# Lithology Erodibility and Channel Cross-Sectional Geometry Control the Evolution of Meandering Bedrock Rivers in Uplifted Oregons

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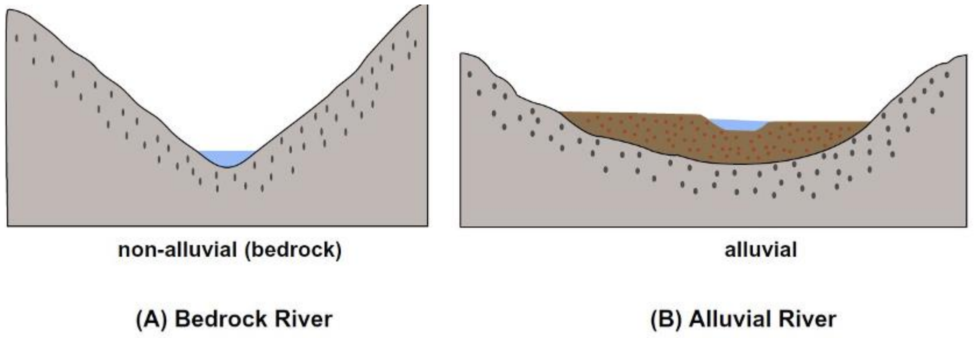
# Bedrock River Overview

- Observed worldwide in areas with continuous surface flow and distinctive topography
- Hold importance in geomorphological, water resource, ecological, recreational, aesthetic, cultural, and historical contexts
- Influenced by the erosional and depositional processes



# THE STABILITY PROBLEM OF BEDROCK MEANDERING RIVERS

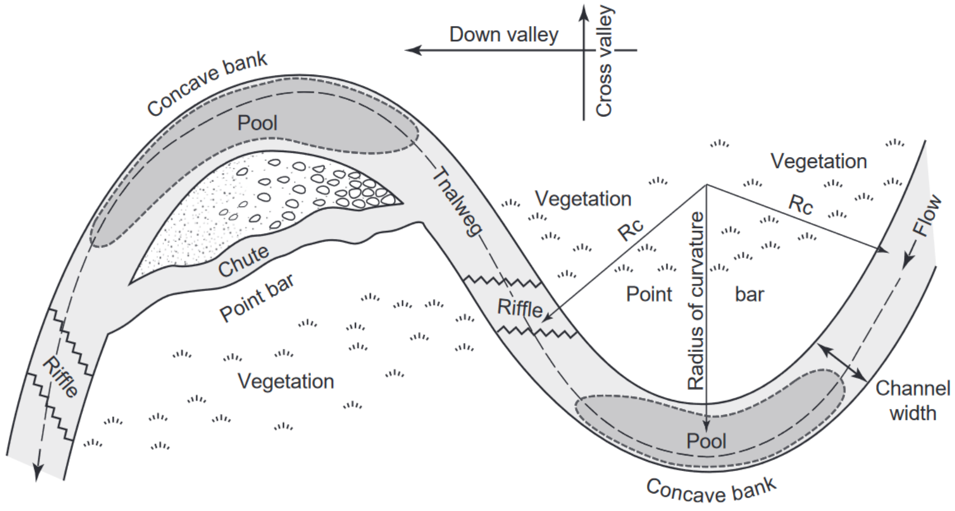
- Bedrock rivers: supply-limited or detachment-limited
- Alluvial rivers: transport-limited




(MIT OCW)

Bedrock rivers are influenced by:

- Tectonics (e.g., Yanites et al., 2010);
- Climate (e.g., Stark et al., 2010);
- **Lithology** (e.g., Johnson and Finnegan, 2015);
- or any combination of these forces




(Hooke, 2013)

# THE ROLE OF LITHOLOGY IN BEDROCK RIVER EROSION

Lithology and erodibility of bedrock rivers:

- Erosion Resistivity (Bursztyn et al., 2015)
- River Channel Width Adjustment(Allen et al., 2013).
- Slaking – sub-aerial bedrock vs submerged bedrock (Montgomery, 2004; Collins et al., 2016; Inoue et al., 2017)

*Slaking bedrock of the Roslyn Formation in central Washington State, USA.*

# Methods/Approach

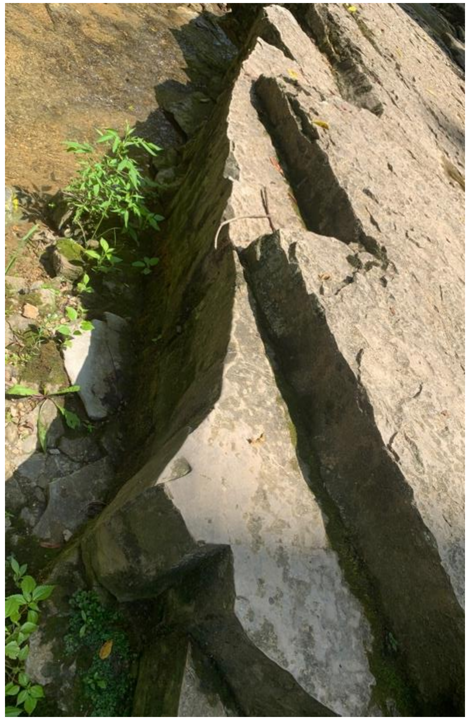
A 1-D numerical model is employed (developed by Drs. Sarah Schanz and Brian Yanites)

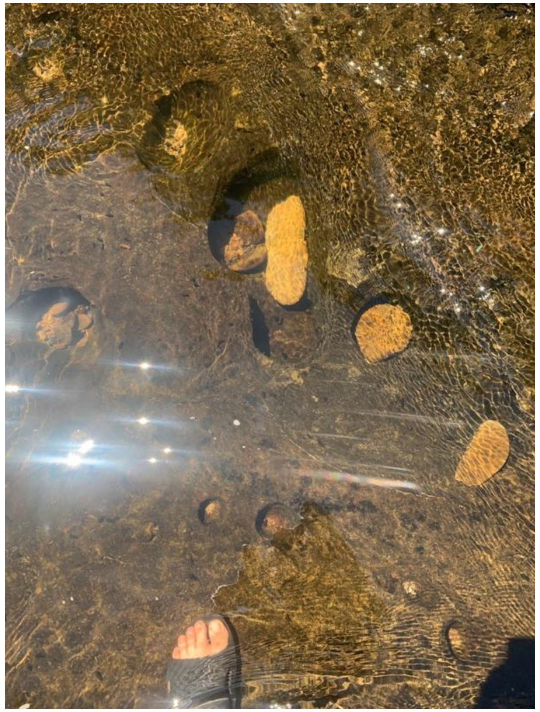
Model purpose: Simulate meandering bedrock channels and vary rock uplift rates, **bedrock strength anisotropy**, and sediment supply/transport capacity.

For my project:

Bedrock Type/Strength → Model variables: kl, kf, and channel type

**I used the numerical model to test the sensitivity of bedrock meandering development to lithologic strength differences (kl, kf)**





# Model Framework: Governing Equations

## (1) Water Depth

$$\begin{cases} H = \left(\frac{n * Q_w}{W}\right)^{0.6} (-1 * S)^{-0.3} \; if \; S < 0 \\ H = 0 \; if \; S \geq 0 \end{cases}$$

(Manning's equation)

The water depth at bankfull discharge is approximated using the wide channel assumption and estimated with Manning's equation

## (2) Vertical Erosion

$$E = k_f \tau_b dt$$

(Howard & Kerby, 1983; Whipple & Tucker, 1999; Whipple et al., 2000)

Vertical erodibility

## (3) Lateral Migration

$$R_0 = W k_l c$$

(Nominal Migration Rate)

Lateral erodibility

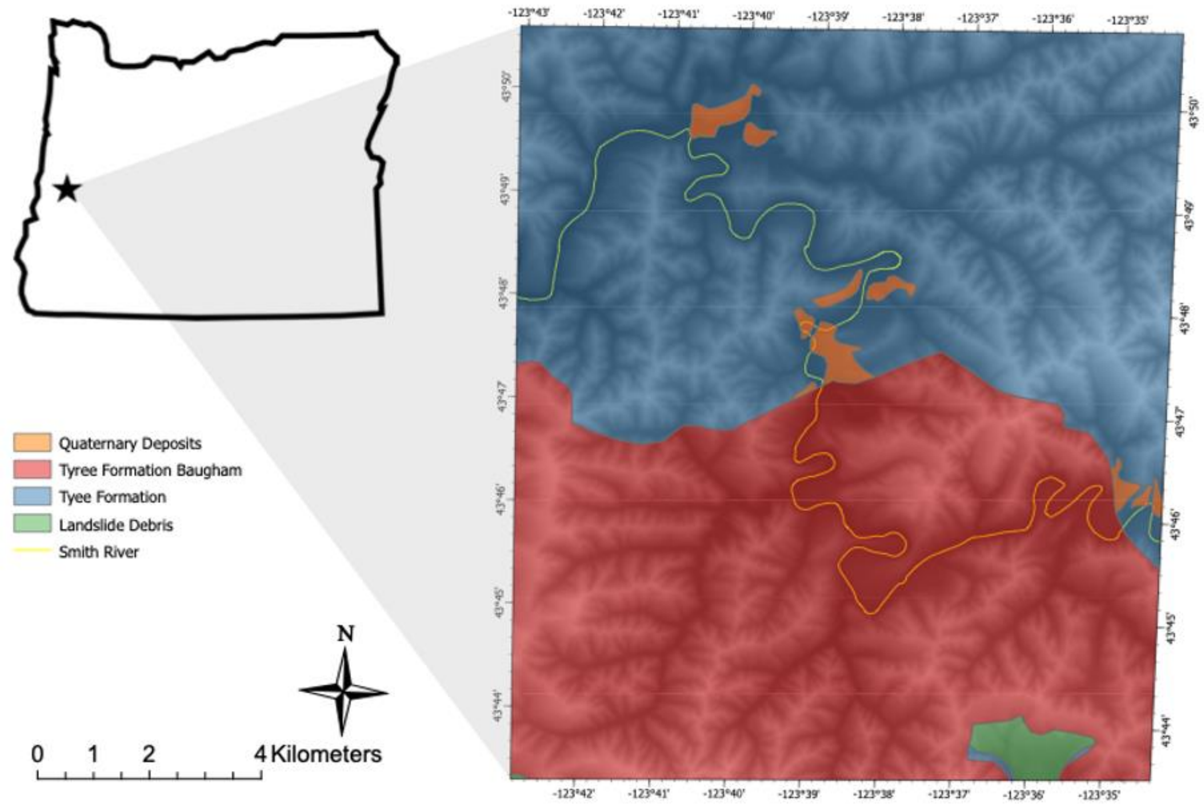
$$R_1(s) = \Omega R_0(s) + \left[\Gamma \int_0^{\infty} R_0(s-\xi) G(\xi) d\xi\right] \left[\int_0^{\infty} G(\xi) d\xi\right]^{-1}$$

(Howard and Knutson, 1984)

Adjusted Migration Rate

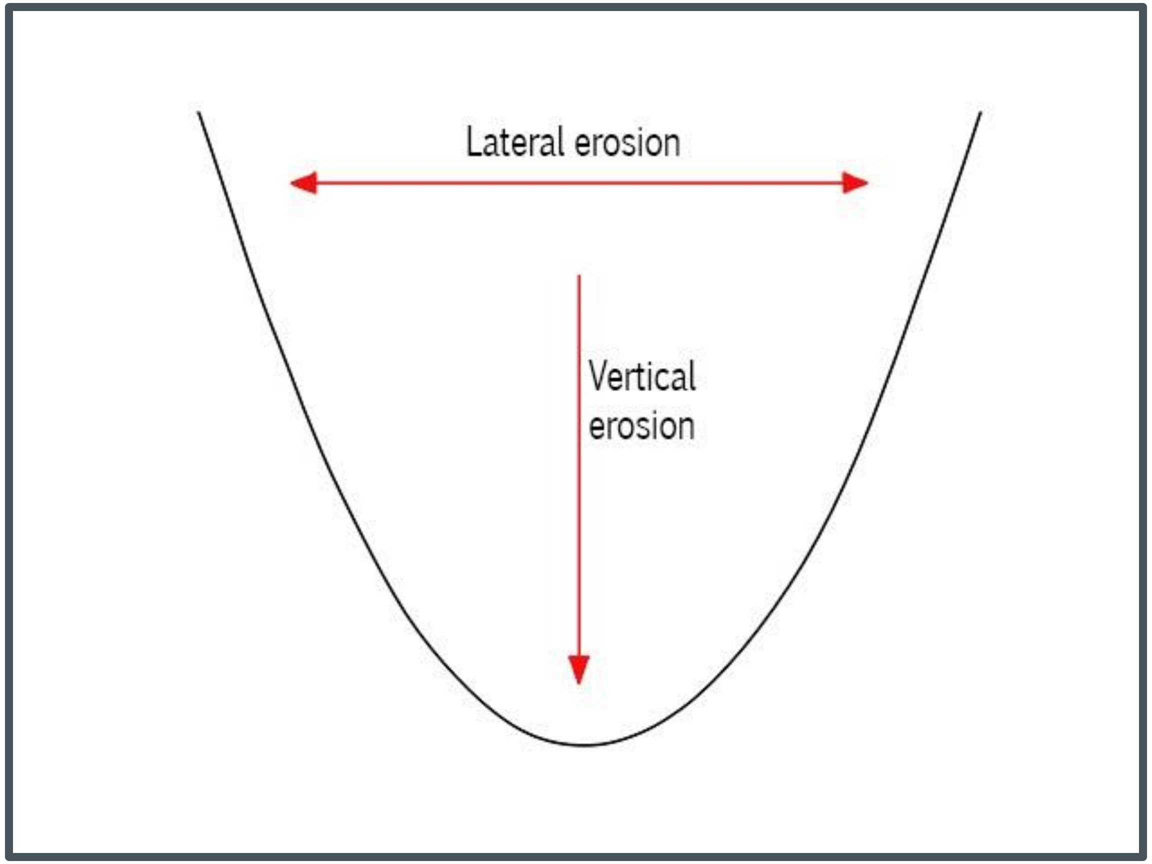
# UPLIFTED OREGON

- The Smith River, one of the largest tributaries of the Umpqua River in Oregon State
- It has been historically proven to be a single thread meandering bedrock river with thin sediments




Primary Area of Interest

# LATERAL & VERTICAL ERODIBILITY (KL & KF)




Lateral and vertical erosion rates vary across meandering channels

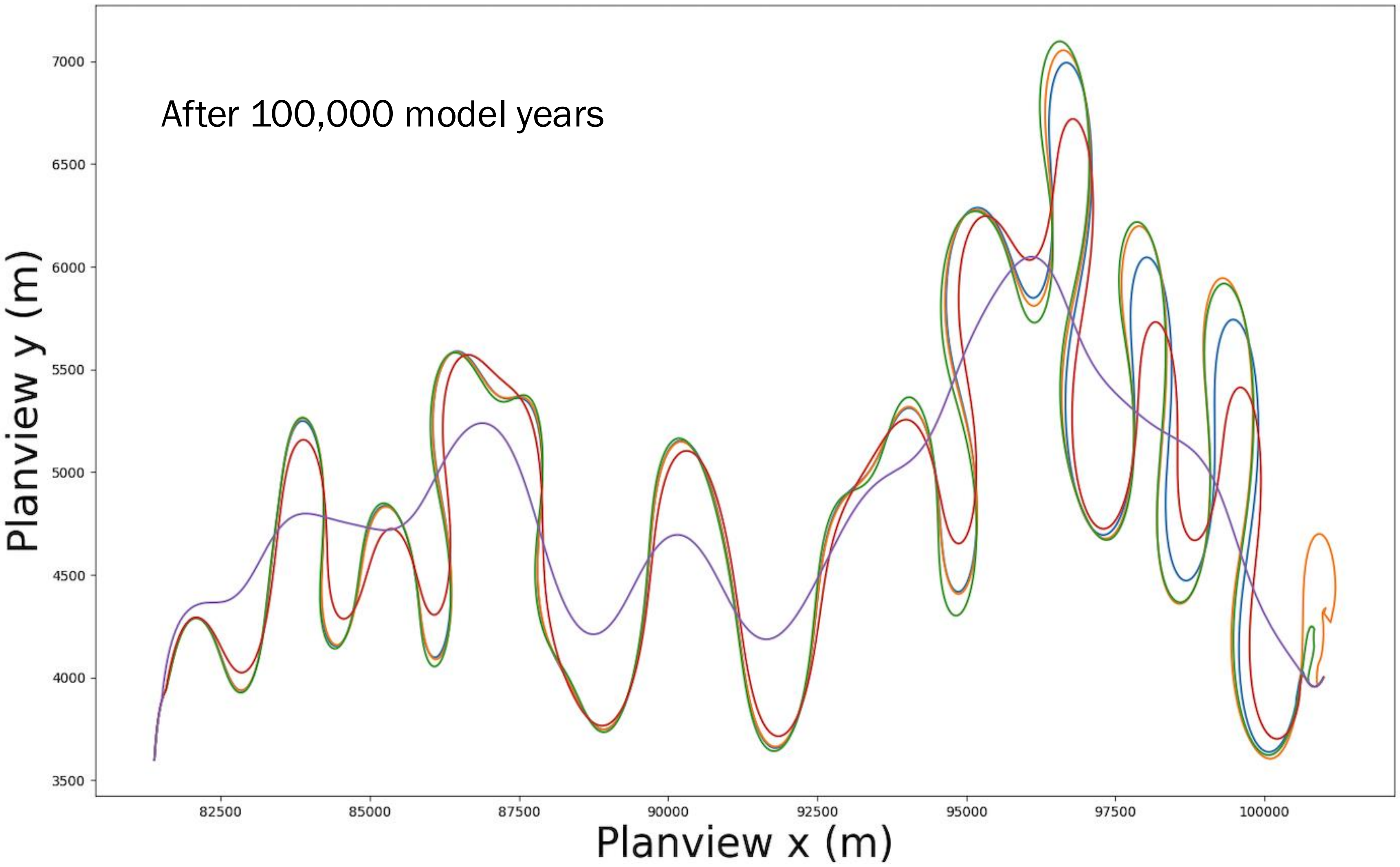
How are those values calculated?

Lateral and vertical erosion depend on the lateral and vertical erodibility, or susceptibility to erosion

What are lateral (kl) and vertical (kf) erodibilities?

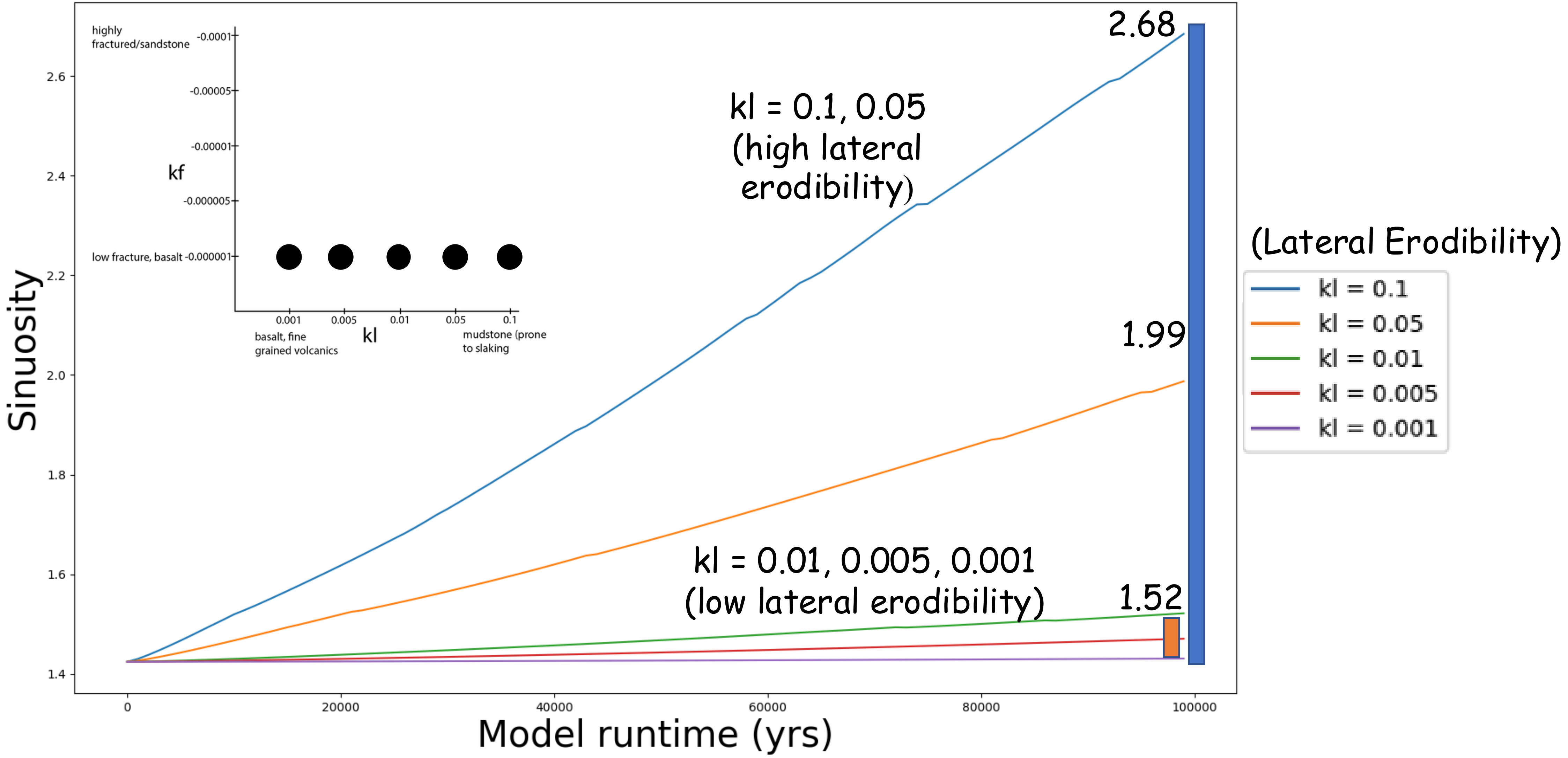
- Empirically derived

# INDEPENDENT VARIABLES

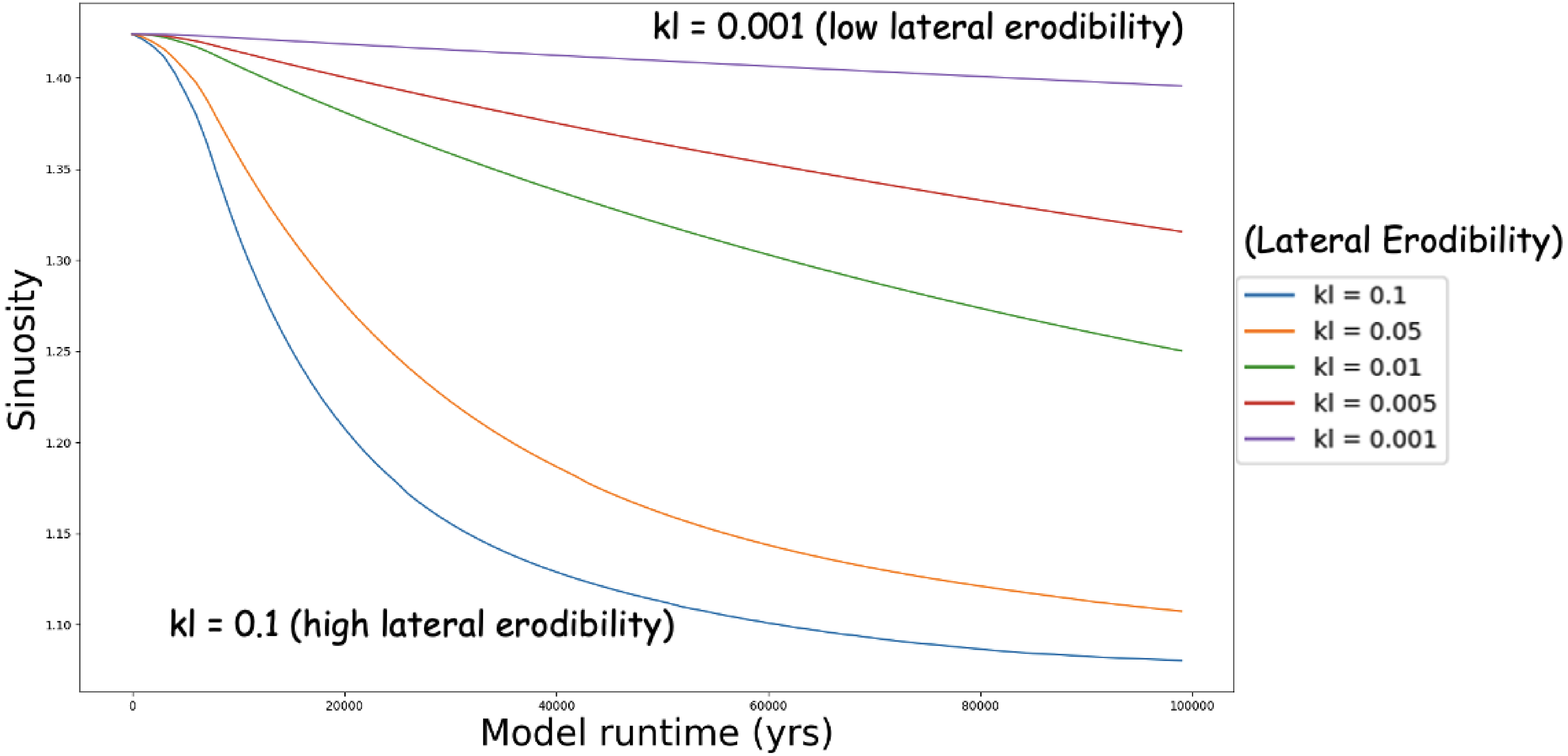


# Variable 1: Lateral Erodibility (kl)

**When kf is set to -0.000001 (low vertical erodibility), high lateral erodibility channels get very sinuous:**

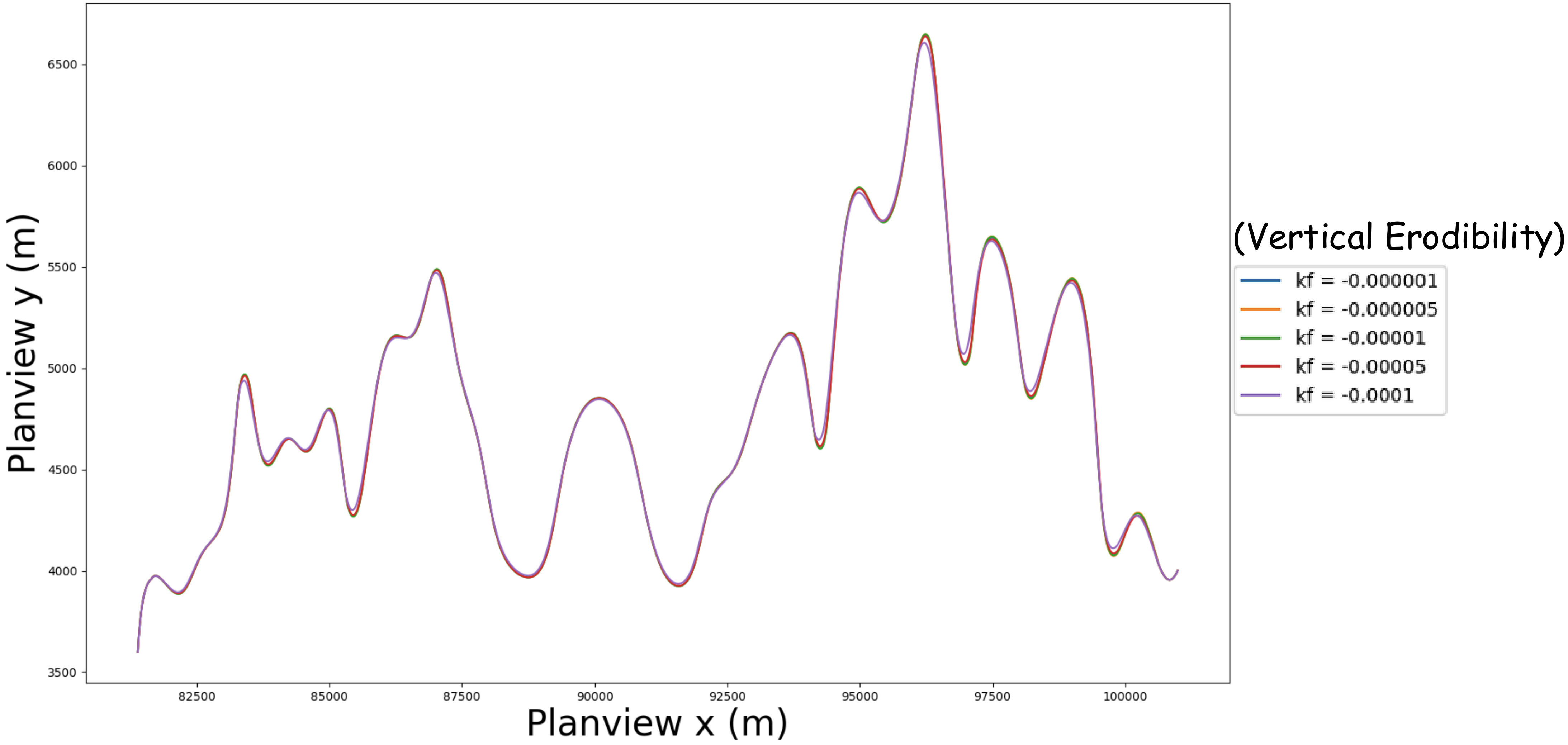


## BUT: when kf is set to -0.0001 (high vertical erodibility), those same high lateral erodibility channels become straight



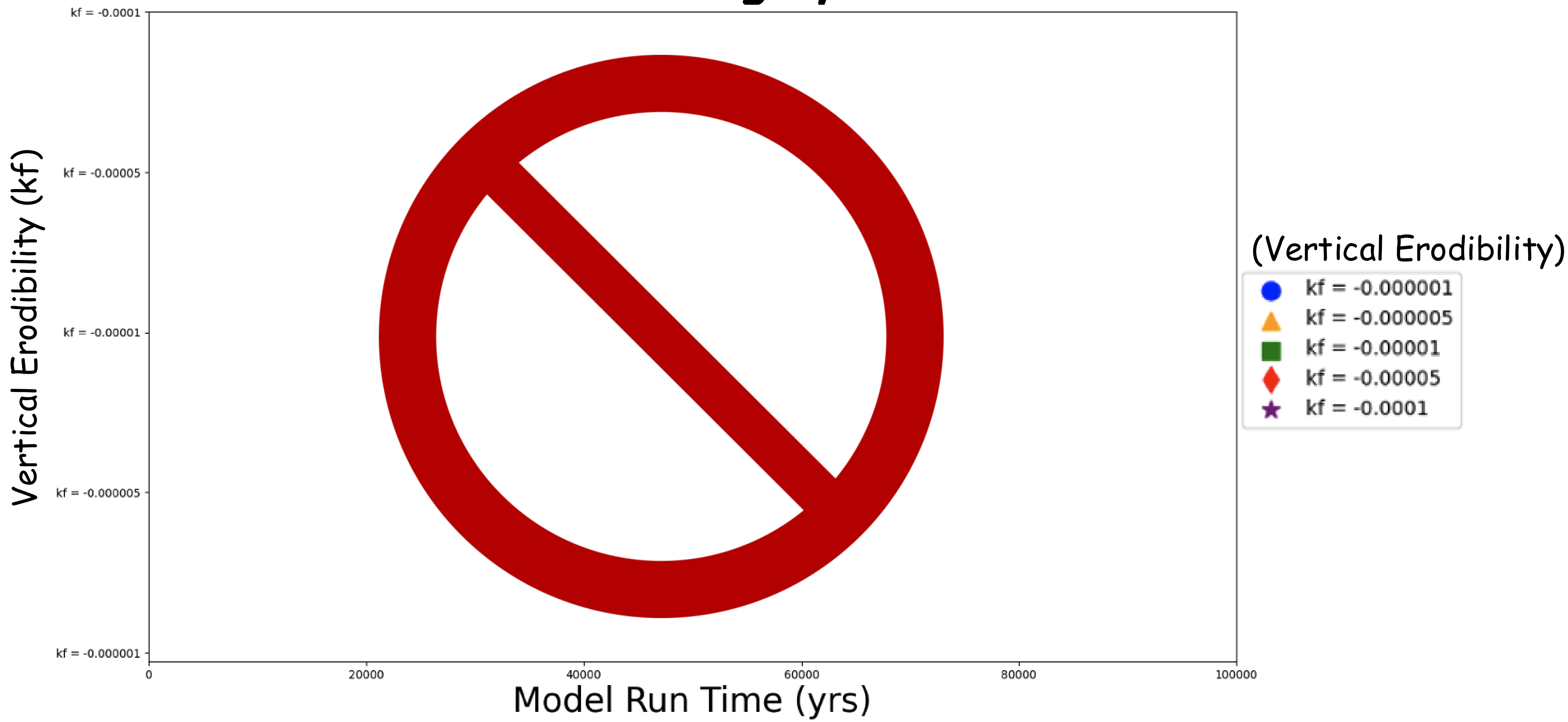
# Variable 2: Vertical Erodibility (kf)

**When kl is set to 0.001 (low lateral erodibility), vertical erodibility has no effect on channel form.**



# And there are no cutoffs!
# Channels are highly stable

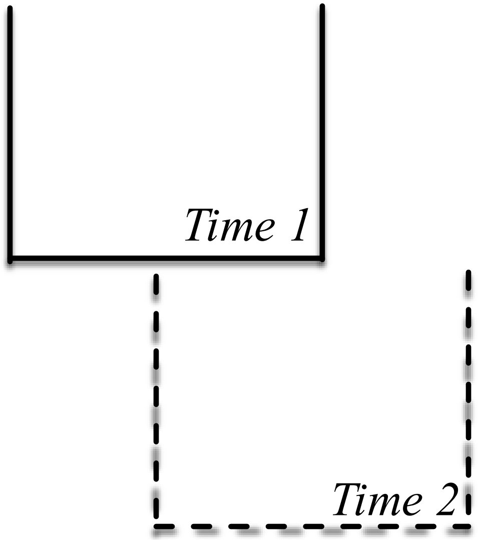
Low Lateral Erodibility kl = 0.001



# CHANNEL TYPE

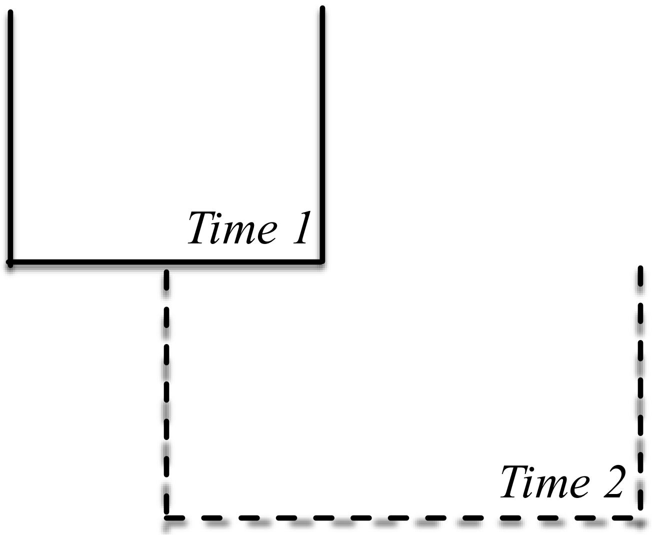
## No Change

- Constant width and height



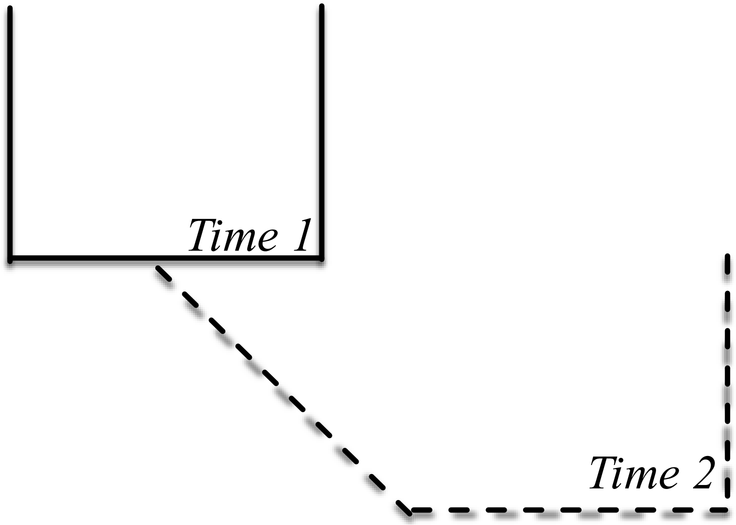

## Rectangular

- Only channel width will grow with any lateral erosion
- Based on slaking bedrock model proposed by Finnegan and Balco (2015)



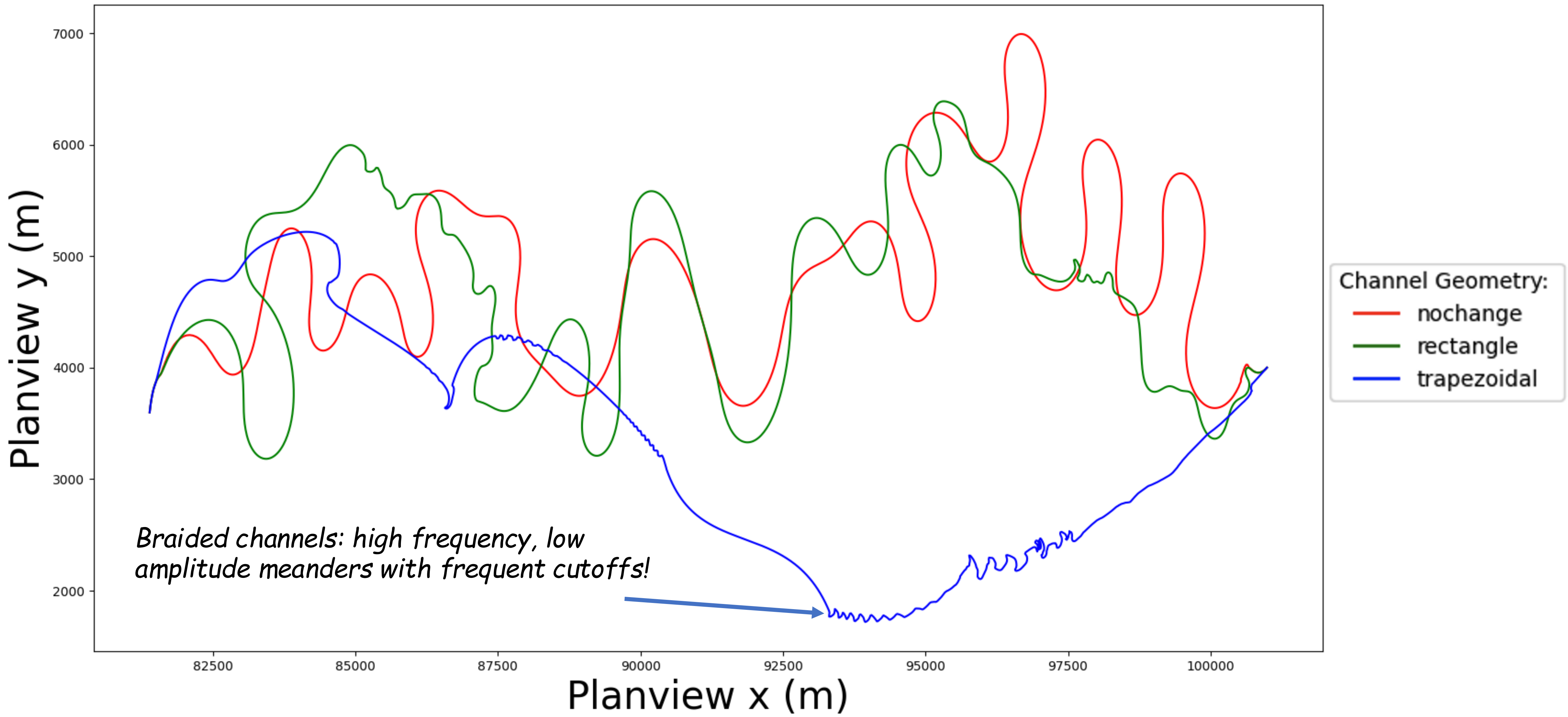

## Trapezoidal

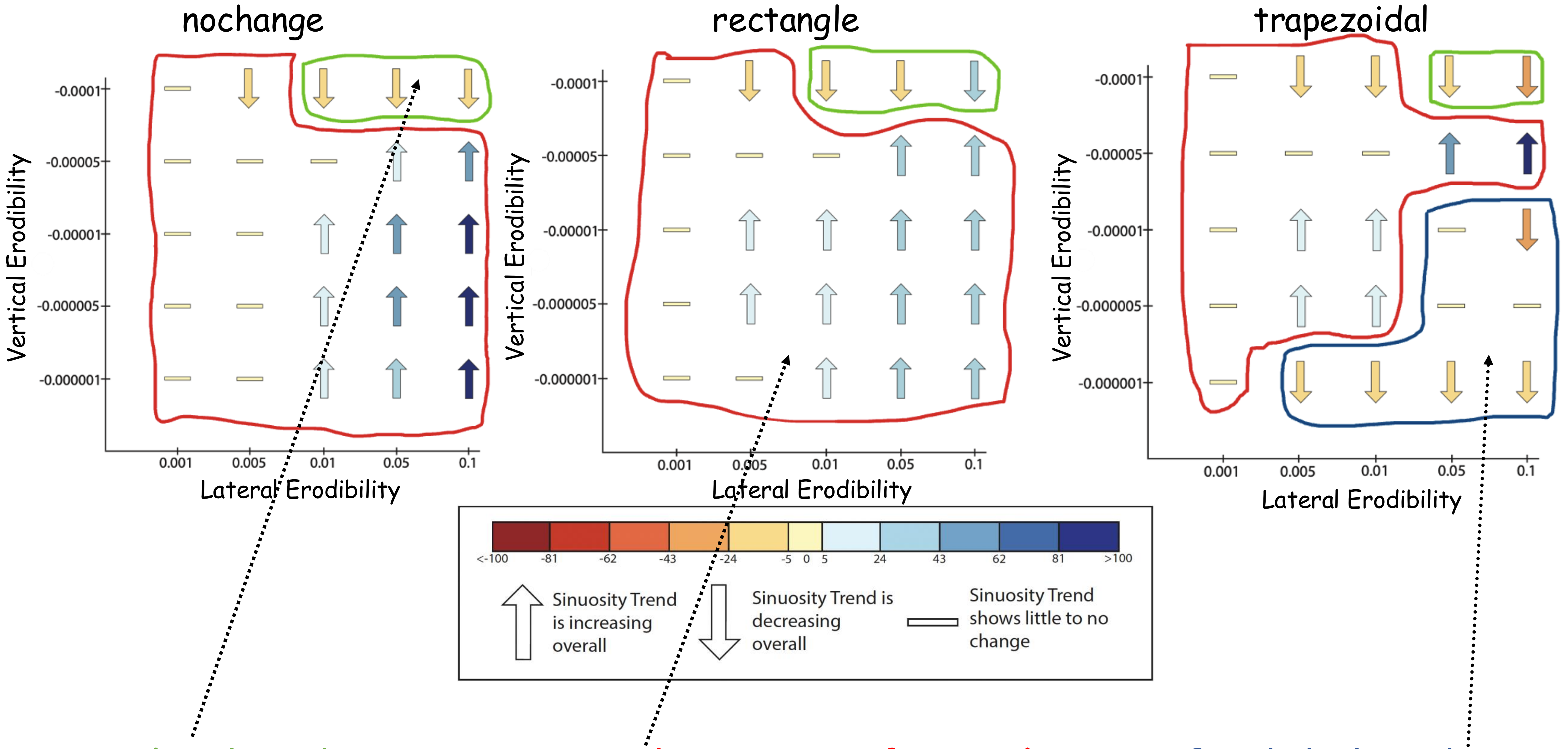
- Channel width and height will grow with both lateral and vertical erosion



# Variable 3: Channel Geometry

**When kl = 0.05 (high lateral erodibility), kf = -0.000001 (low vertical erodibility), the trapezoidal channel shape becomes braided!**






Straight: dependent on vertical erodibility

Meandering: ratio of vertical to lateral erodibility

Braided: dependent on simulated channel type

# LITHOLOGIC ANISOTROPY

1. Stable meandering (has cutoffs but still has an increased sinuosity)

2. Straight channels (high kf/decreasing trend in sinuosity/few cutoffs)

3. Braided River Channels (low sinuosity/too many cutoffs/ unable to maintain meander stability)

Yellow Stone River

Kali Gandaki Gorge (Nepal)

Grand Canyon - Colorado River

# Acknowledgements

# QUESTIONS?