Modification of Sediment Fluxes by the Transfer Fluvial System

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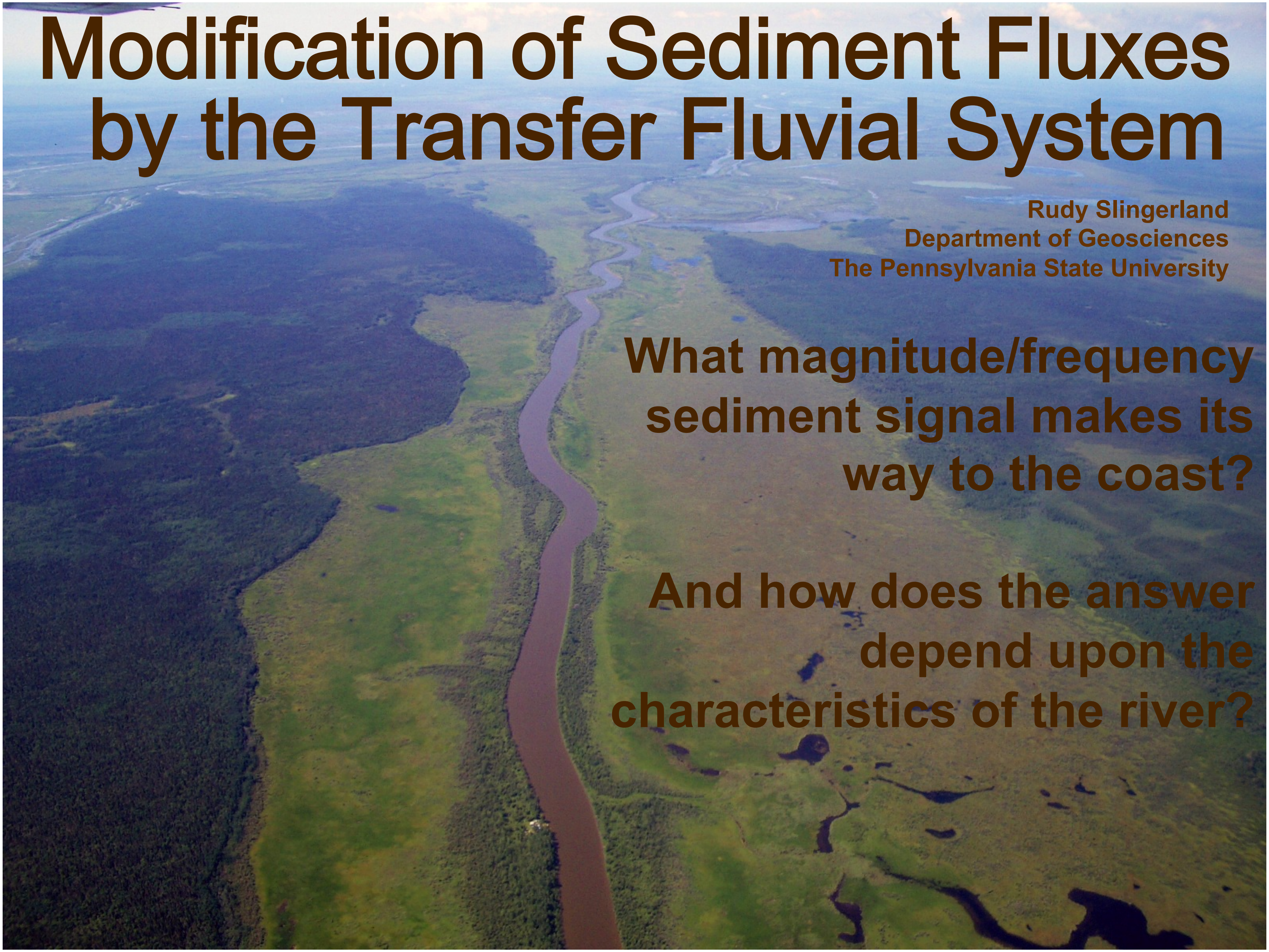
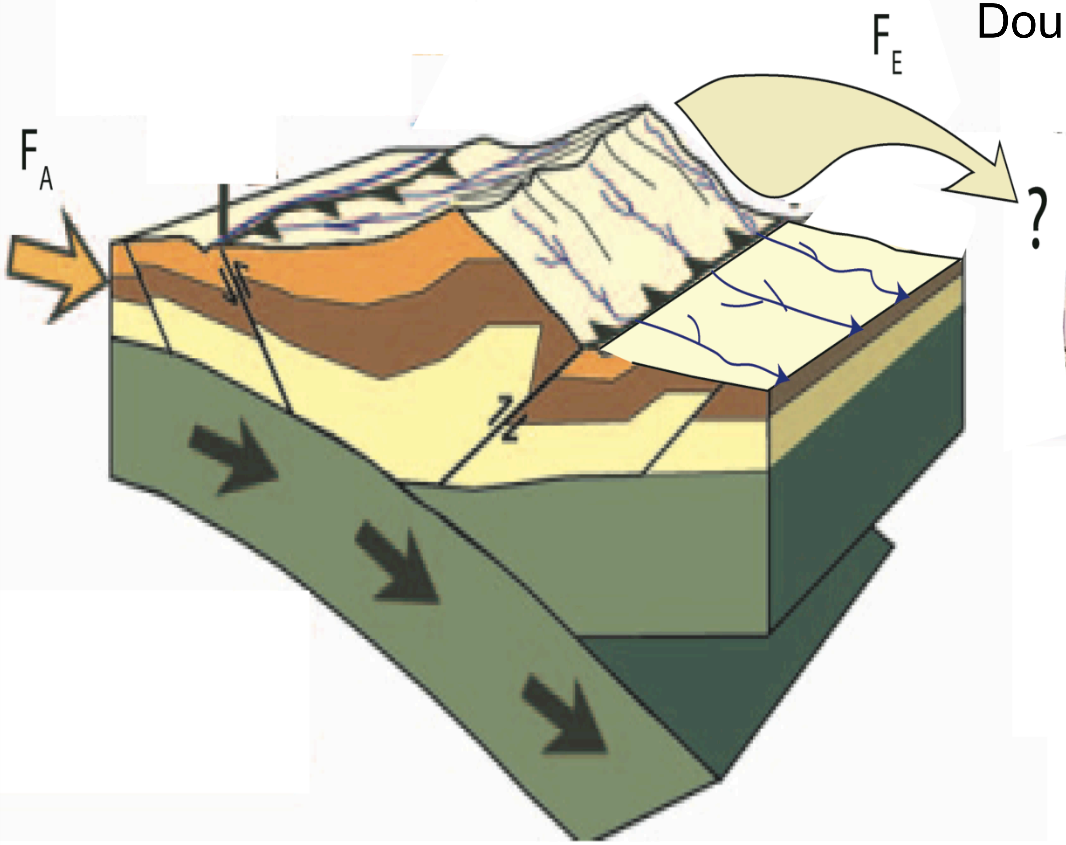
What magnitude/frequency sediment signal makes its way to the coast?

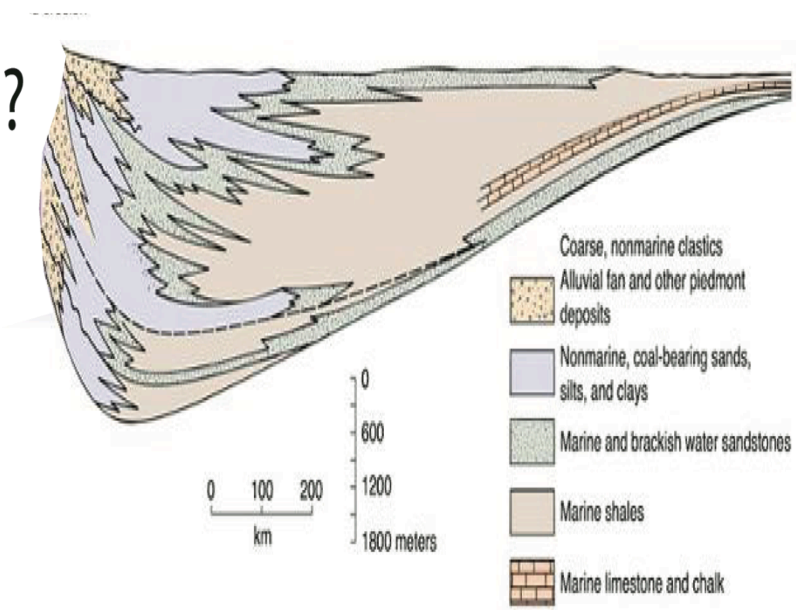
And how does the answer depend upon the characteristics of the river?



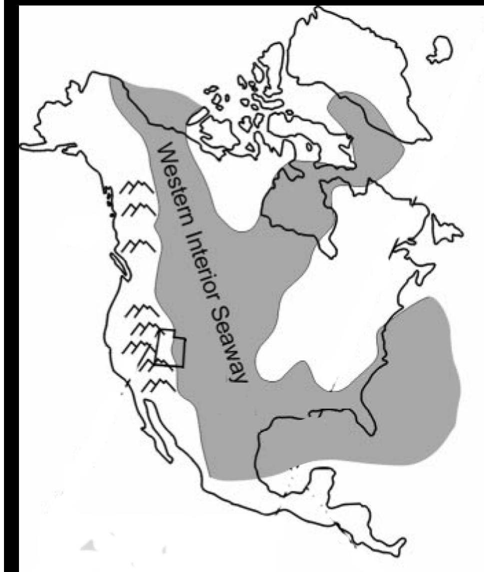
Motivation

Doubly vergent wedge and foreland basin



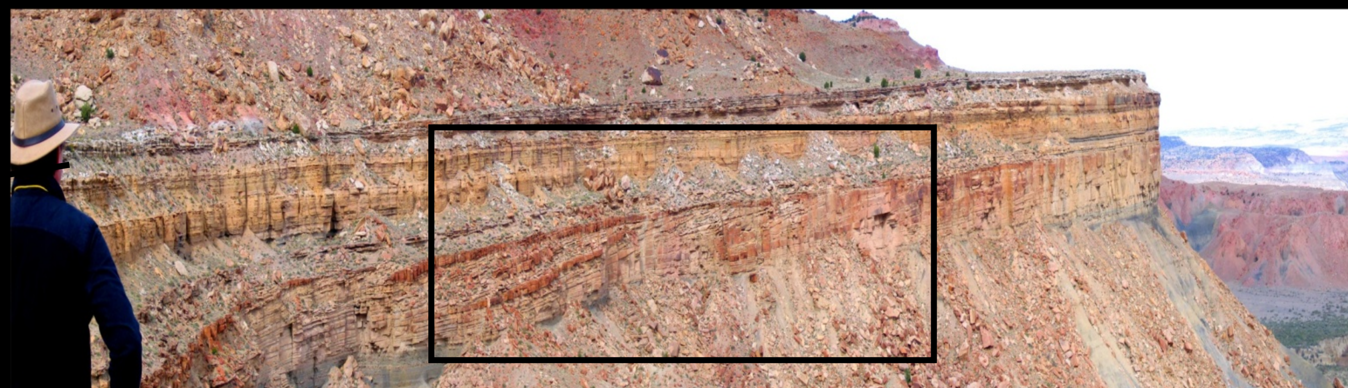


Modified from: Stolar et. al. 2006



An Example: The Turonian "Last Chance Delta", Ferron, UT

Relevant literature:
Gardner (1995);
Moiola
(2004)
Bhatta
Tye (20



An Example: Turonian "Last Chance Delta" of Utah

Seven parasequences deposited over 1.7 million years

Are these seven parasequences a result of fluctuations in sediment flux and type?

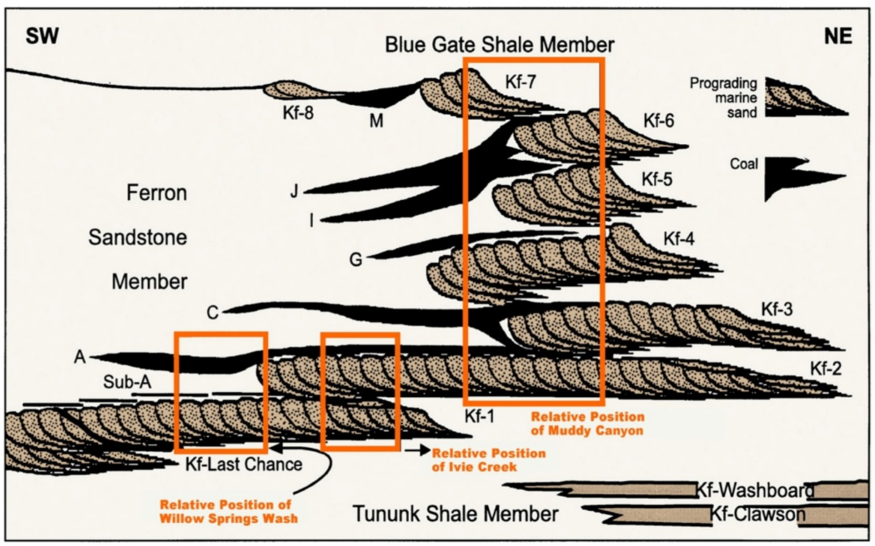
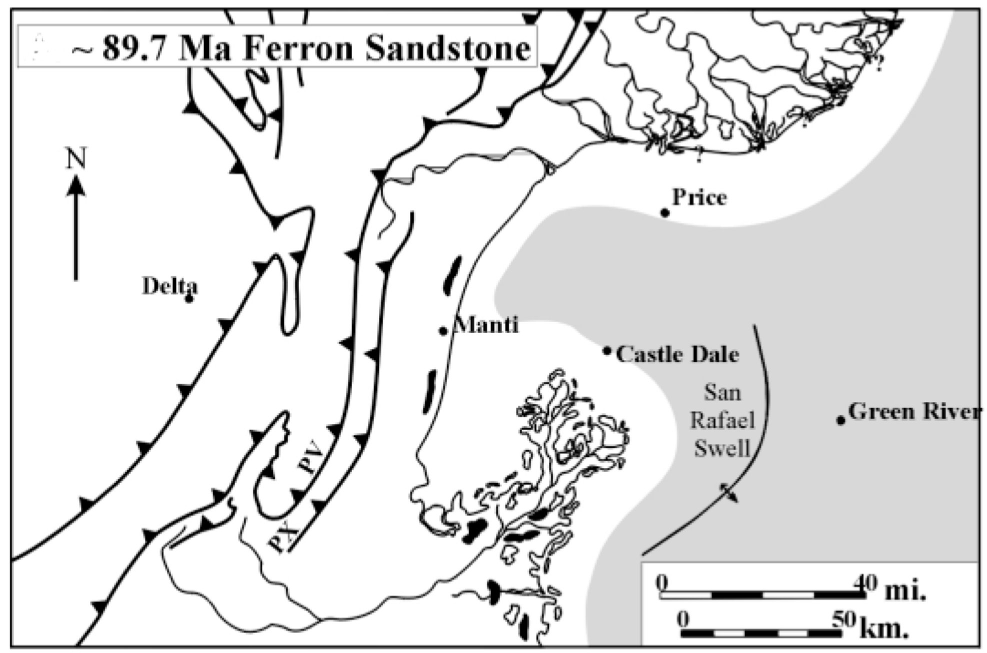


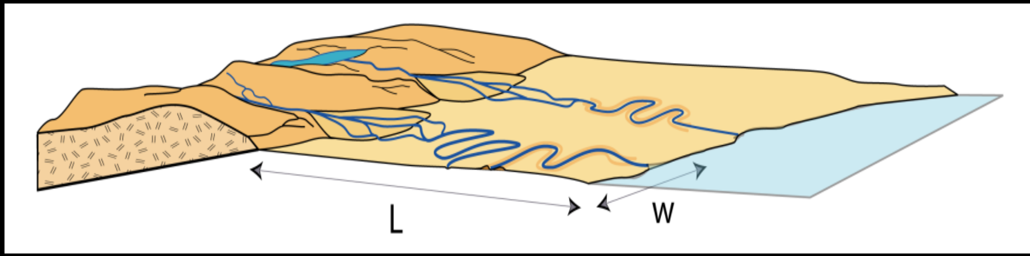
Figure 2. Diagrammatic cross section showing relative positions of Ferron parasequence sets with their associated coal zones (black), and the relative positi on of the Ivie Creek, Willow Springs Wash, and Muddy Canyon case-study areas within the Ferron Sandstone (from Ryer, 1991; Anderson and others, 1997). The diagram has no scale.



Edwards et al. (2005)

Signal Modification by the Transfer Fluvial System

- Relevant literature: Humphrey and Heller 1995; Dade and Friend 1998; Métivier and Gaudemer 1999; Castelltort and Van Den Driessche 2003; Allen 2008
- Assume a river exits a high relief terrain and passes a sediment load to a coast 100s of km away. Assume a periodic change in load occurs of period λ and amplitude A.



- Will the signal in the sediment flux reach the coast, and if so with what phase lag and damping?

Signal Modification by the Transfer Fluvial System

- Assume sediment flux is linear with water surface slope, and therefore the diffusion equation applies with diffusivity κ
  - Defendable for bedload and self-formed streams

$$\frac{\partial h}{\partial t} = -k\frac{\partial q_s}{\partial x}$$

$q_s \propto (\tau_o - \tau_{cr})^{3/2}$ but because it is a self-formed channel

$\tau_o - \tau_{cr} \propto \grave{o}\tau_o$, and therefore

$q_s \propto \tau_o{}^{3/2} \propto VHS \propto qS$, or

$\mathrm{q_s} = -\kappa \, \frac{\partial h}{\partial x}$, where κ depends mainly upon q

Signal Modification by the Transfer Fluvial System

- Distance over which a periodic disturbance of amplitude A and period λ decreases by *1/e given by:*

$$d_e = \sqrt{\frac{\kappa\lambda}{\pi}}$$

- e-folding time: the time it takes for the difference between a perturbed value of a state variable and its equilibrium value (Δf) to have increased (decreased) by Δf/e:

$$\frac{L^2}{\kappa}$$

Signal Modification by the Transfer Fluvial System

- e-folding distance of 93 rivers centers on 500 km;
- e-folding time ranges from 10^4 (25%) to 10^5 (62%) to 10^6 (13%) yrs

- But what about the mud?
  - Wash load signal should propagate at speed of floodwave, and for wide, shallow rivers:

$$C = u + \sqrt{gh}$$

  - Sediment signal also diffused by lowering and flattening of wave

Effect of Floodplains

- Ok Tedi Mine created 50% increase in fines, but 25% of the sediment load is permanently stored overbank (Aalto et al., 2008)

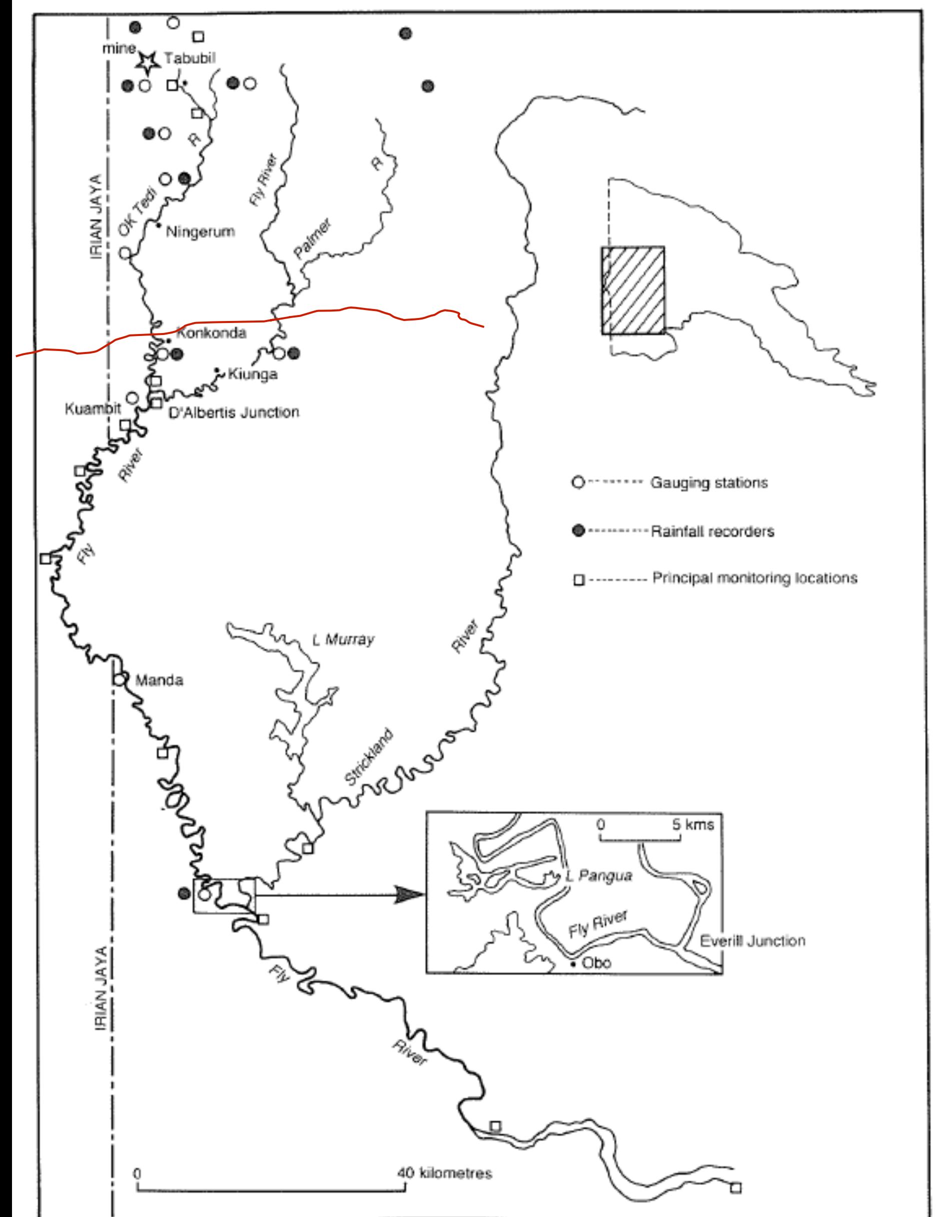
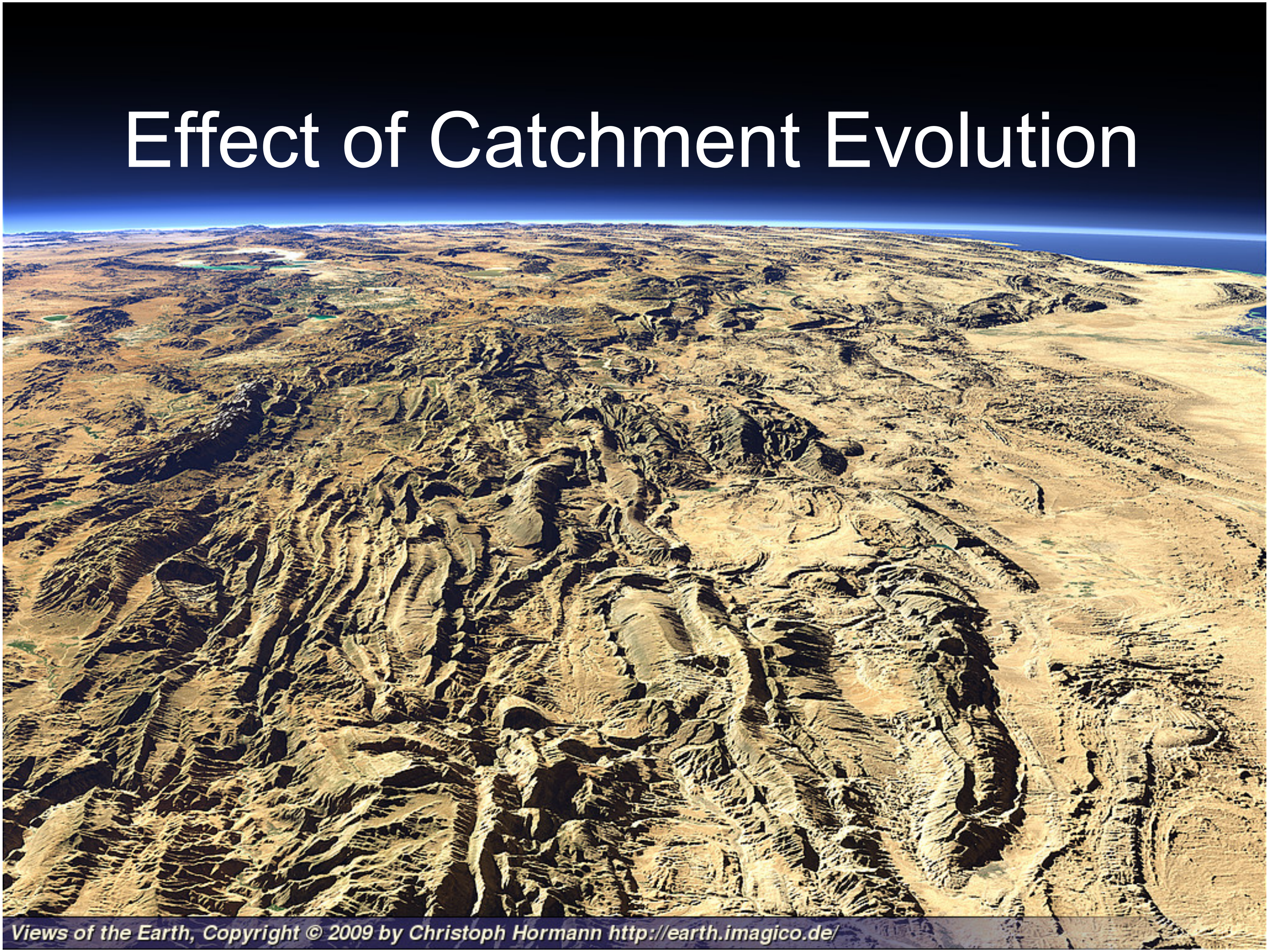


Fig. 1 Location map of Fly River basin.

Markham and Day (1994)

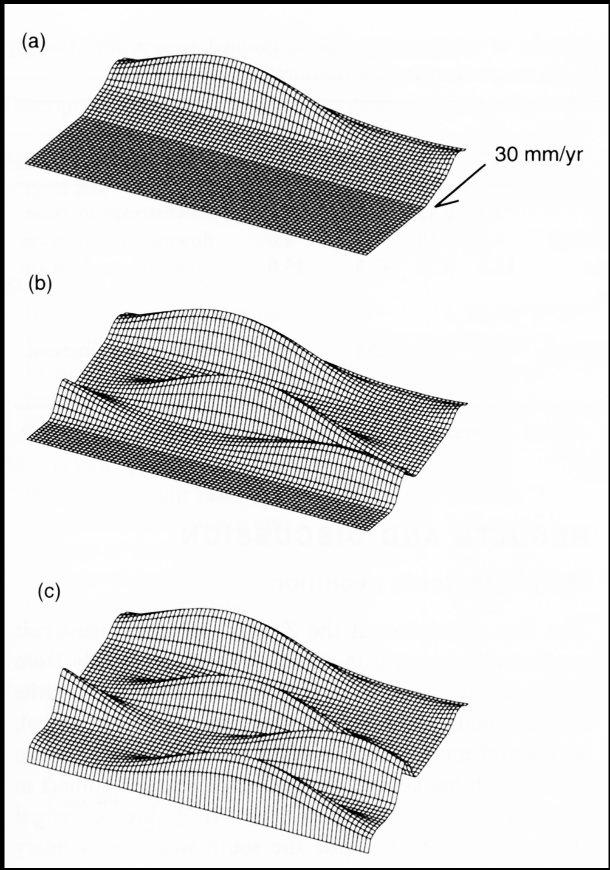
Effect of Catchment Evolution



Sediment Fluxes from Fold and Thrust Belts

$$\frac{\partial h}{\partial t} = u(x, y, t) - E_h - E_b - E_a$$

U(x,y,t)

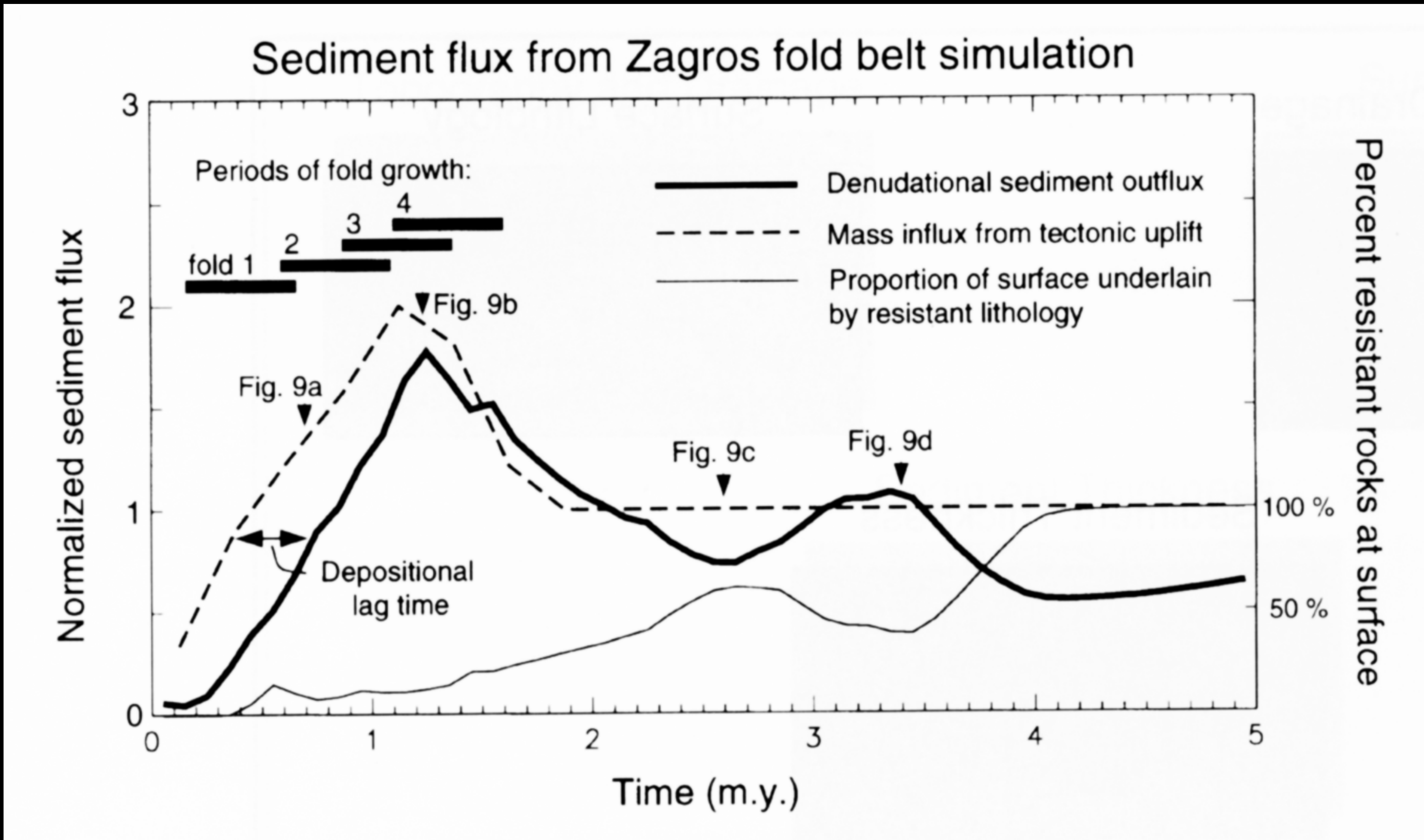


Hillslopes: $E_h = -k_d \left(\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} \right)$

Bedrock channels: $E_b = k_v \left(\frac{Q}{Q_*} \right)^{1/3} S^{2/3}$

Alluvial Channels: $E_a = \frac{k_f}{W} \frac{\partial QS}{\partial \vec{x}}$

Sediment Fluxes from Fold and Thrust Belts



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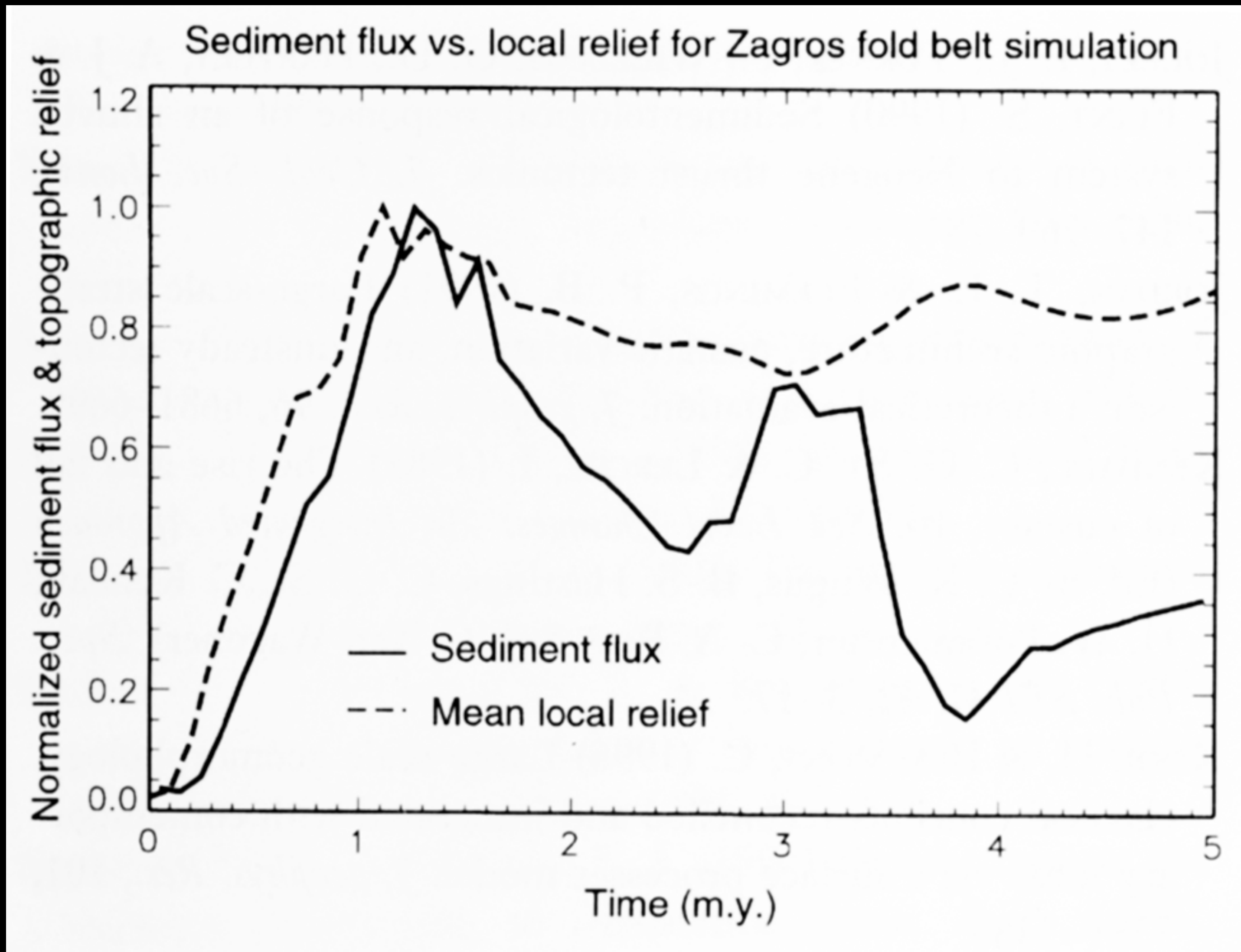

Summary

- Transfer river systems phase delay sediment flux signal by O(10^4 to 10^6 yrs) and damp it with e-folding distances O (10^2 km)
- Co-evolution of drainage systems and foreland folds causes complex sediment flux signal with period O(10^5 yrs)
- Sediment fluxes can be out of phase with relief
- Best chance at faithful signal transfer: short, fine-grained rivers with minimal floodplains
- And what of the Last Chance parasequences?