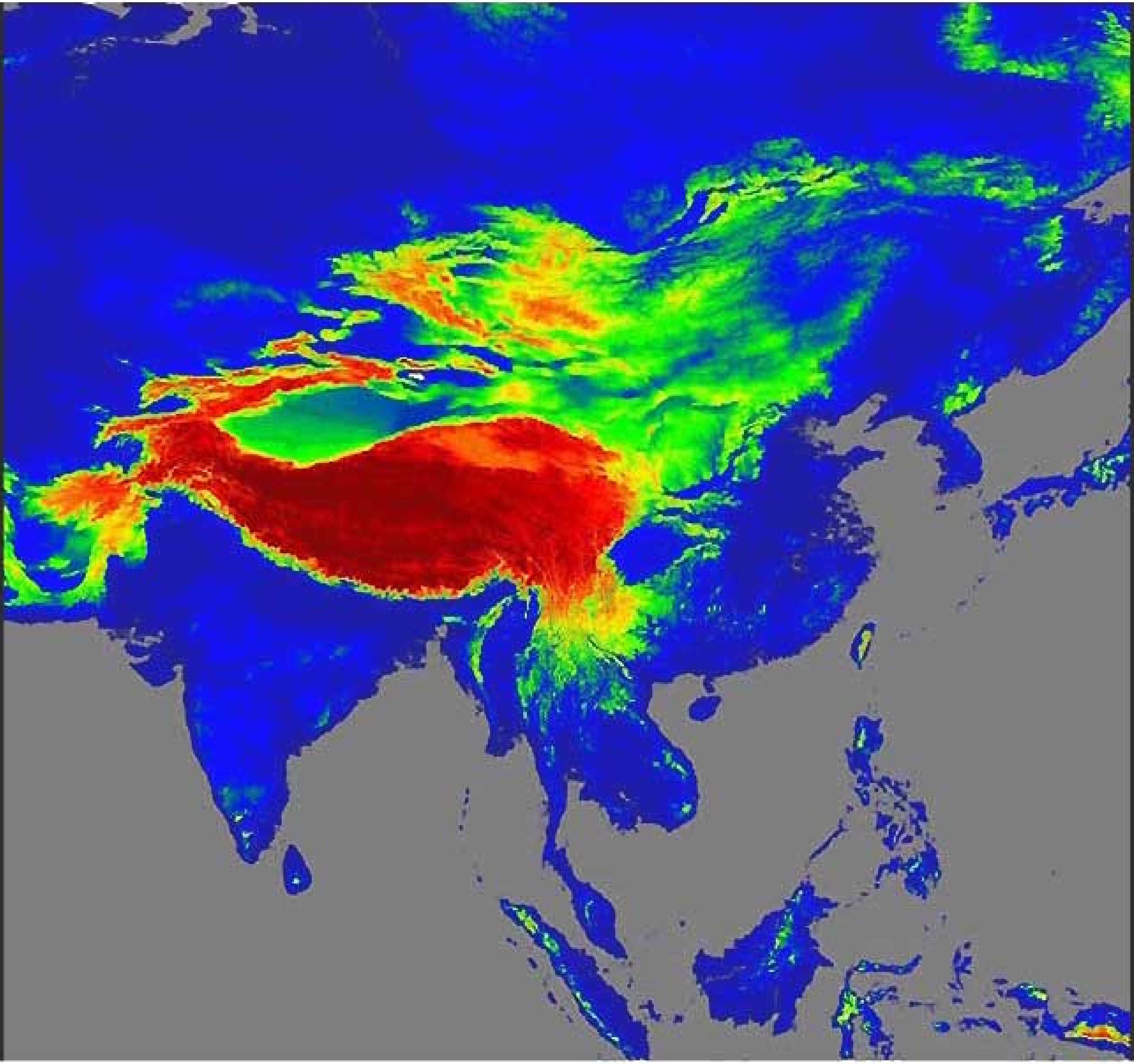
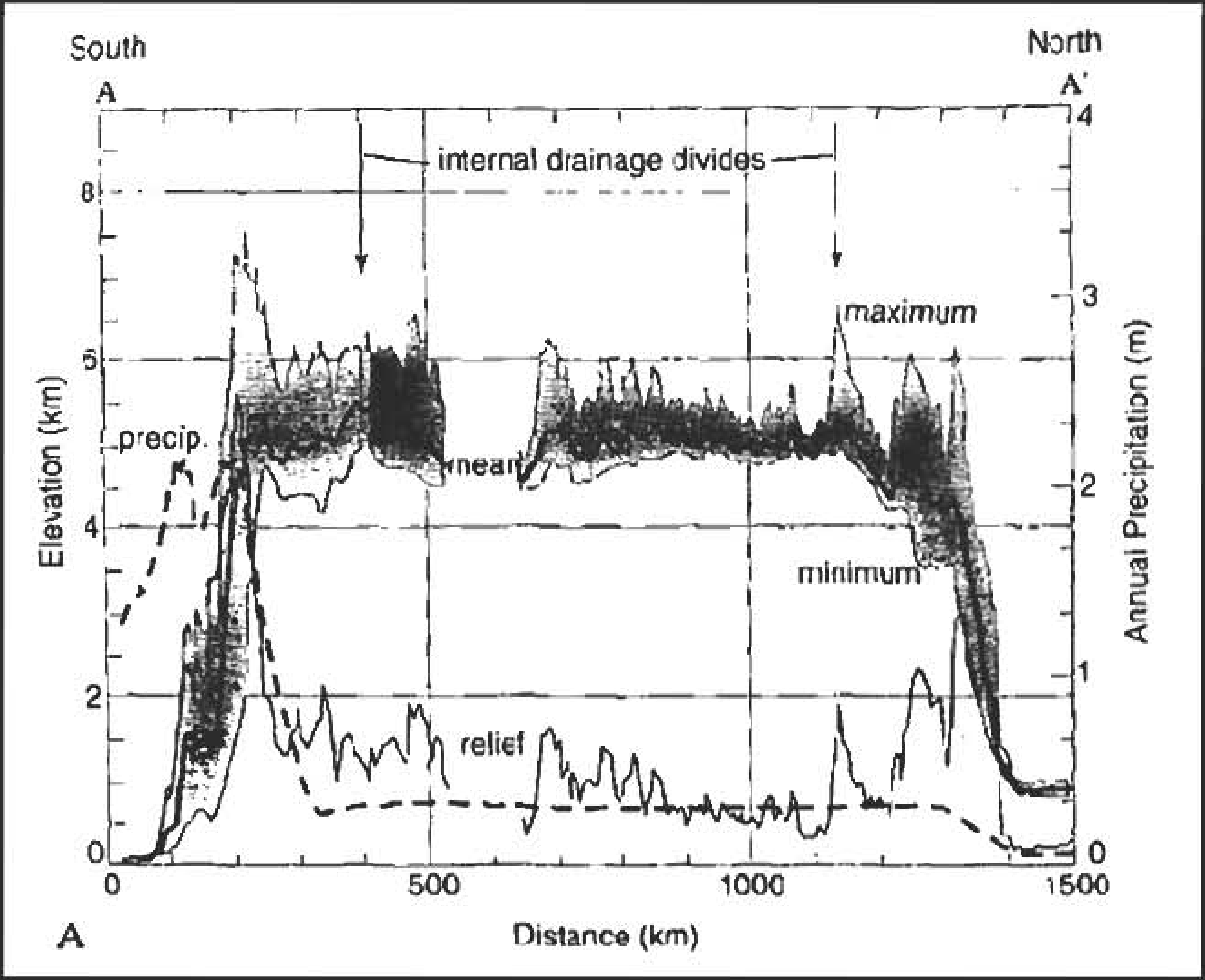


Fielding et al., 1994, Geology



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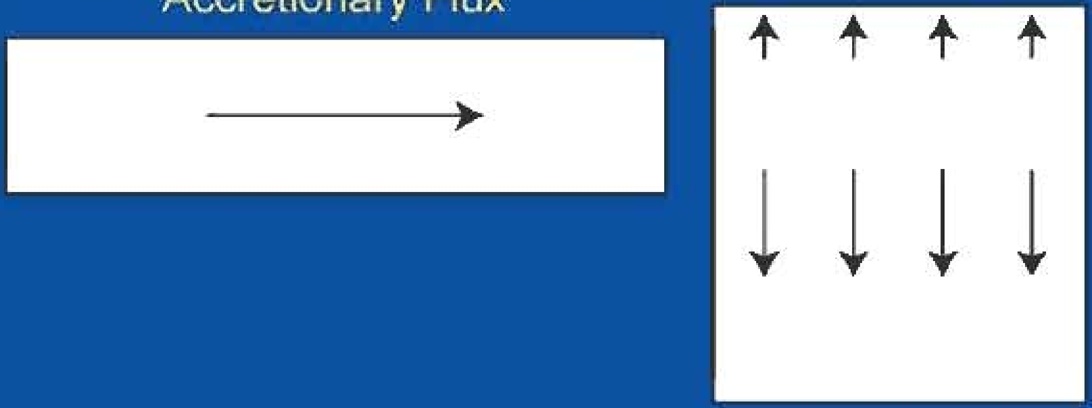
No Erosion

Accretionary Flux

Mountains Rise Due to Thickening



Near-surface rocks rise
rate = surface uplift

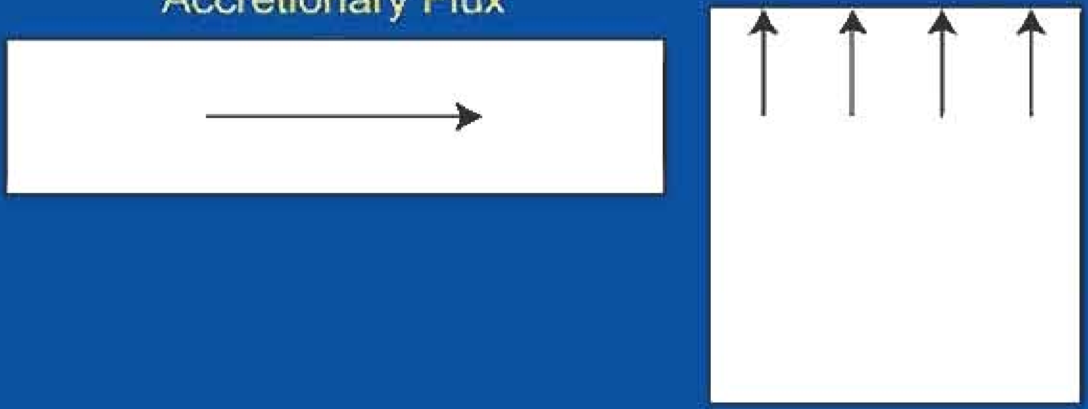
$$U = [(\rho_m - \rho_c)/\rho_m]\ F_A/W$$

Deeper rocks sink

Erosion Balances Accretion

Accretionary Flux

Mountains at Steady Elevation



Rapid rock uplift
no surface uplift

$$U = F_A/W$$

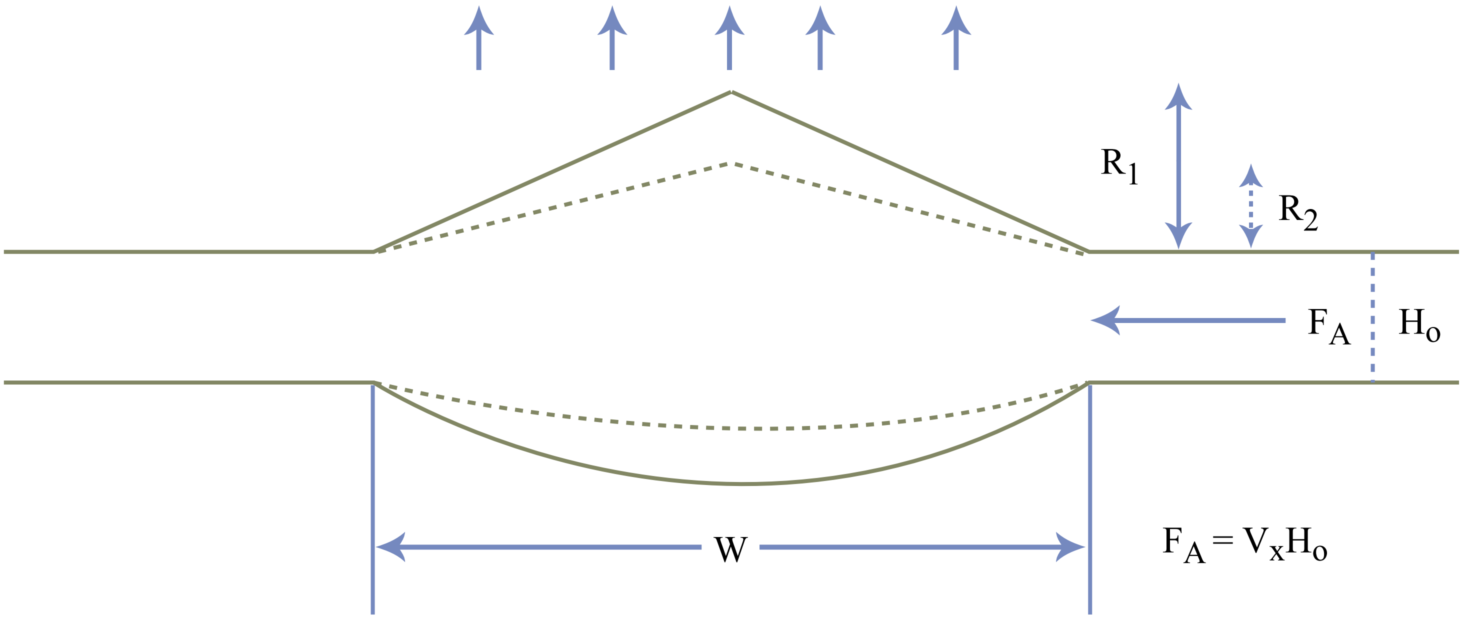
Tectonic Uplift is Isostatic Uplift

Constant Width Orogen (dW/dt = 0)

Homogeneous pure shear
dU/dx = 0

Airy isostatic compensation

$U_1 = U_2 = V_x H_o / W$



$F_A = V_x H_o$

Enhanced erosion reduces steady state topography and crustal thickness but not steady state rock uplift rate ($F_E = F_A$).

Montgomery et al., 2001 Geology

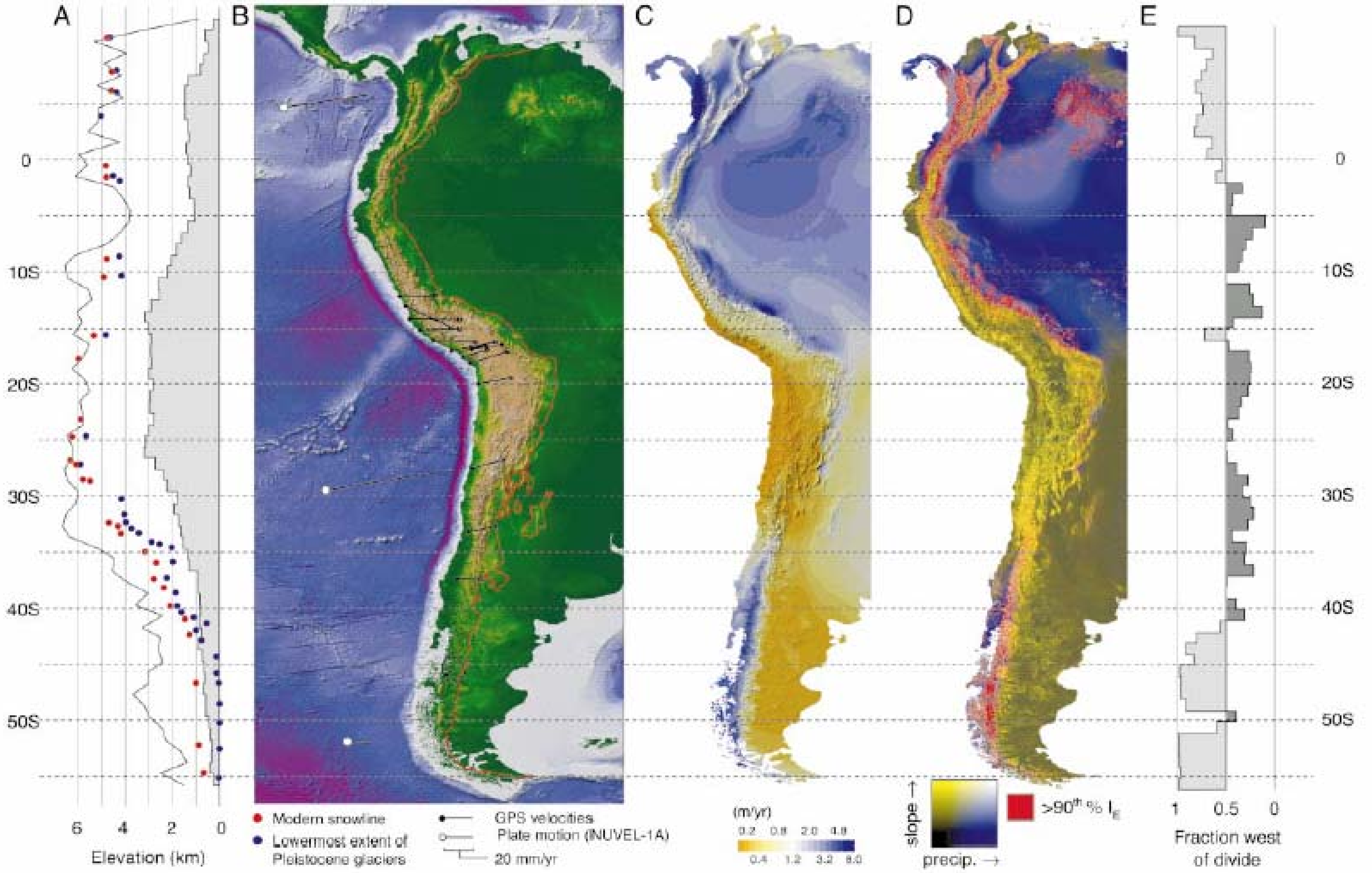


Figure 1. A: Maximum (dark line) and mean (gray area) elevation in 1° latitude bins. Red circles are elevations of modern perennial snowline and blue circles are lowest elevation of Pleistocene glacier extent, both from Schwertfelder (1976). B: Topography and convergence velocity. Vectors headed in open circles denote long-term velocity of Nazca and Antarctic plates relative to South American plate (DeMets et al., 1994); those headed in closed circles denote global positioning system (GPS) velocities at coastal sites, relative to stable South America (Norabuena et al., 1998; Kendrick et al., 1999). C: Mean annual precipitation, overlain on shaded-relief map of western South America. D: False-color image of South America showing areas with steep slope in yellow, high precipitation in blue. Red pixels have calculated I_E above 90th percentile relative to all pixels in image. E: Cross-range asymmetry, defined to be fraction of range volume above sea level that drains to west: values greater than 0.5 (lighter shade of gray) indicate that bulk of range is west of divide.

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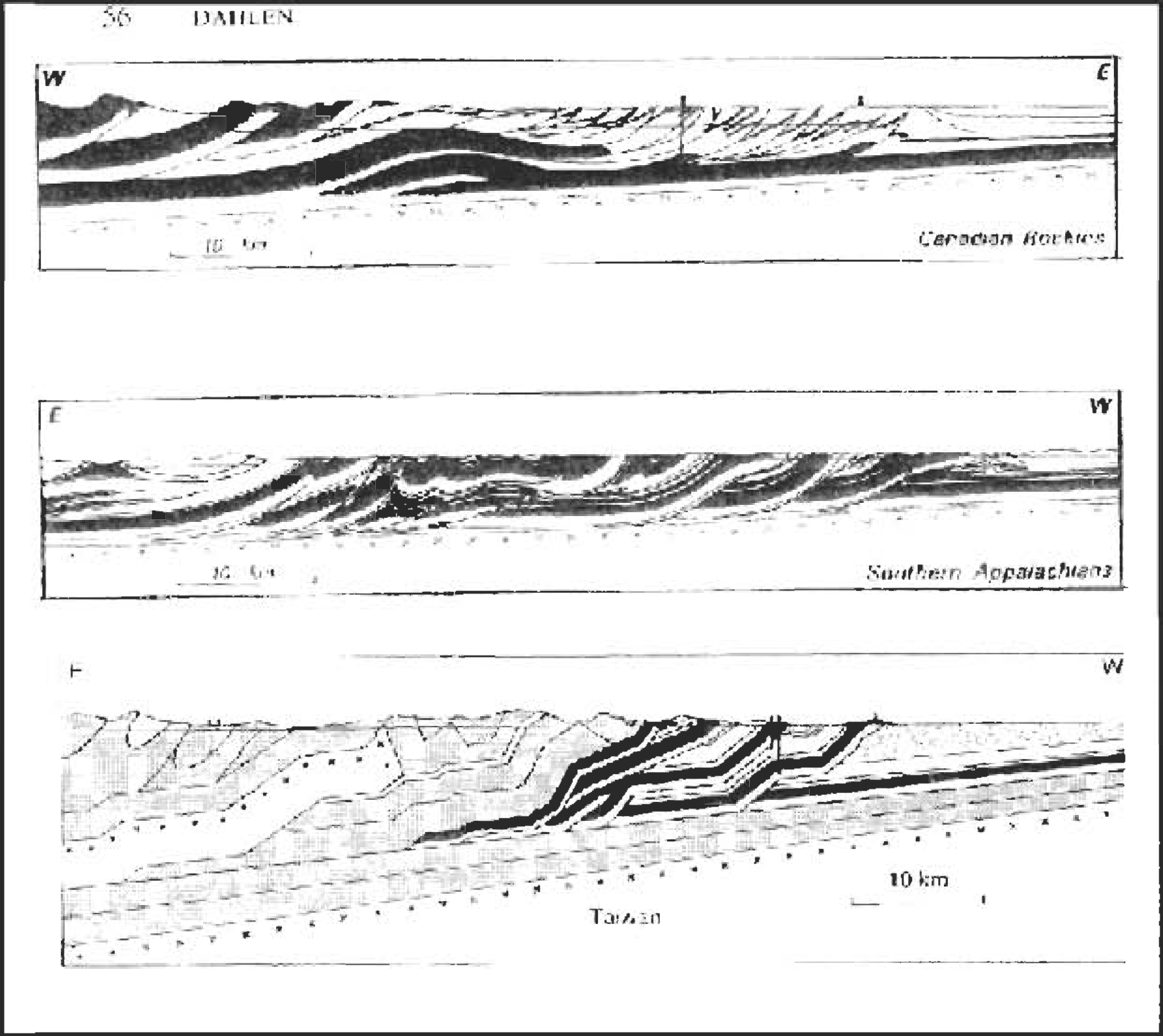
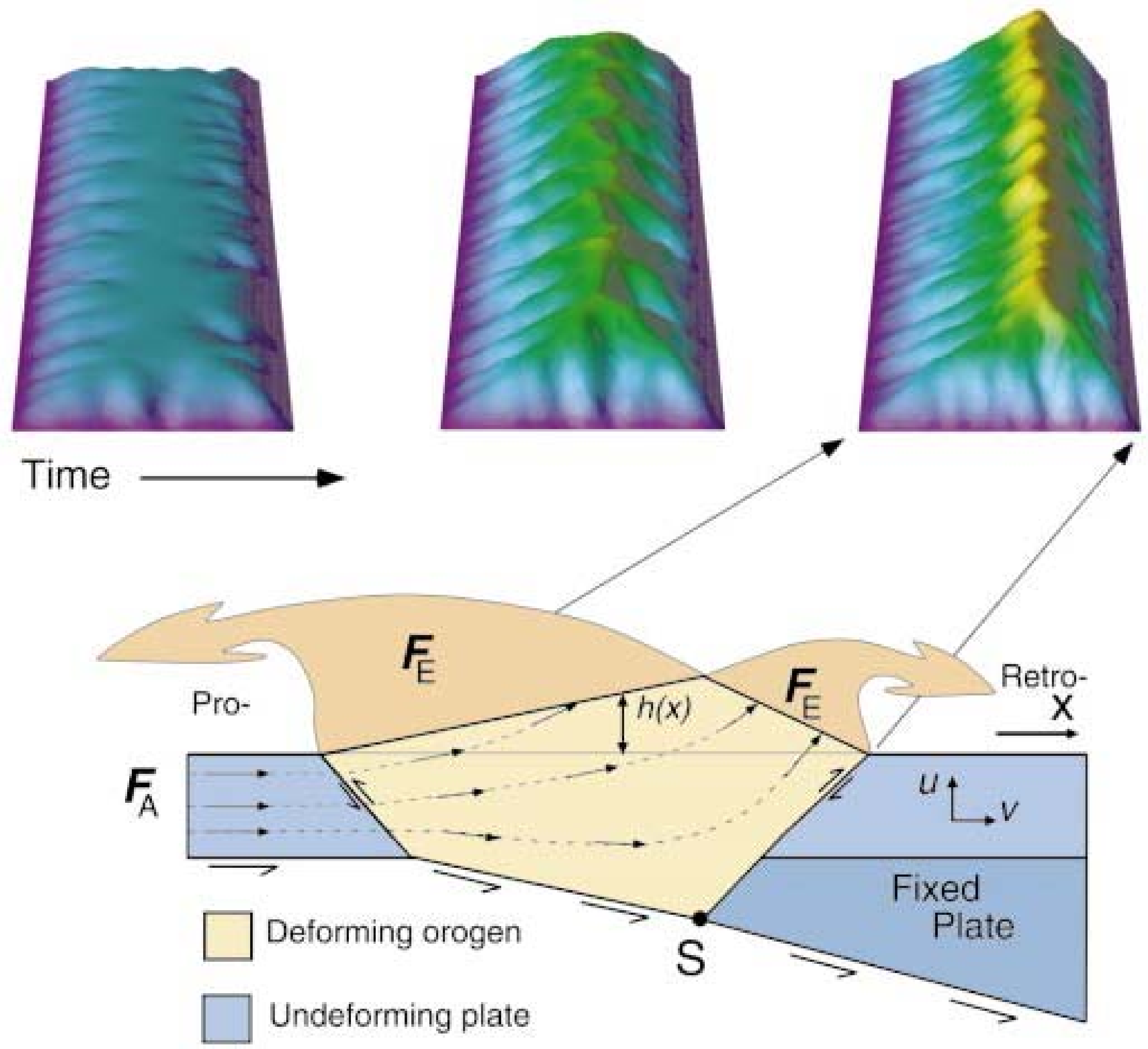
Dahlen, 1990, Annual Reviews

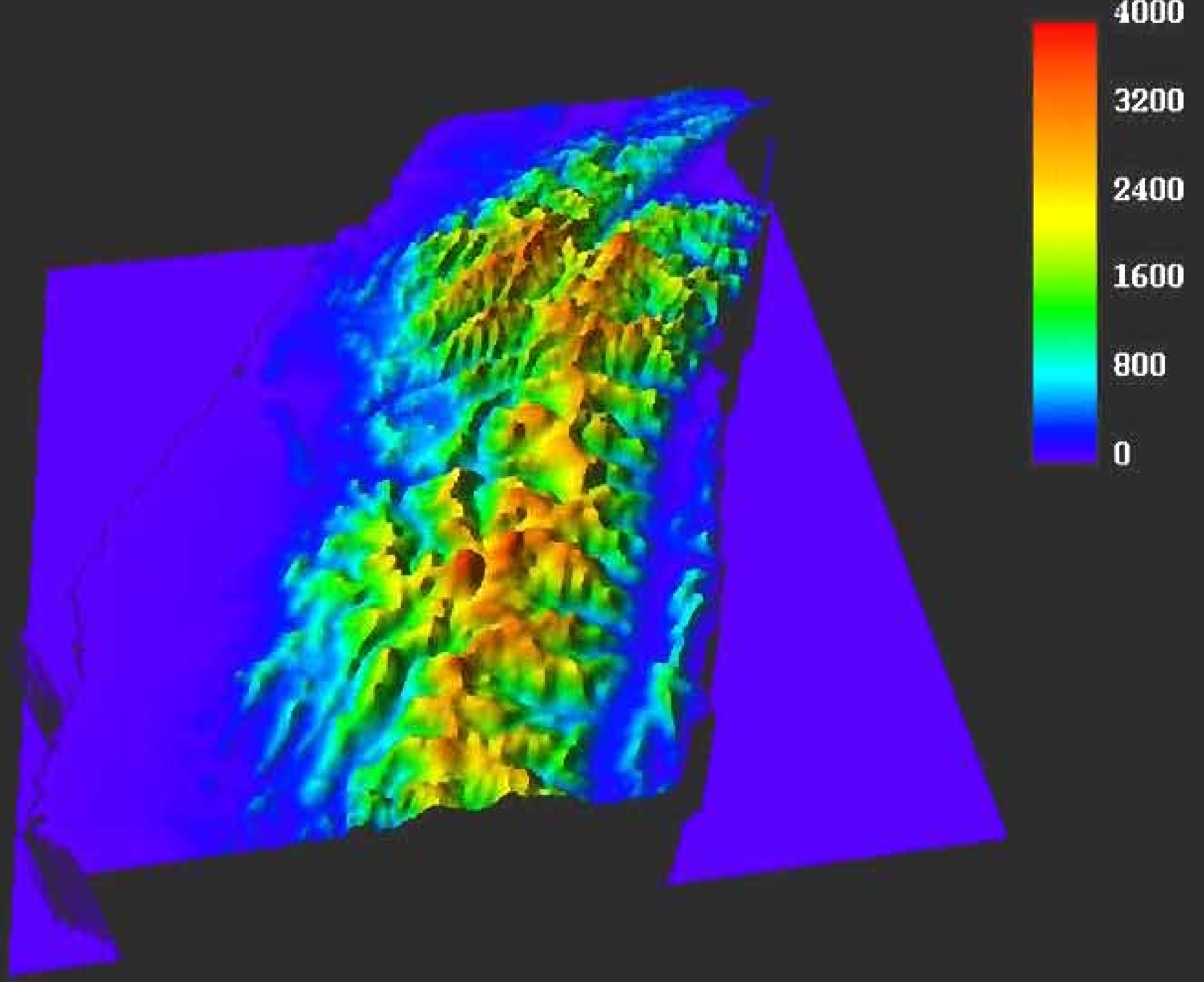


Courtesy of Annual Reviews. Used with permission.

Willett and Brandon, 2001: Geology

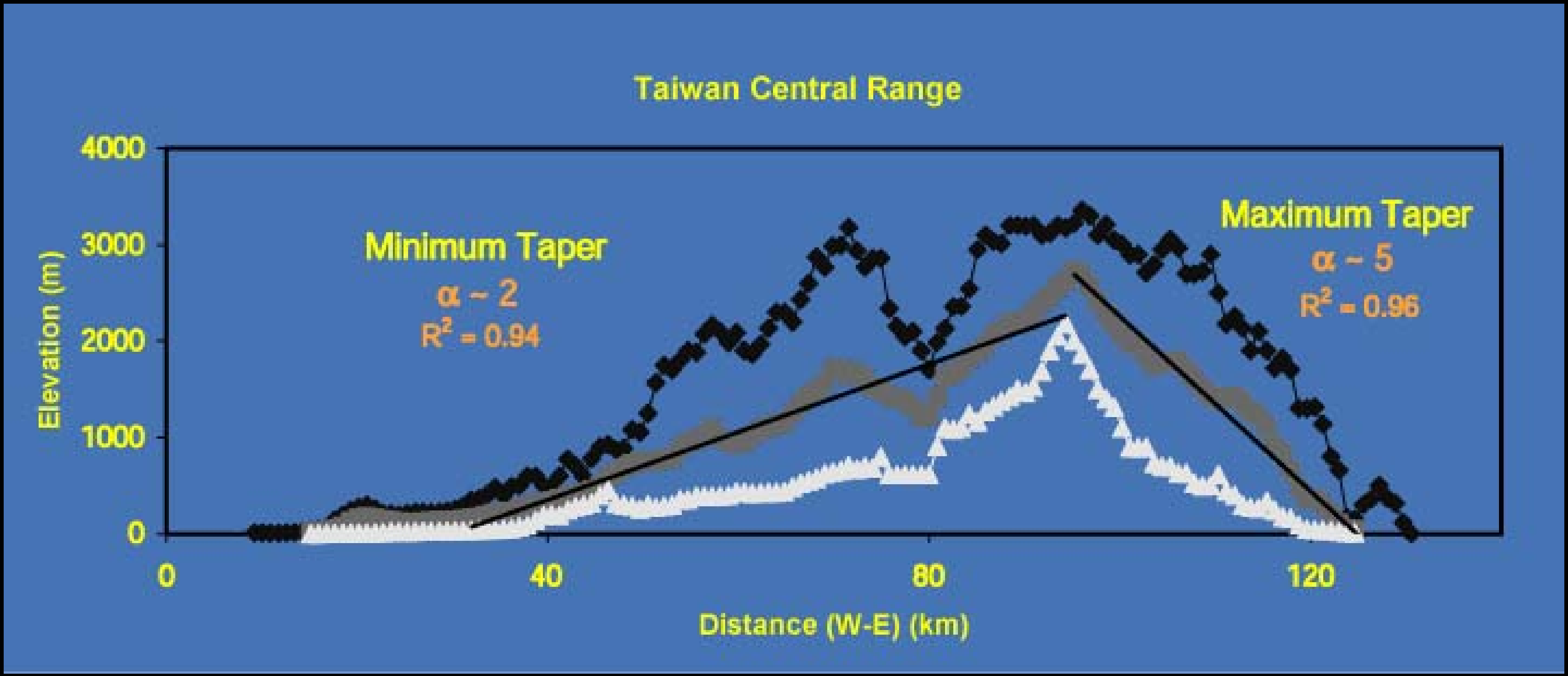


Courtesy of The Geological Society of America. Used with permission.

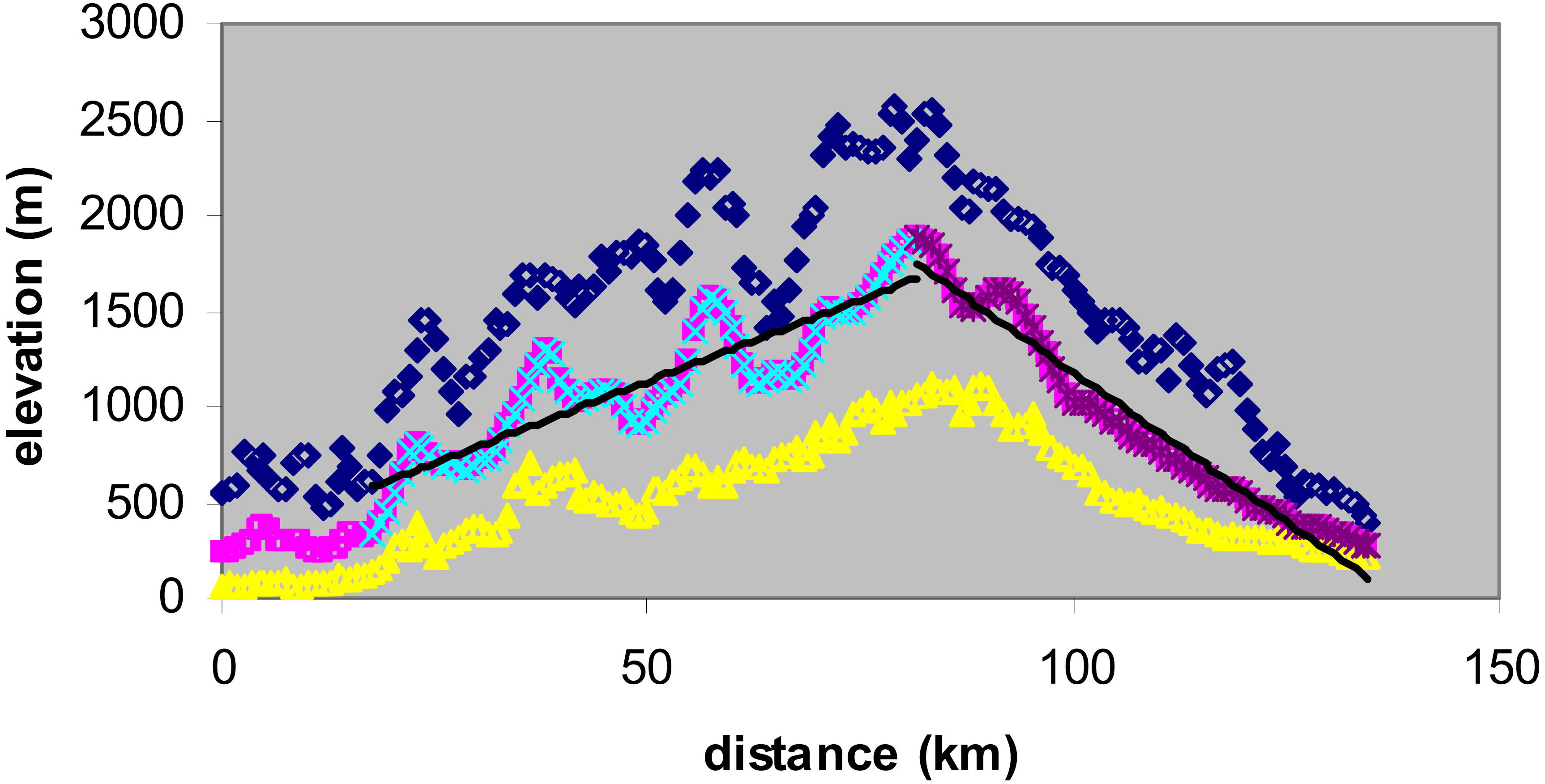


4000
3200
2400
1600
800
0

Critical Taper Theory:
Framework for Examining Controls on Orogen Width



Indo-Burman Range

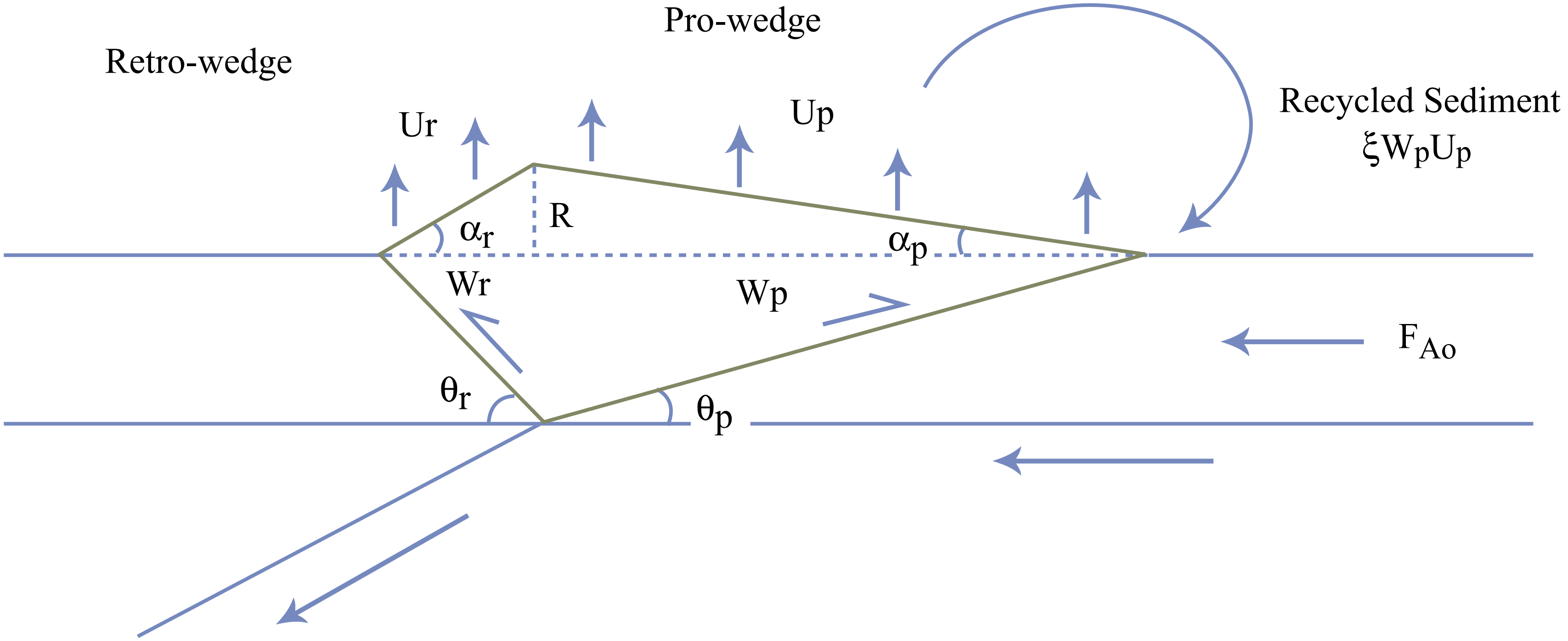


General Analytical Solution

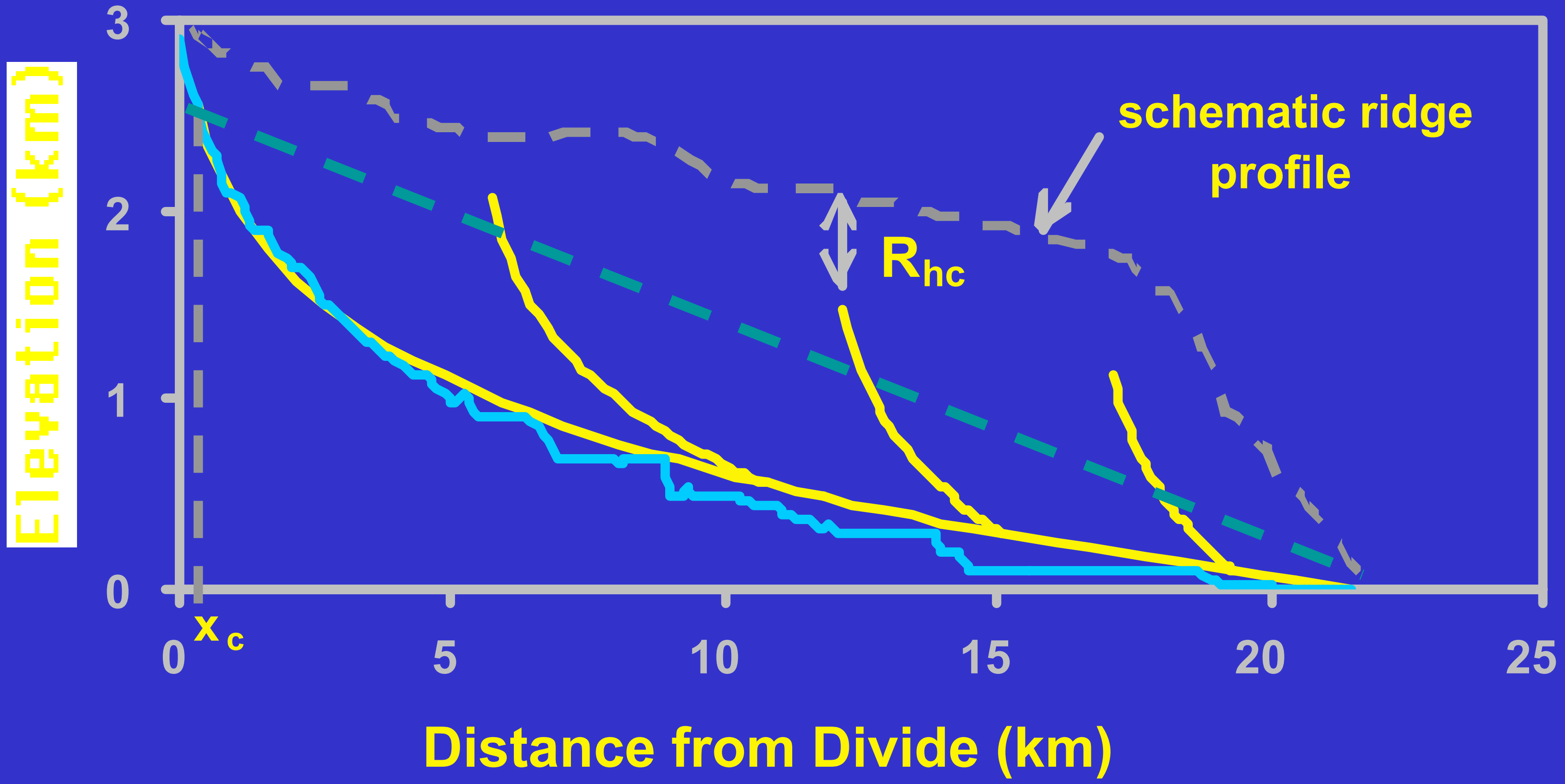
- Mass Balance in a 2-Sided Wedge at Flux Steady State
    - Account for Recycling of Foreland Sediment
- Critical Taper: Wedge Geometry (mean topography)
    - Assumes Topographic Taper Invariant with Accretionary Flux, Climate, Orogen Width
- Generic Orogen-Scale Erosion Rule

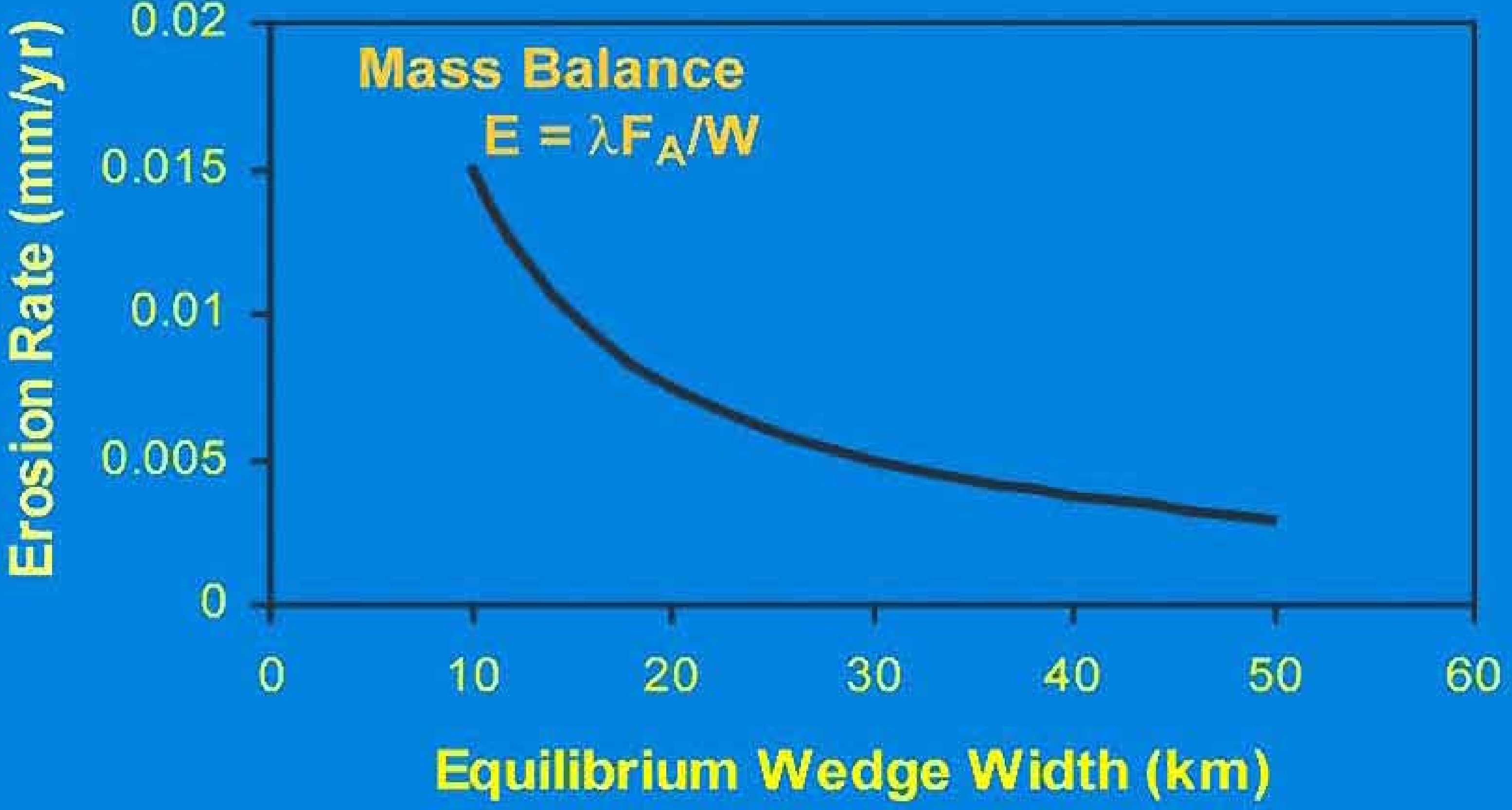
Relations for Steady State Frictional Wedges

Definition Sketch



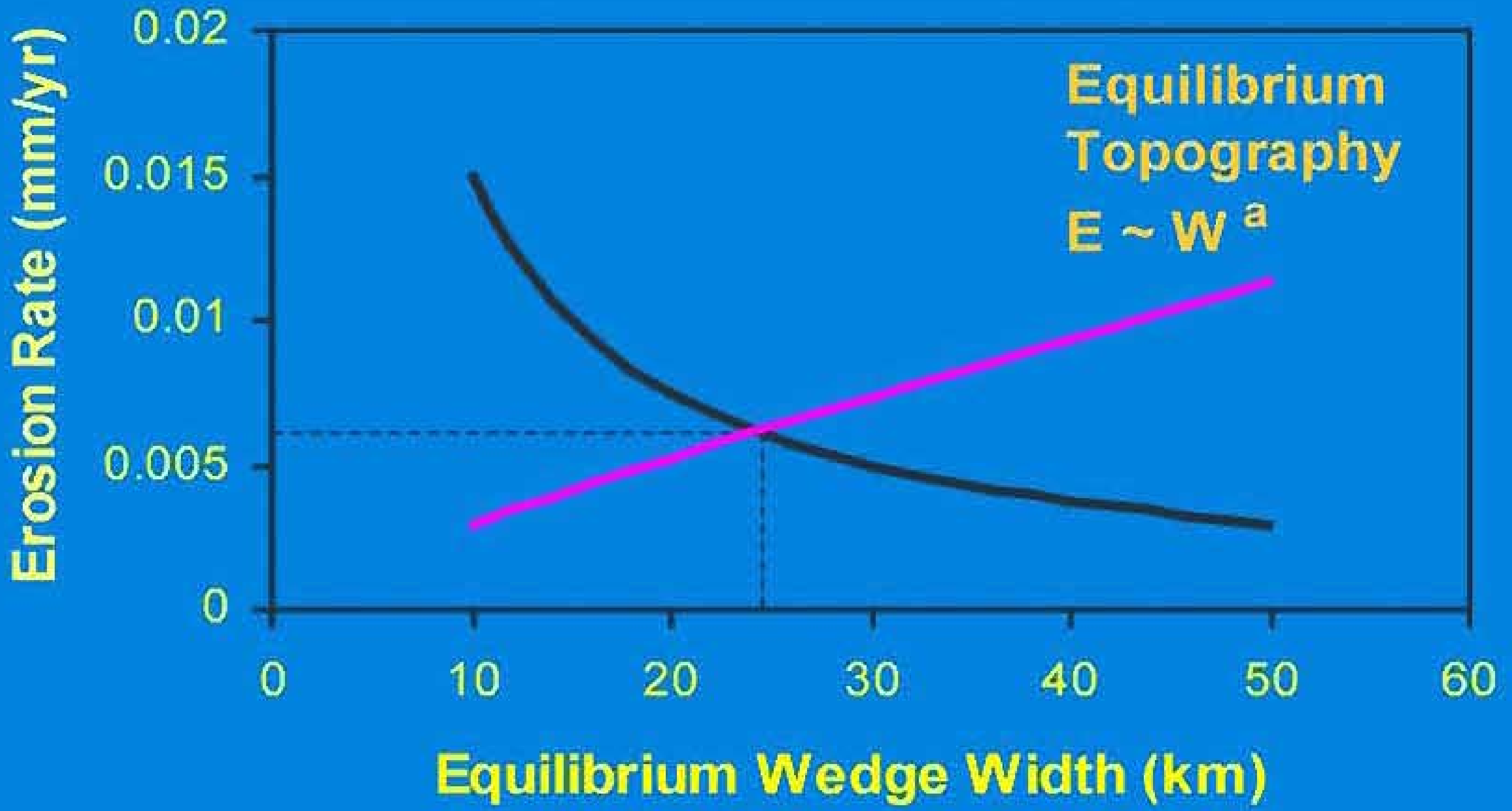
Taiwan Topographic Envelope



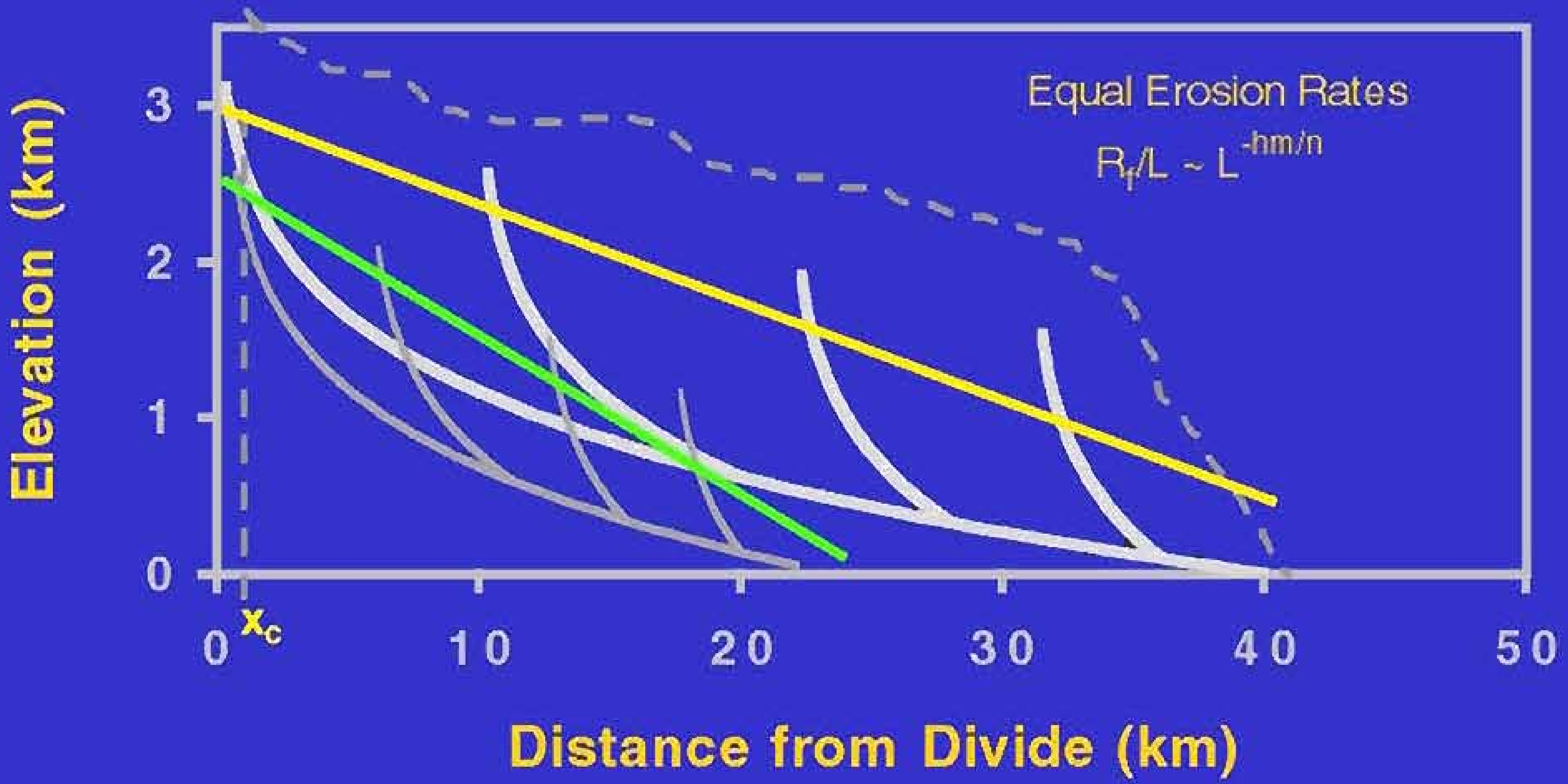


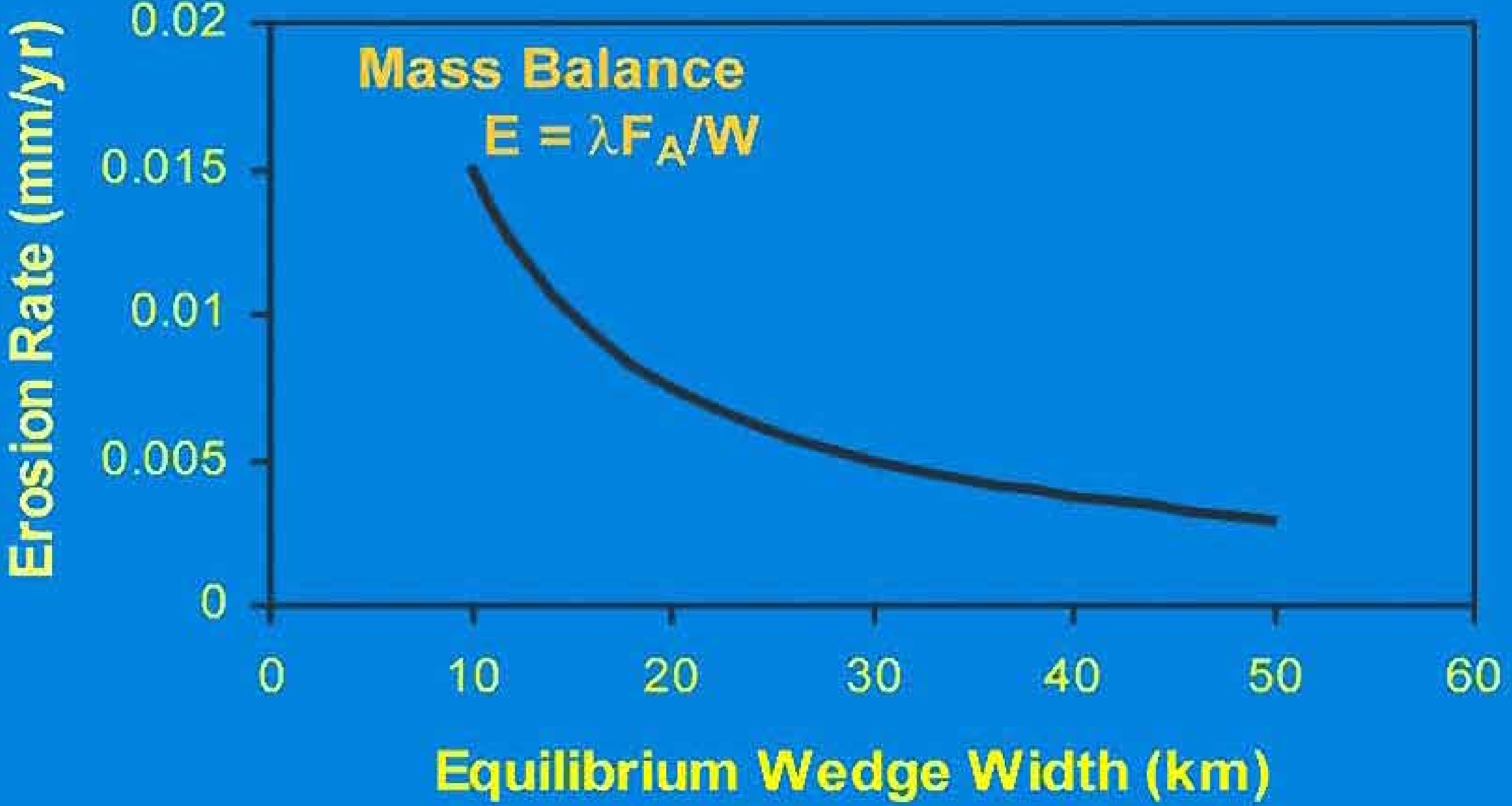
Mass Balance

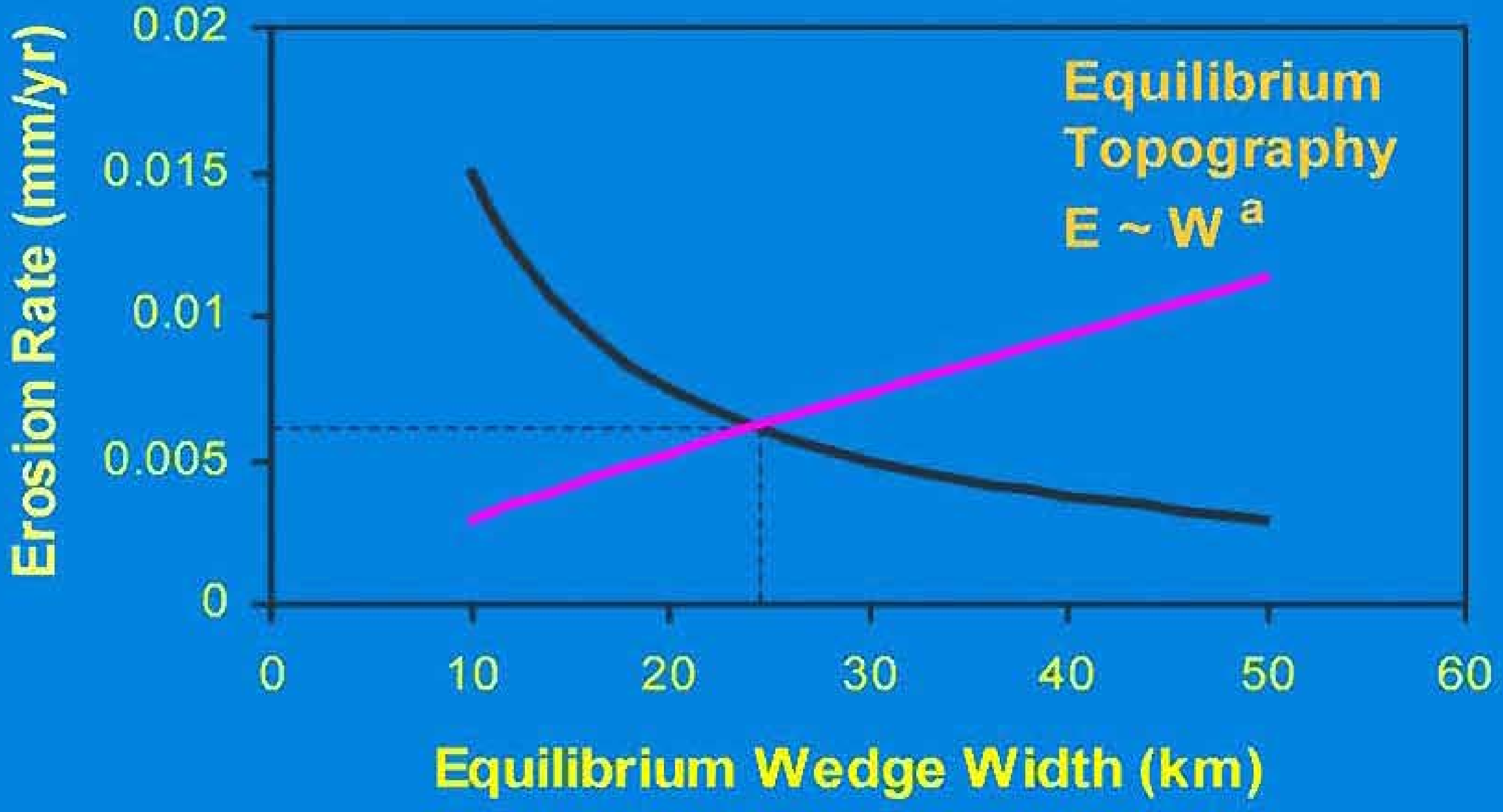
$E = \lambda F_A / W$

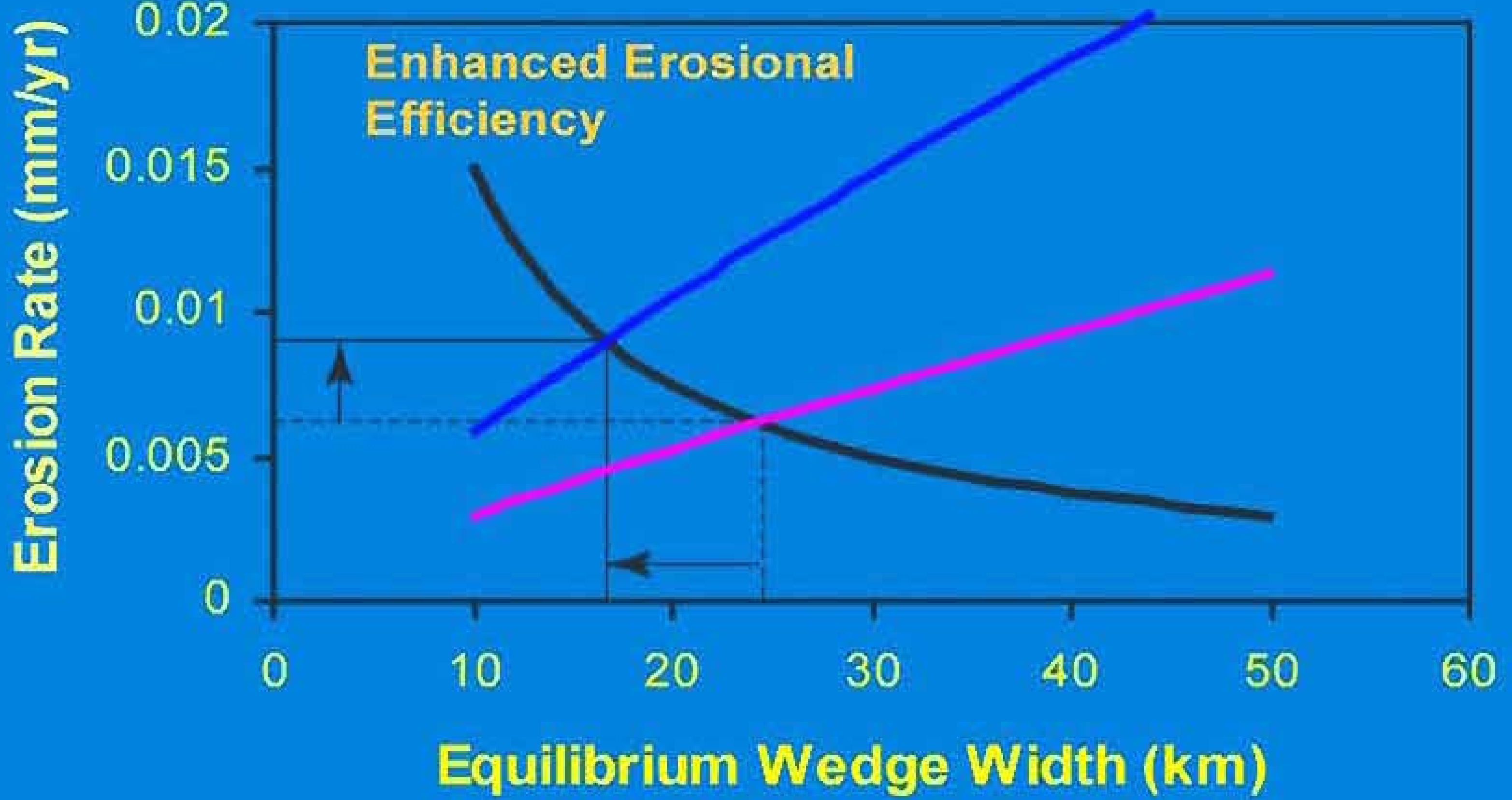

Equilibrium
Topography
E ~ W a
Erosion Rate (mm/yr)
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
Equilibrium Wedge Width (km)

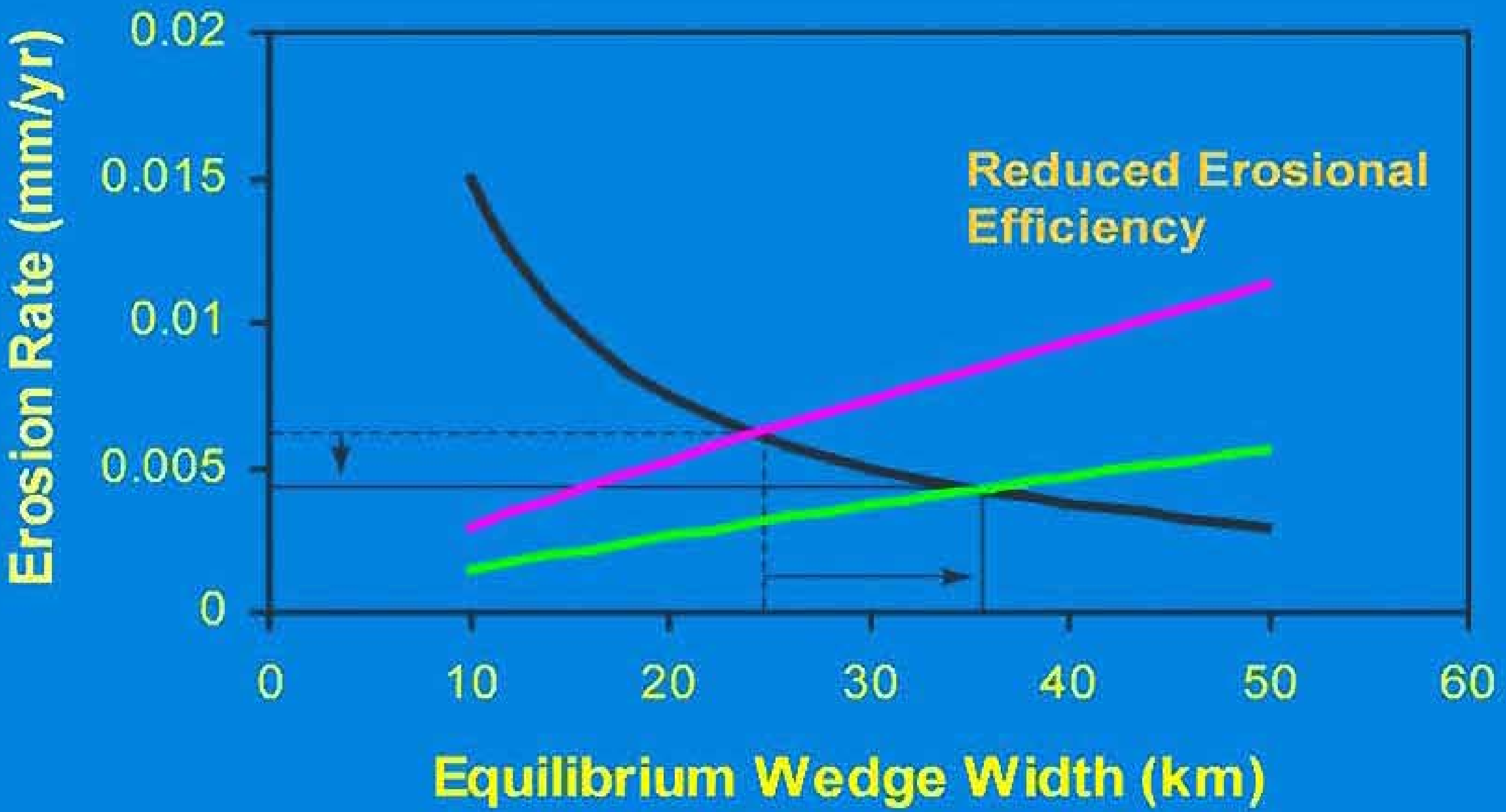
Regional Gradient vs. Channel Length




Mass Balance
E = λF_A/W
Erosion Rate (mm/yr)
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
Equilibrium Wedge Width (km)


Equilibrium
Topography
$E \sim W^a$
Erosion Rate (mm/yr)
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
Equilibrium Wedge Width (km)


Enhanced Erosional Efficiency
Erosion Rate (mm/yr)
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
Equilibrium Wedge Width (km)


Reduced Erosional Efficiency
Erosion Rate (mm/yr)
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
Equilibrium Wedge Width (km)

Relations for Steady State Frictional Wedges

Senstivity to Tectonic and Climatic Differences / Changes

$$R \sim W \sim K^{-(1/2 - 2/3)} F_A^{1/2 - 2/3}$$

$$U \sim K^{1/2 - 2/3} F_A^{1/2 - 1/3}$$

$$K \sim Pe^{1/4 - 2/3}$$

$$\phi = \frac{U_p}{U_r} = \left(\frac{K_p}{K_r}\right)\left(\frac{\tan\alpha_p}{\tan\alpha_r}\right)^{n-hm}$$

Relations for Steady State Frictional Wedges

Senstivity to Tectonic and Climatic Differences / Changes

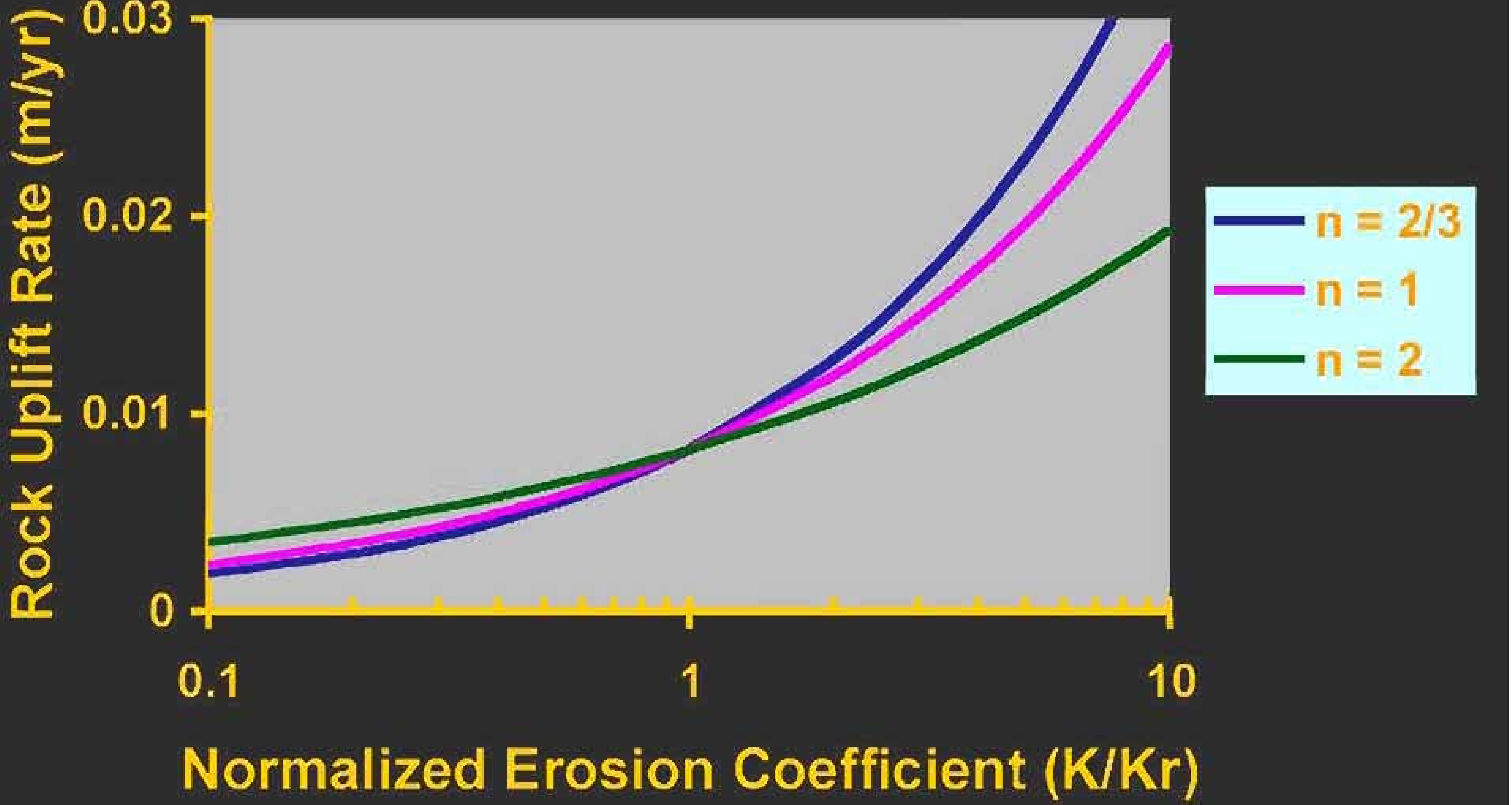
$$R \sim W \sim K^{-(1/2\,-\,2/3)} F_A^{\,1/2\,-\,2/3}$$

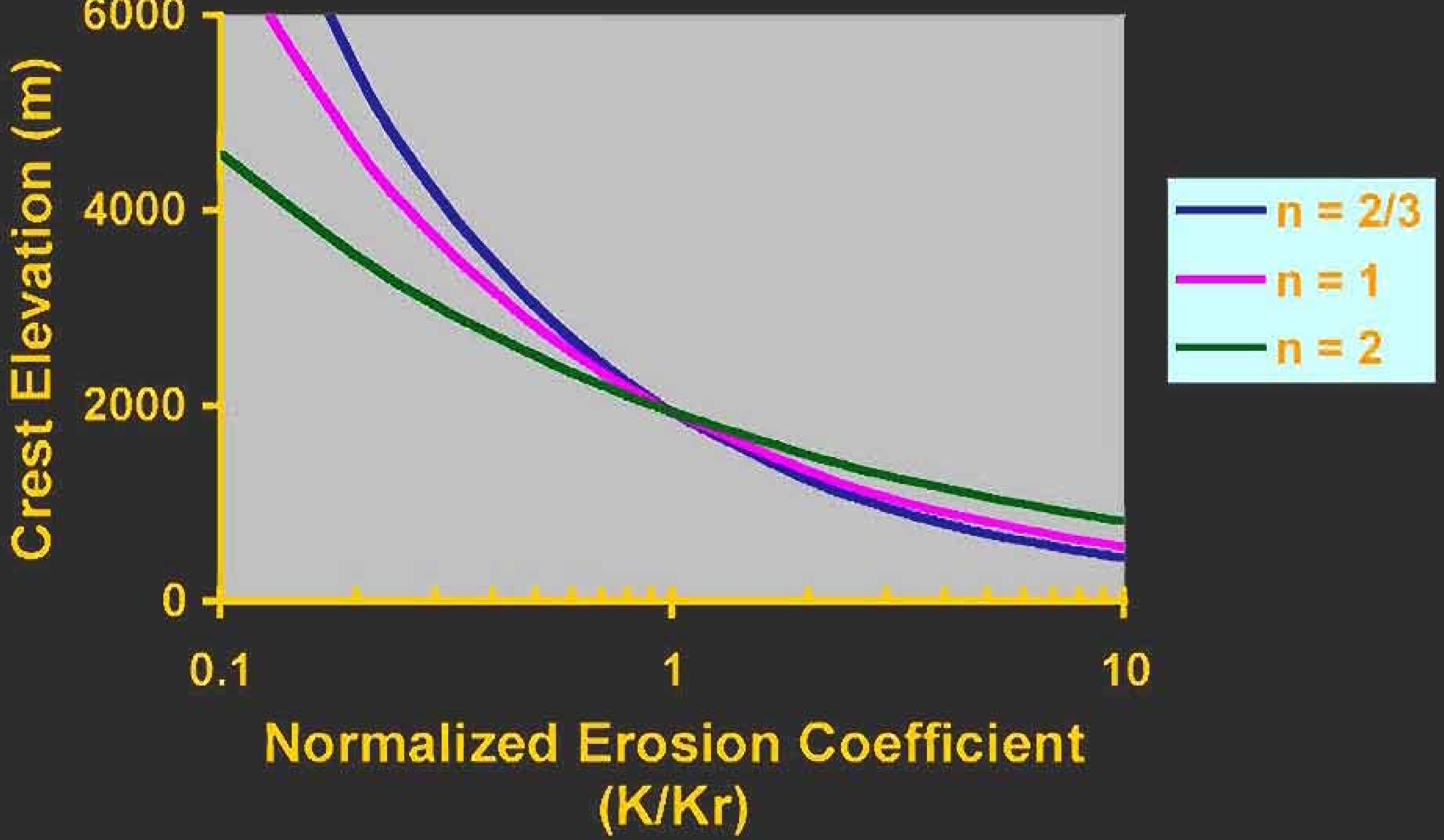
$$U \sim K^{1/2\,-\,2/3} F_A^{\,1/2\,-\,1/3}$$

$$\xcancel{K \sim Pe^{1/4\,-\,2/3}}$$

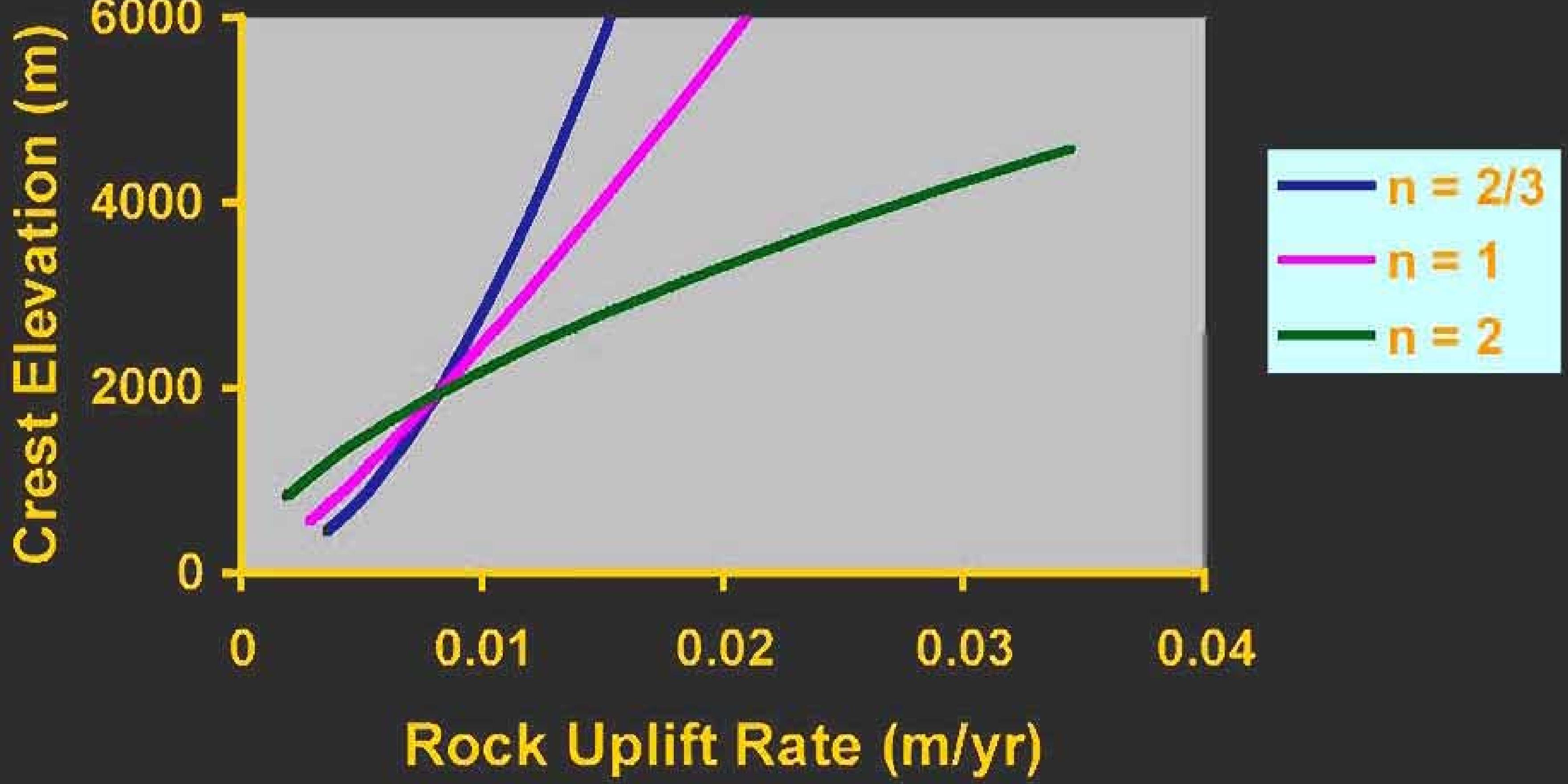
$$K = f(P_e, I, D_{50}, K_r, \tau_{cr} \ldots)$$

$$\phi = \frac{U_p}{U_r} = \left(\frac{K_p}{K_r}\right)\left(\frac{\tan\alpha_p}{\tan\alpha_r}\right)^{n-hm}$$

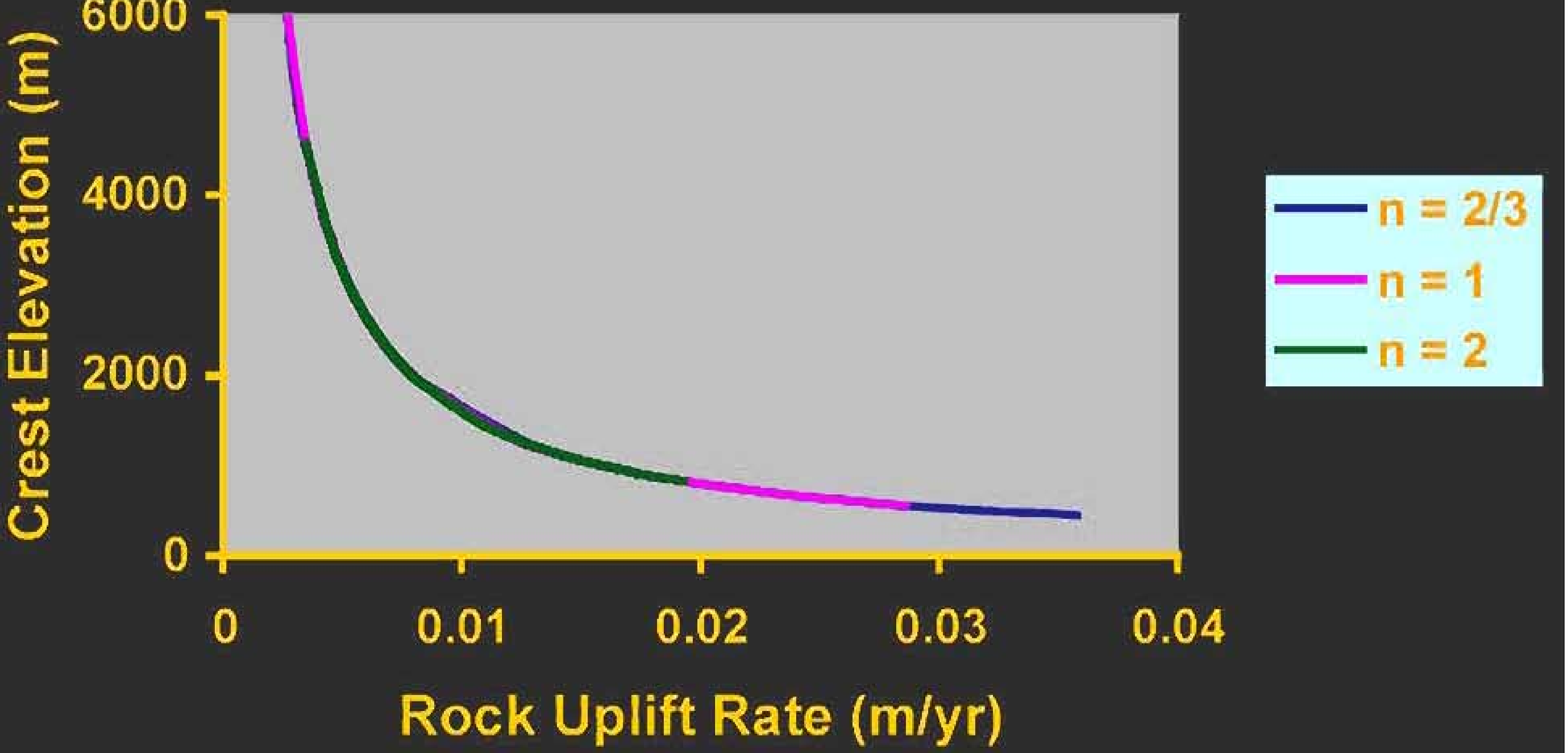

Rock Uplift Rate (m/yr)
0.03
0.02
0.01
0
0.1
1
10
Normalized Erosion Coefficient (K/Kr)
n = 2/3
n = 1
n = 2


Crest Elevation (m)
6000
4000
2000
0
0.1
1
10
Normalized Erosion Coefficient
(K/Kr)
n = 2/3
n = 1
n = 2

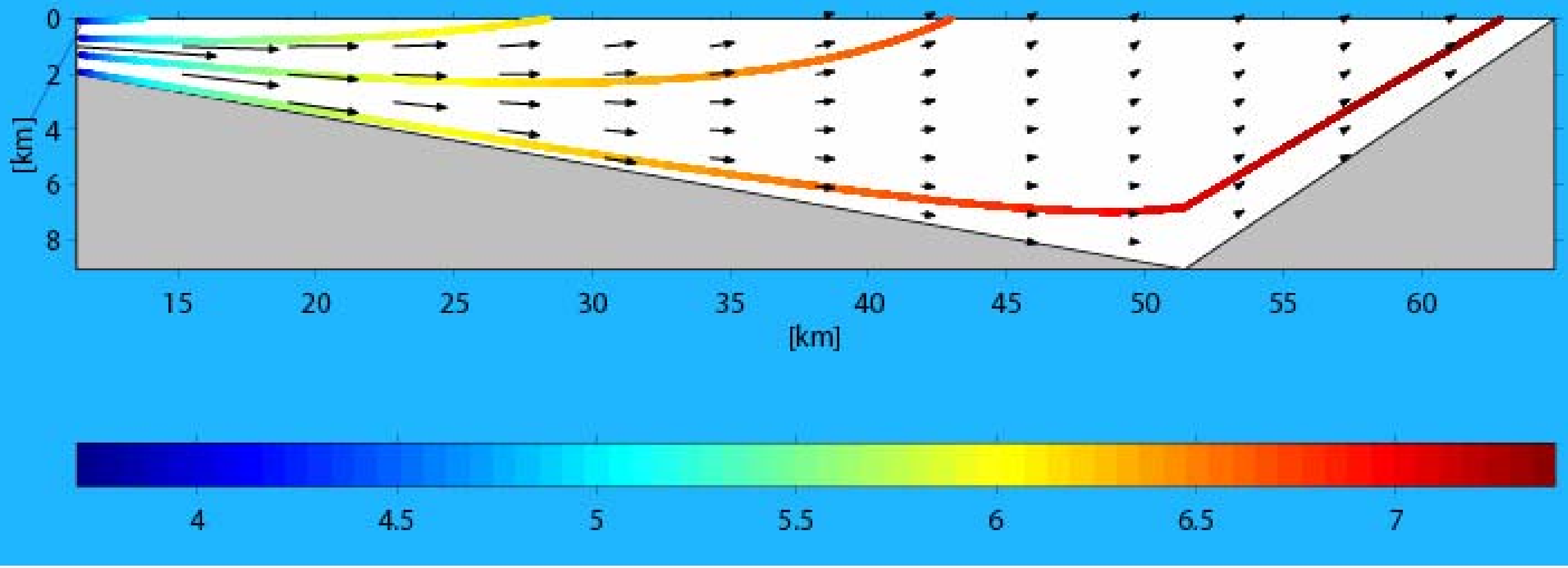
Varying Convergence Velocity



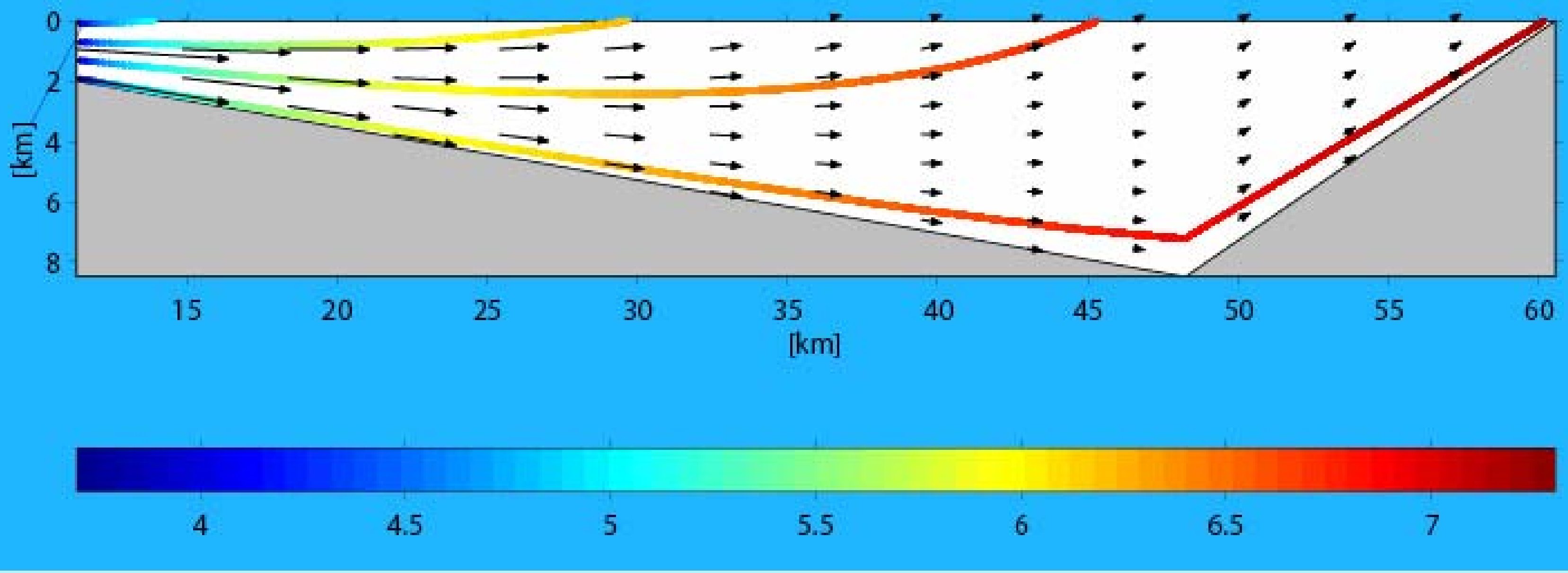
Varying Erosion Efficiency



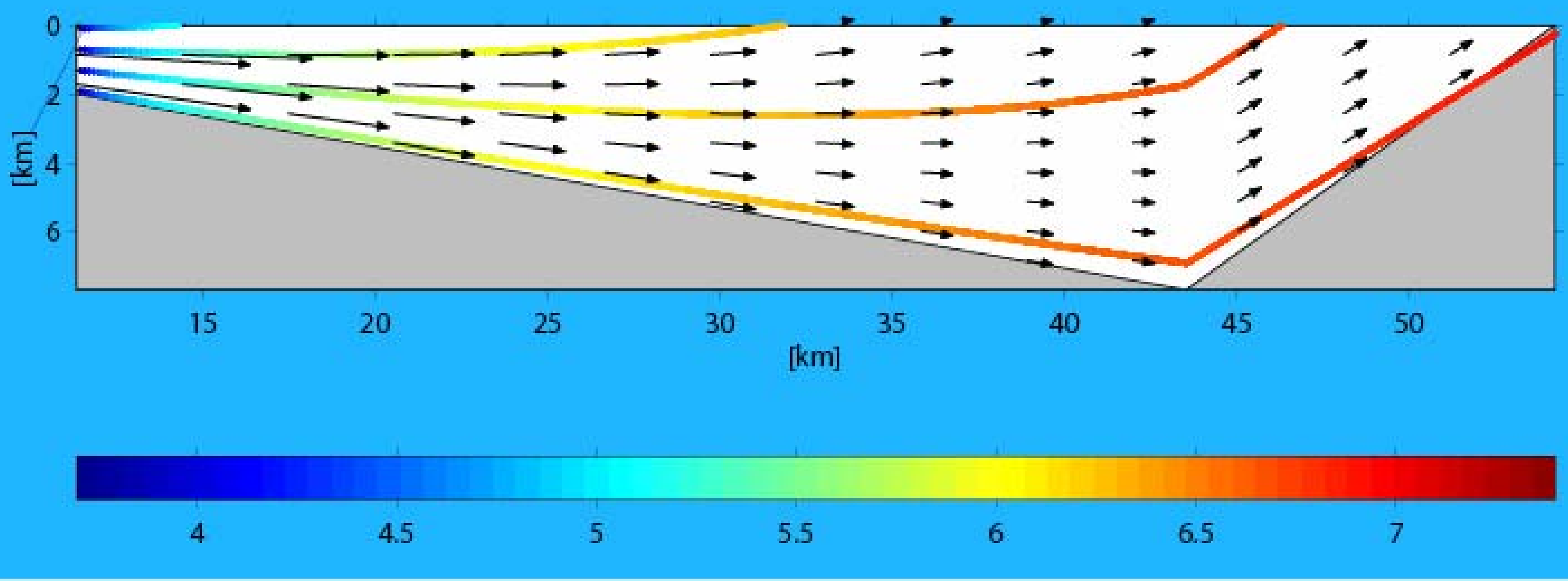
Dry Retro-Wedge



Uniform Precipitation



Wet Retro-Wedge



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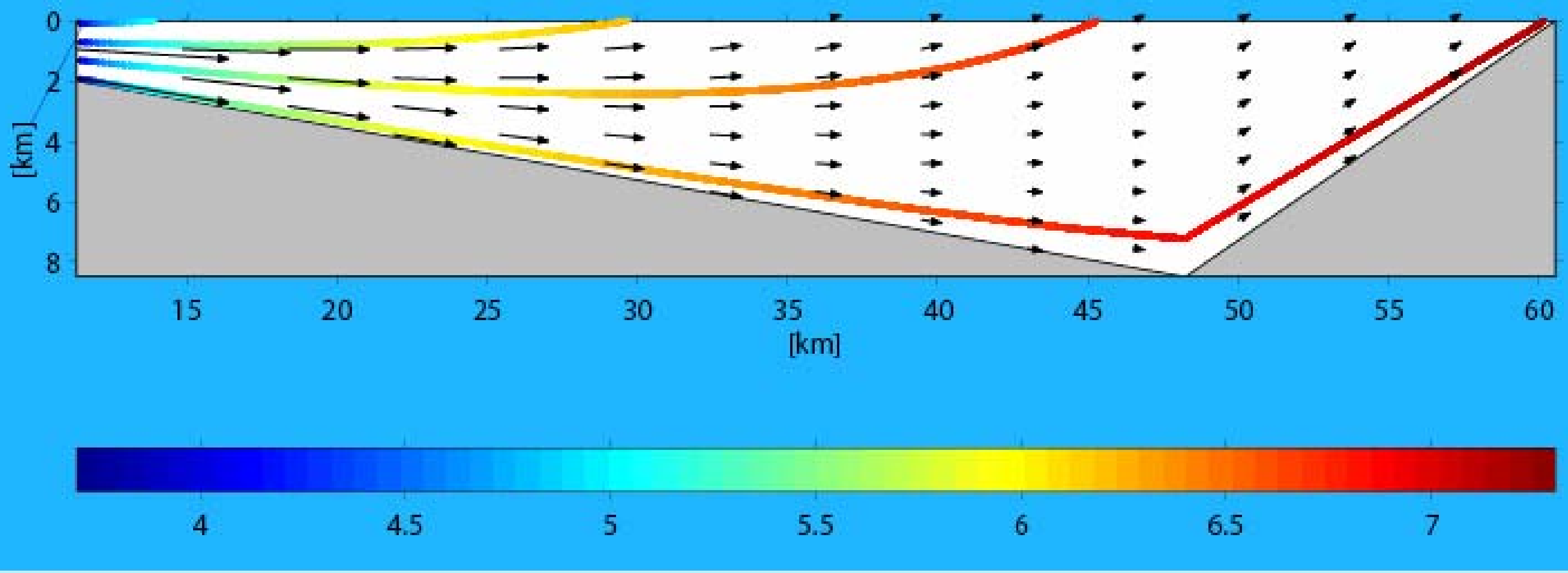
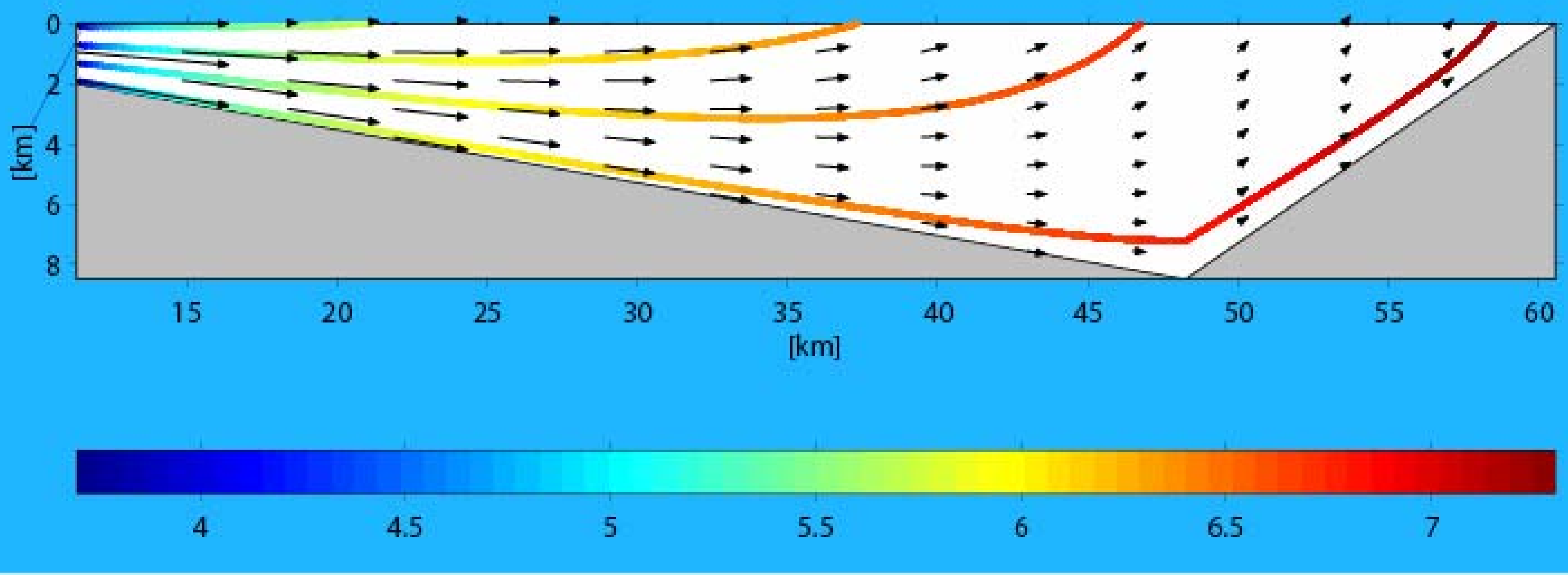
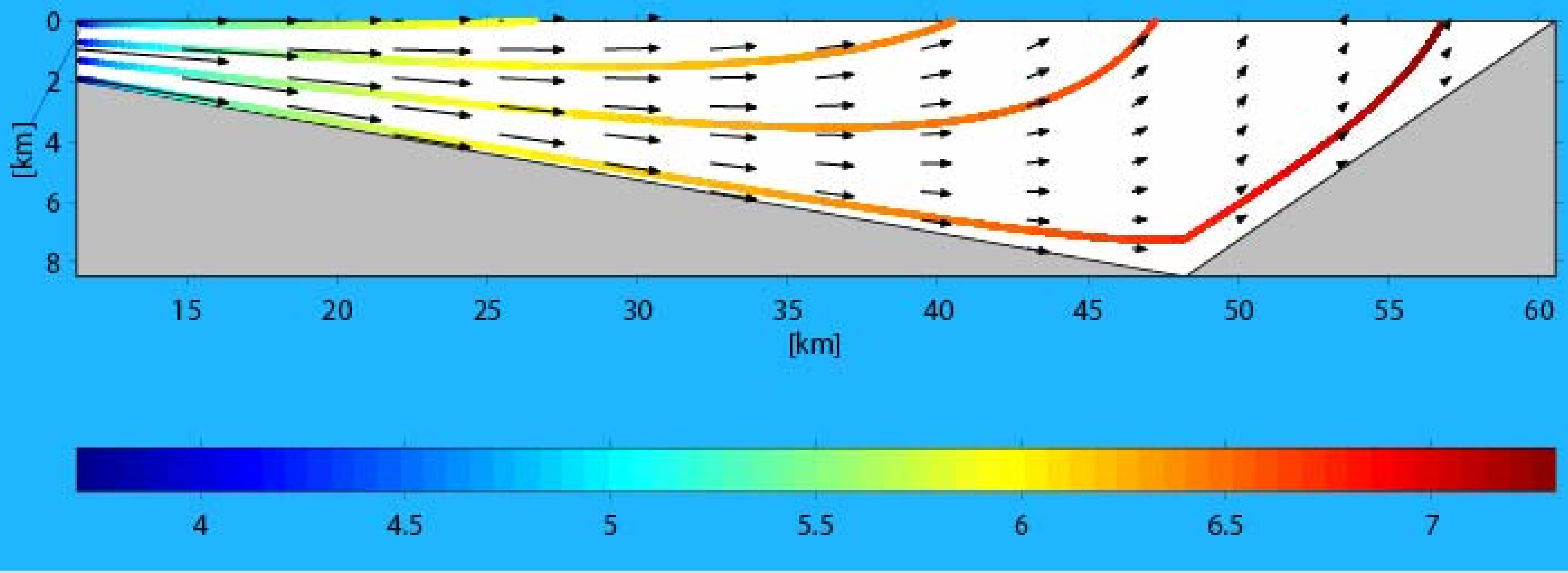
Uniform Precipitation



Erosion Increase to Divide, linear



Erosion Increase to Divide, non-linear



Limitations

- Rheology – viscous effects not modeled (Himalaya-type more sensitive to climate)
- P, θ, ϕ and therefore topographic taper invariant with W, F_A, Climate
  - P = *F* (climate)?
  - θ = *F* (wedge width)?
  - ϕ = *F* (depth / temperature)?
- Erosion law – hides potentially important internal feedbacks and controls on spatial pattern of erosion (channel width, sediment flux/size, threshold stress, orographic ppt)

Wedge Solution Equally Valid for Transport Limited Model