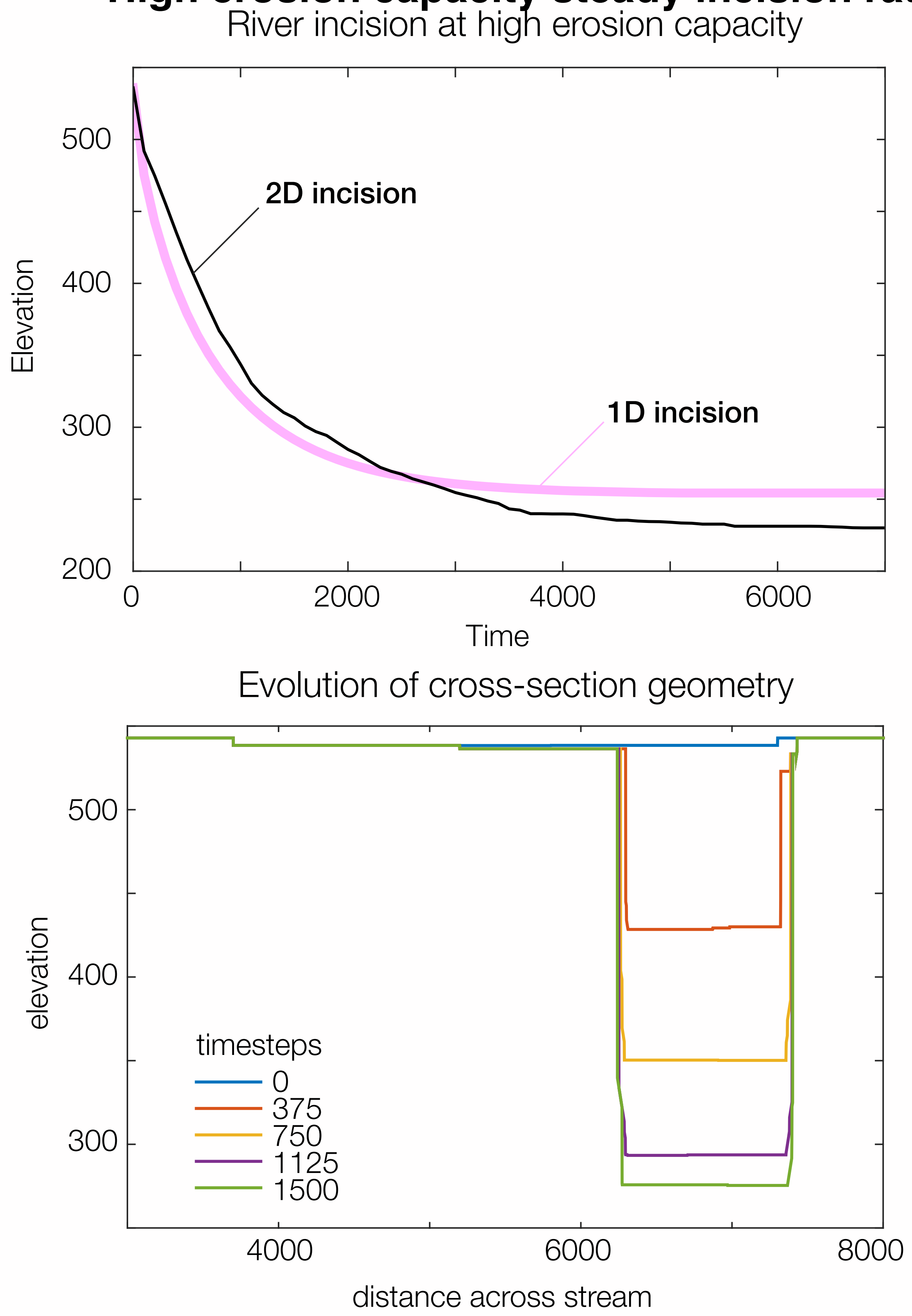
Limited terrace record

Moderate channel narrowing

Extensive terrace record

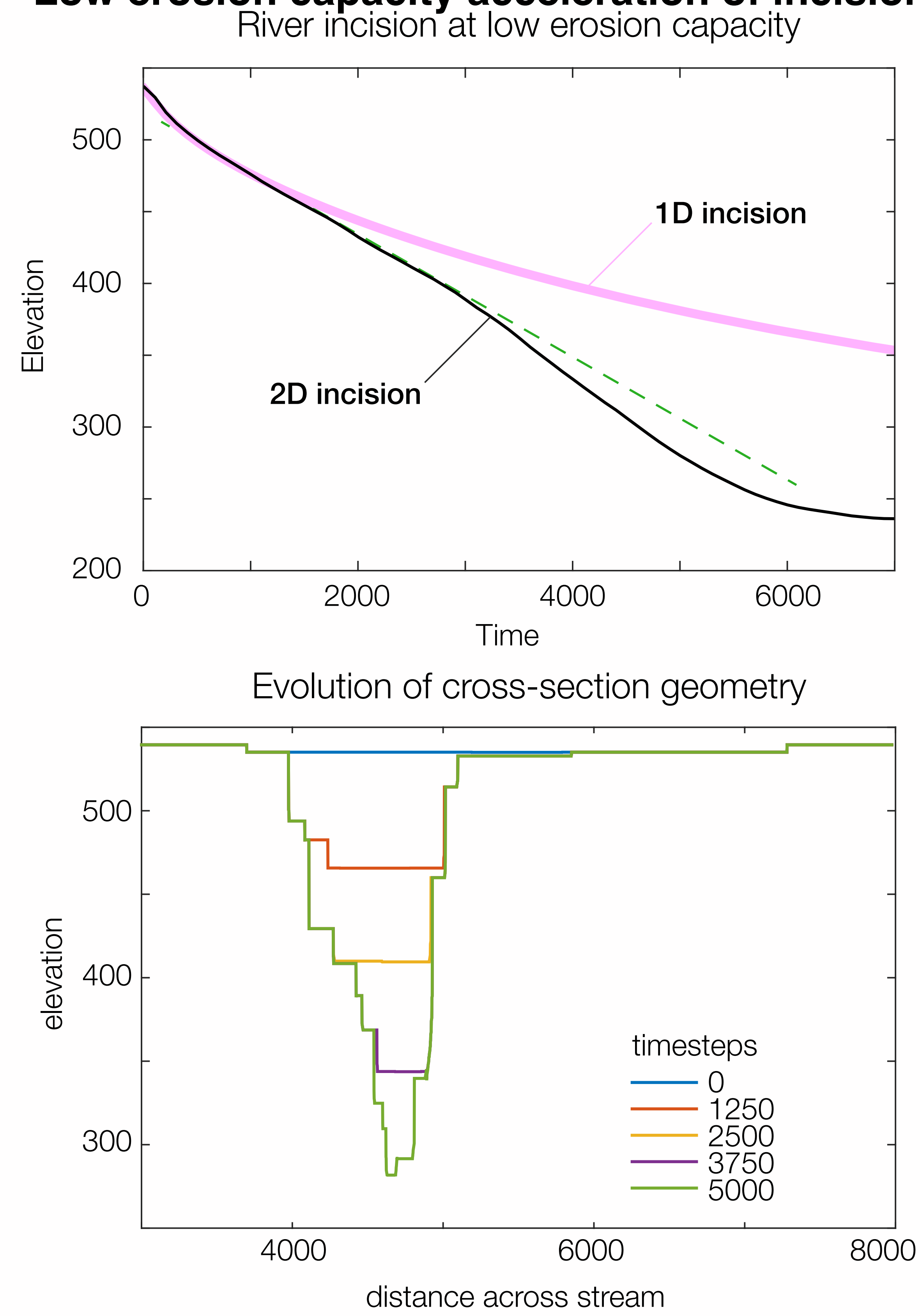
Important channel narrowing

High erosion capacity steady incision rate



Channel narrowing mitigates the slowdown of incision.

Low erosion capacity acceleration of incision rate



Channel narrows while the channel remains steep, forcing acceleration of the incision

Conclusions

Terrace record

- Autogenic effects have to be factored in to quantify the relationship between forcing and incision
- Accelerated incision does not require a change in external forcing.
- A combination of topography and ages is generally required to identify external forcing

Sediment routing system

- Lateral feedbacks cause channel narrowing, and rivers can erode (and remobilize) deeper and older strata.