Quantifying the growth (and decay) of topography in collisional orogens

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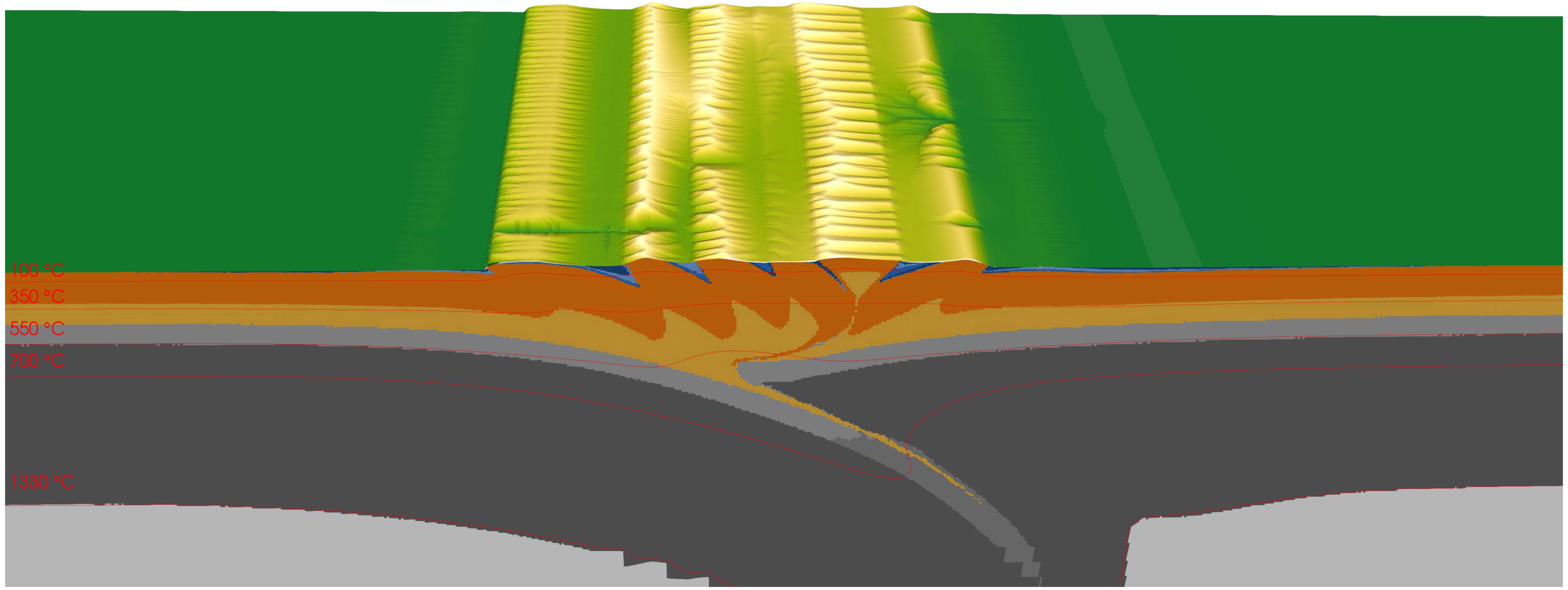

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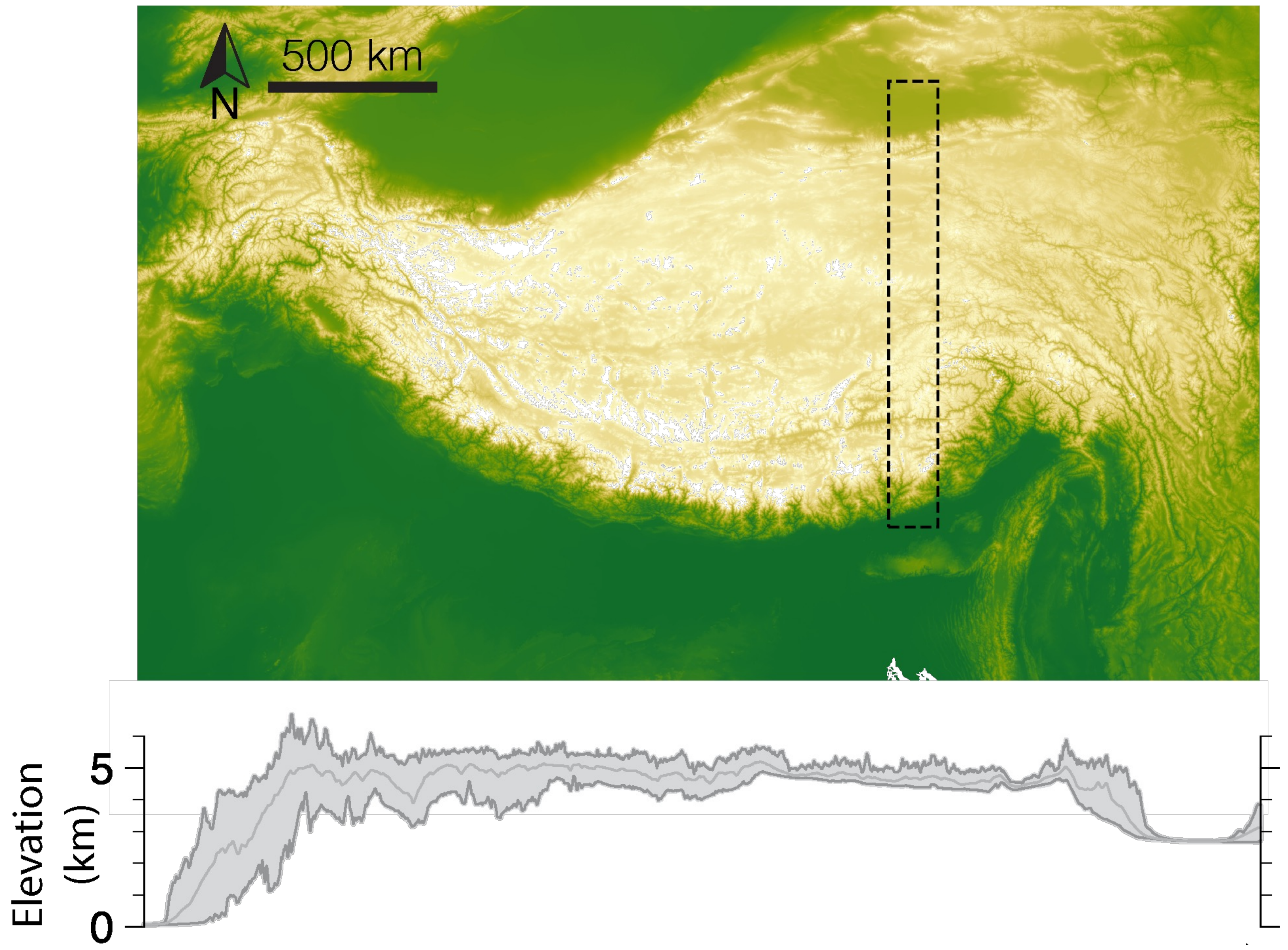
TotalEnergies

Tectonics or climate - what controls mountain belt height and width?

Himalaya-Tibet

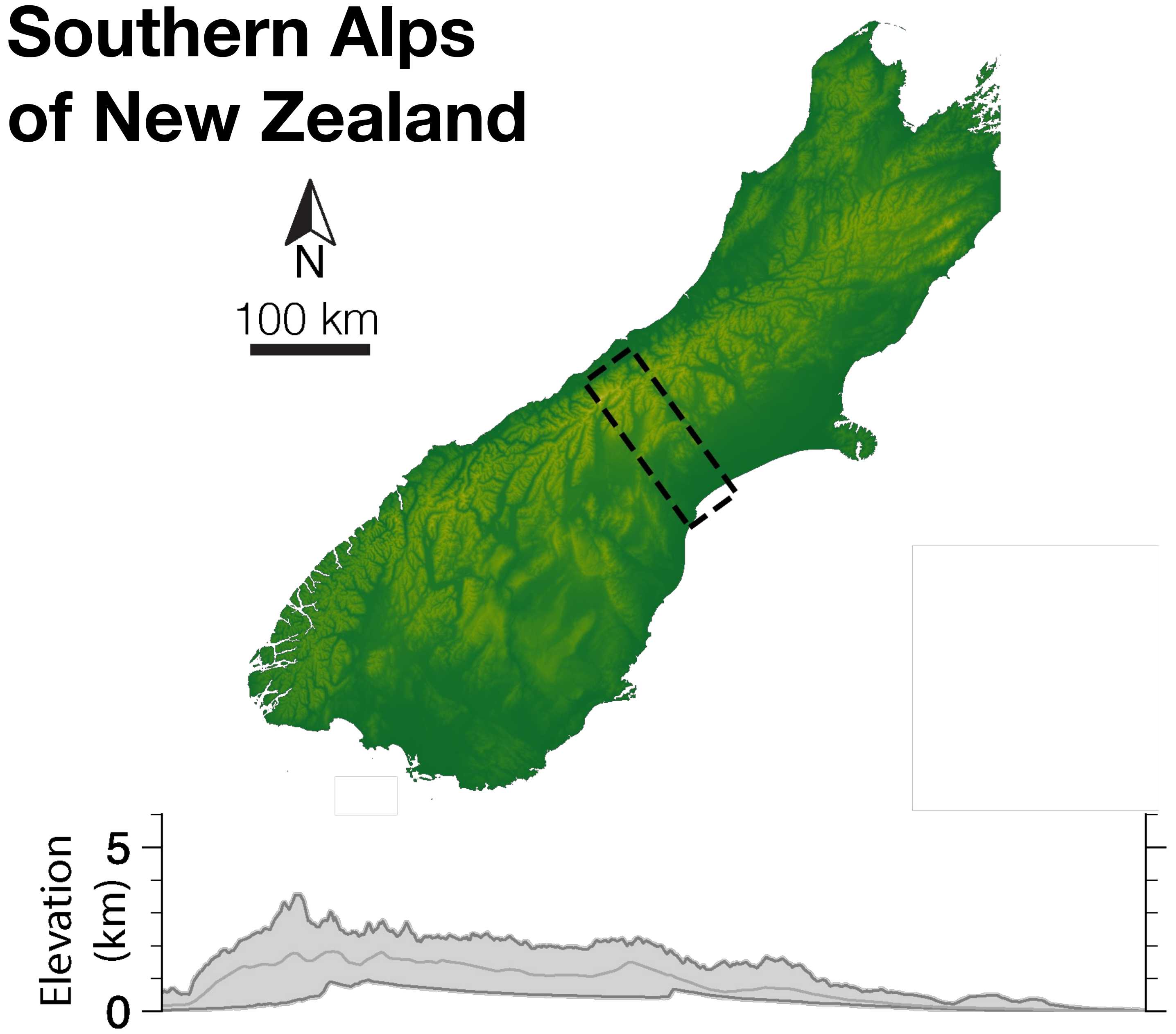


Tectonics:
Crust is too weak

$$\text{Argand Number} = \frac{\text{Buoyancy force from crustal thickening}}{\text{Lithospheric strength}}$$

England & McKenzie, 1982

Southern Alps of New Zealand



Geomorphology:
Erosion is too fast

$$\text{Uplift/erosion Number} = \frac{\text{Time scale to reach max height}}{\text{Time scale to erode orogen}}$$

Whipple & Tucker, 1999; Willett 1999

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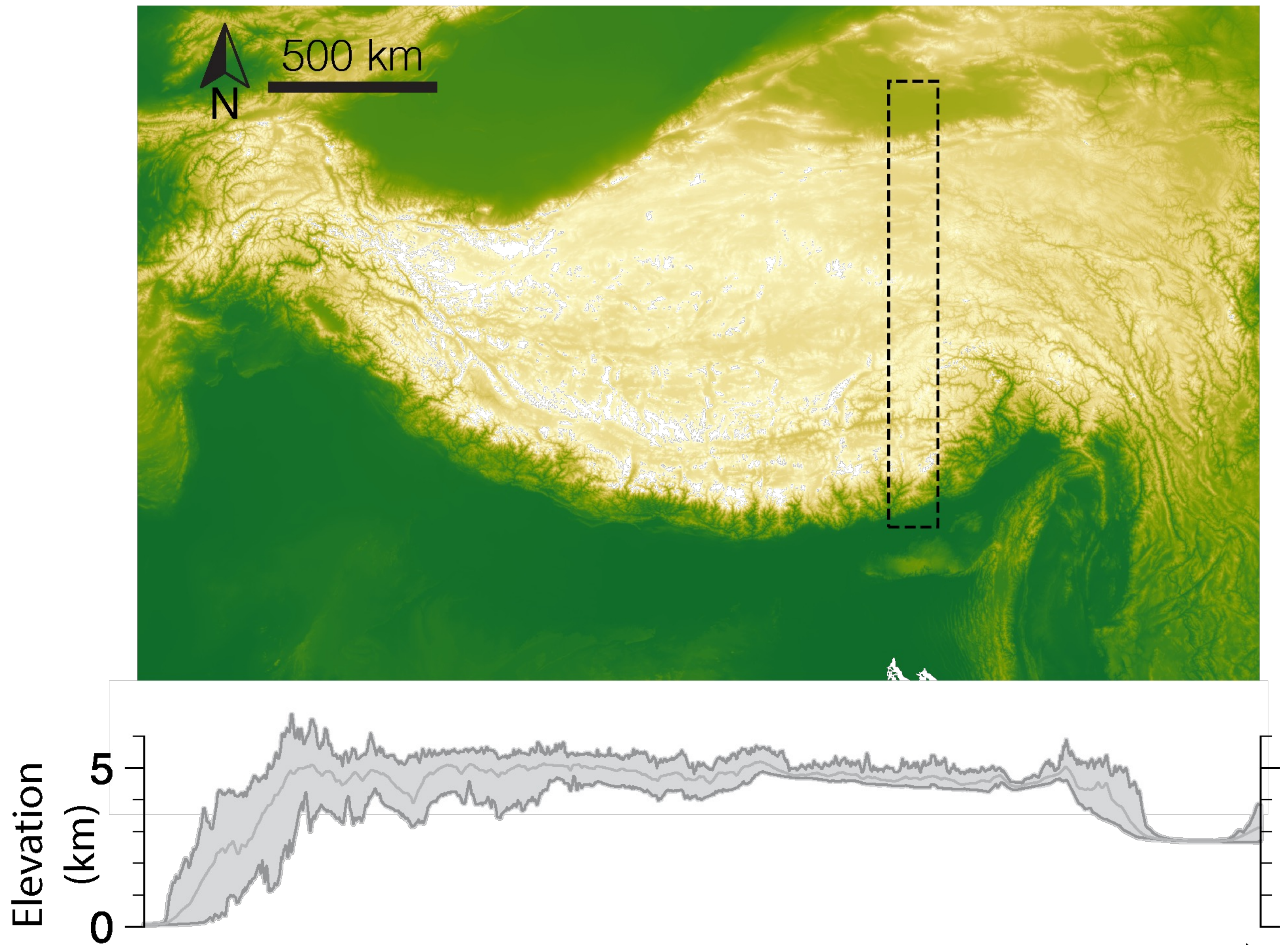

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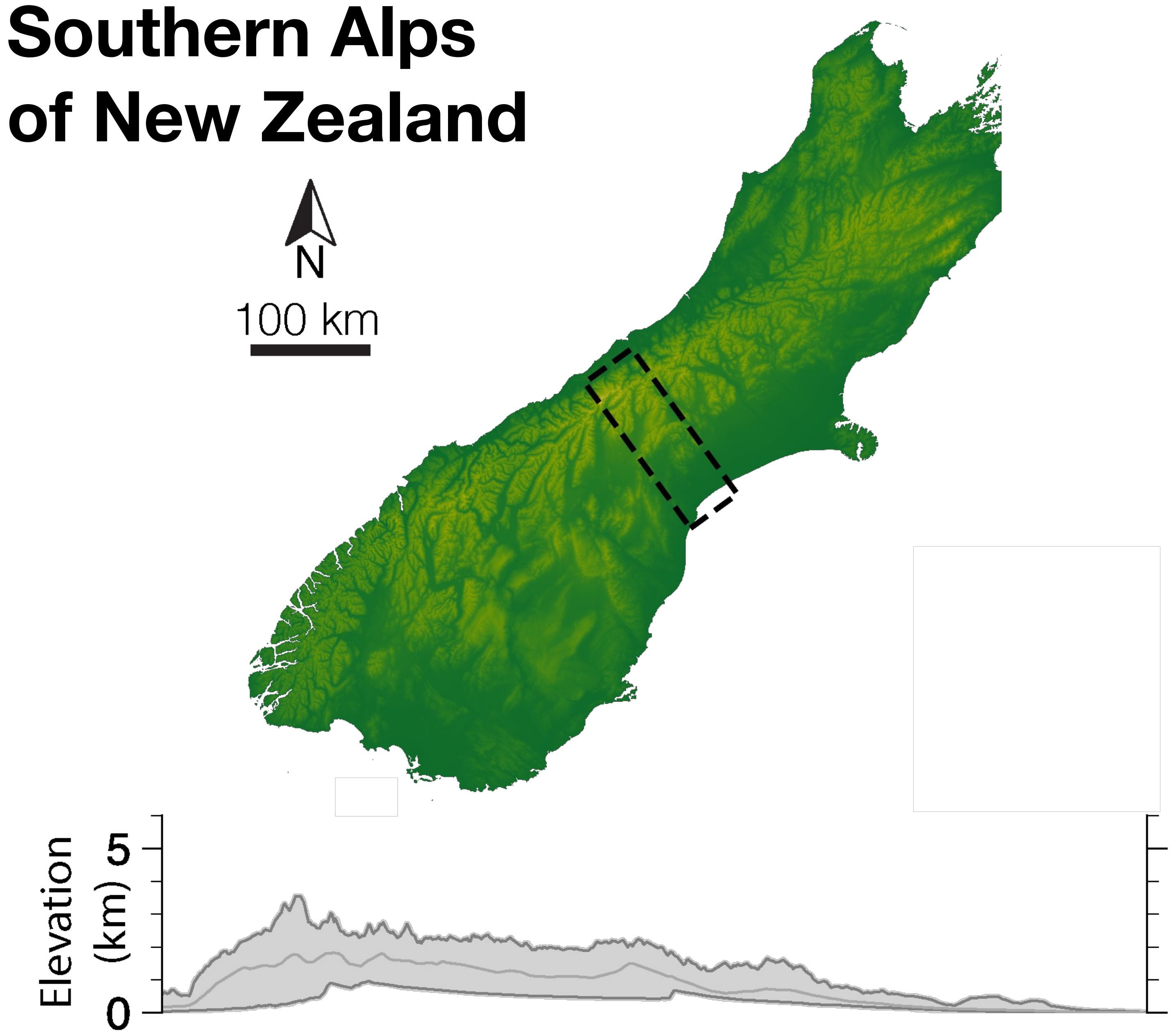

LINK

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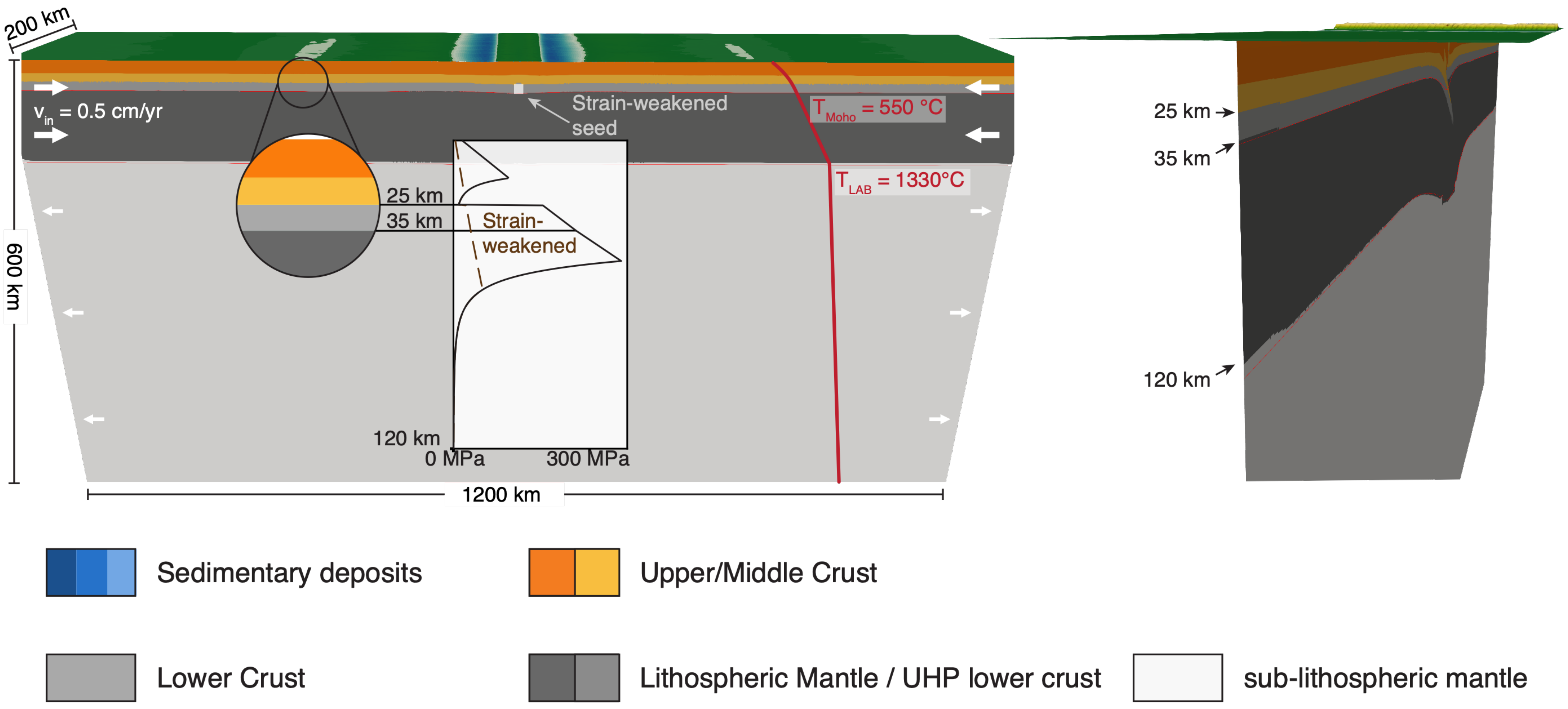
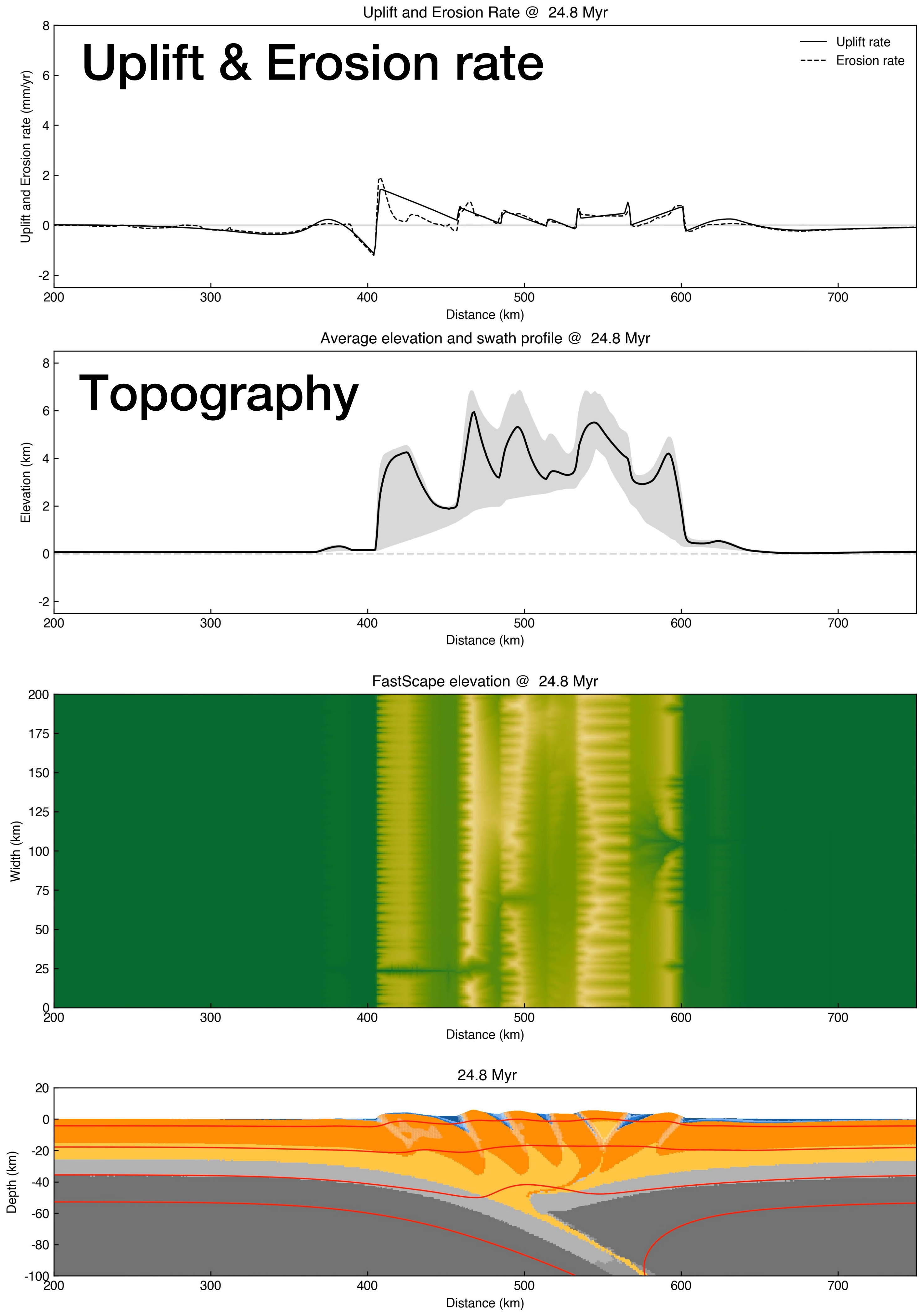
Thermo-mechanical-landscape-evolution model



Physics based forward models:

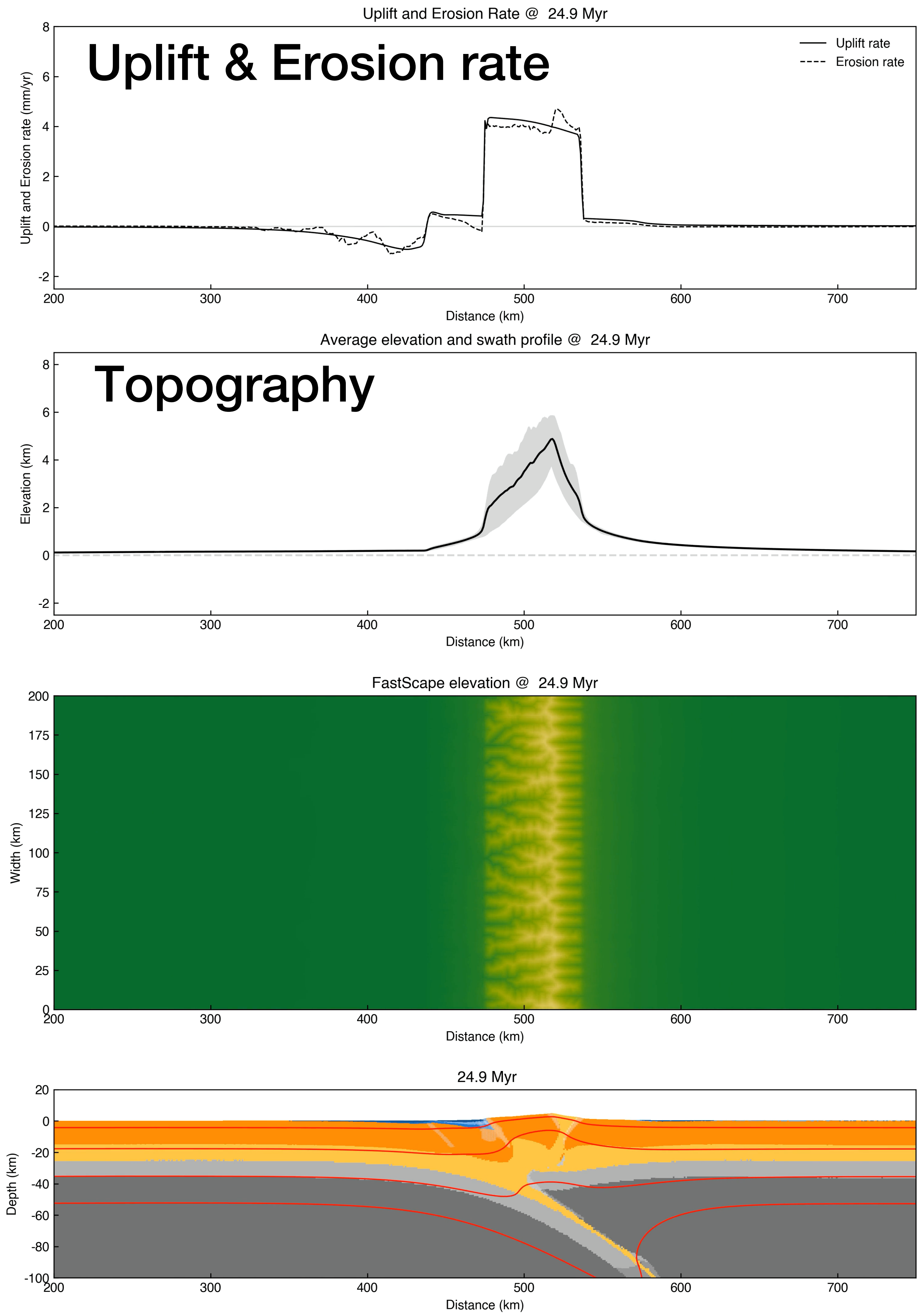
- 2D thermo-mechanically coupled tectonic model (FANTOM, Thieulot 2011, Wolf et al. 2021)
- 2D surface process model (FastScape, Braun and Willett 2013, Yuan et al. 2019)
- Both models are tightly coupled in T-coupling manner
- Simple setup with crustal thickening and one-sided subduction of lithospheric mantle

Type 1: Low surface process efficiency



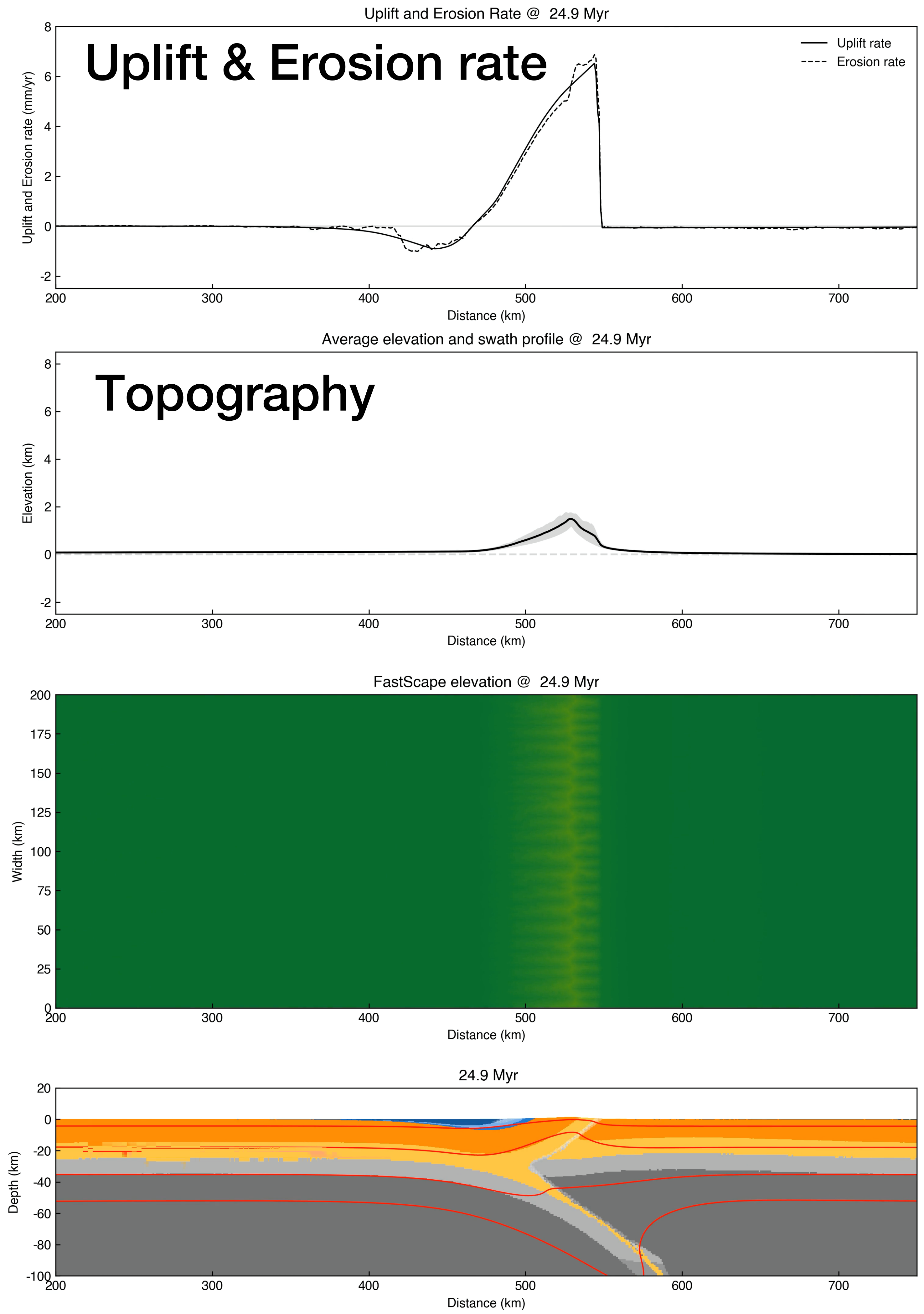
- Growth in height followed by constant widening.

Type 2: High surface process efficiency



- Growth in height, then width, followed by steady state with bivergent thrusting.

Type 3: Very High efficiency



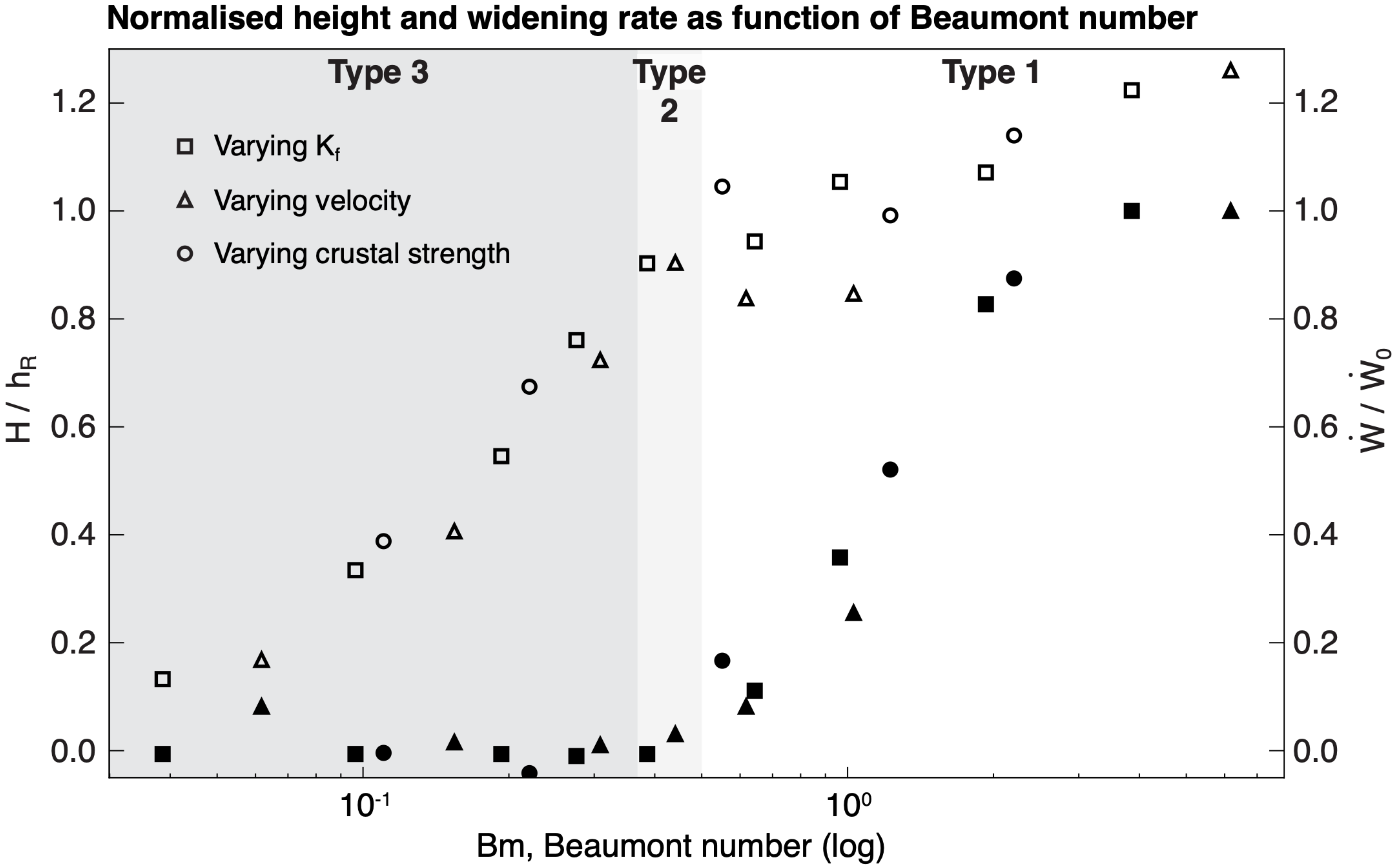
- Growth in height limited by erosion; thrusting on single retro-shear zone.

We define a new non-dimensional number, the Beaumont number that relates tectonics and surface processes.

$$Bm = \frac{Ar}{N_e} \propto \frac{v_c}{F_{int} K_f}$$

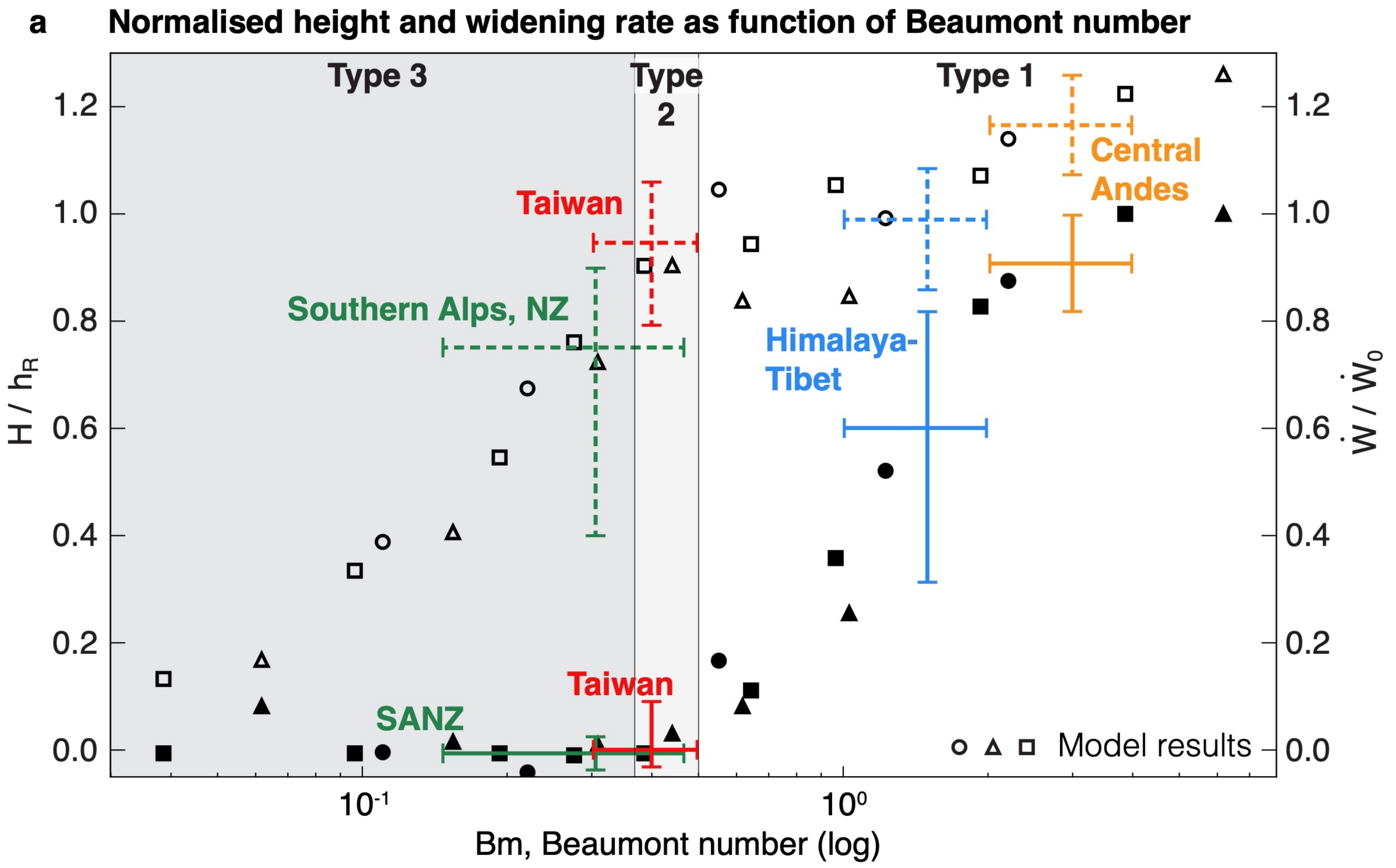
$$Ar = \frac{\rho_c \rho' g h_{dec}^2}{F_{int}}$$

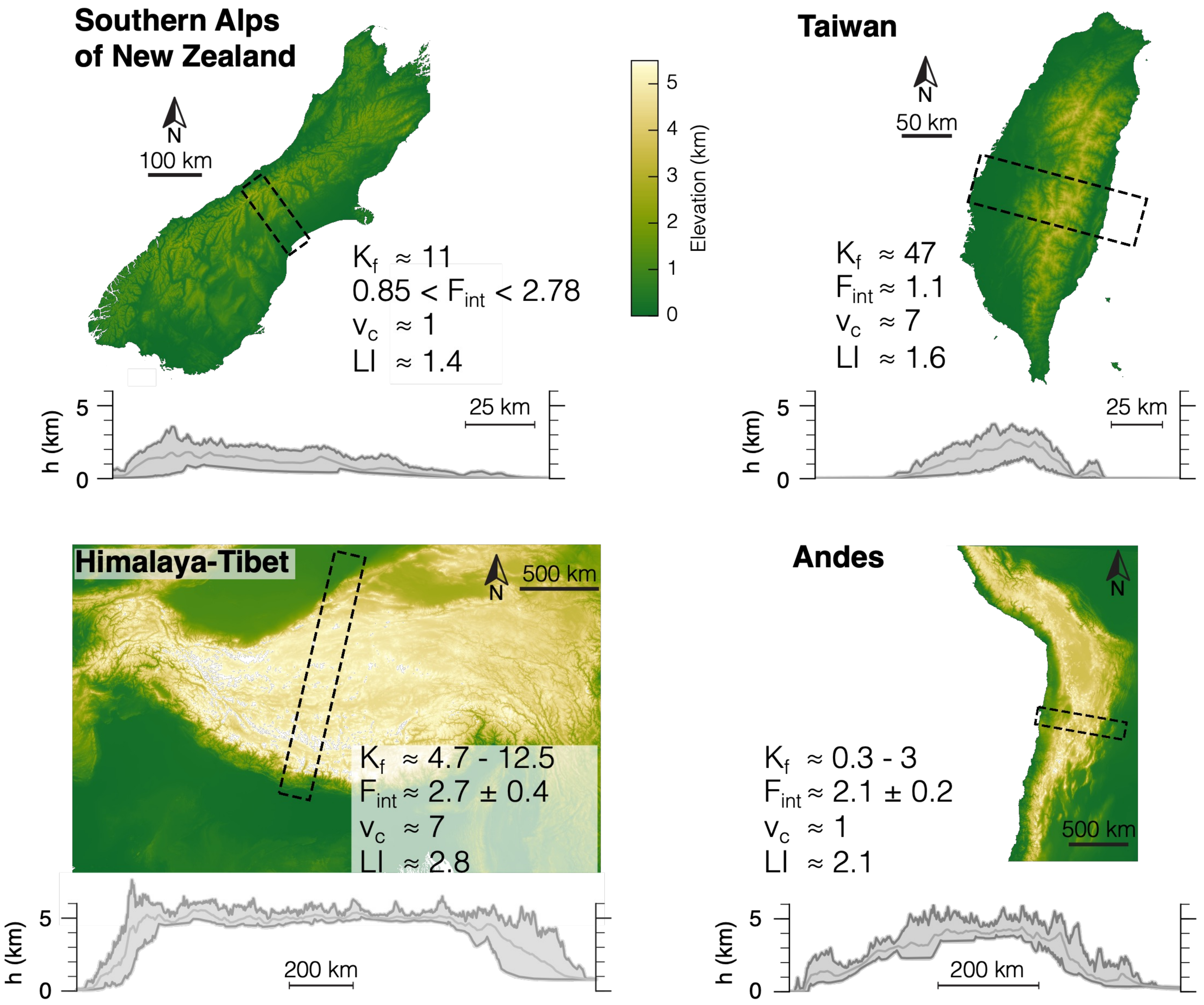
$$N_E = \frac{K_f L^{-0.2} H}{U}$$



- Bm uniquely characterizes mountain belt type and relative importance of tectonics and surface processes
- Bm allows computing crustal strength (F_{int}) and fluvial erodibility (K_f)

The Beaumont number of models and orogens



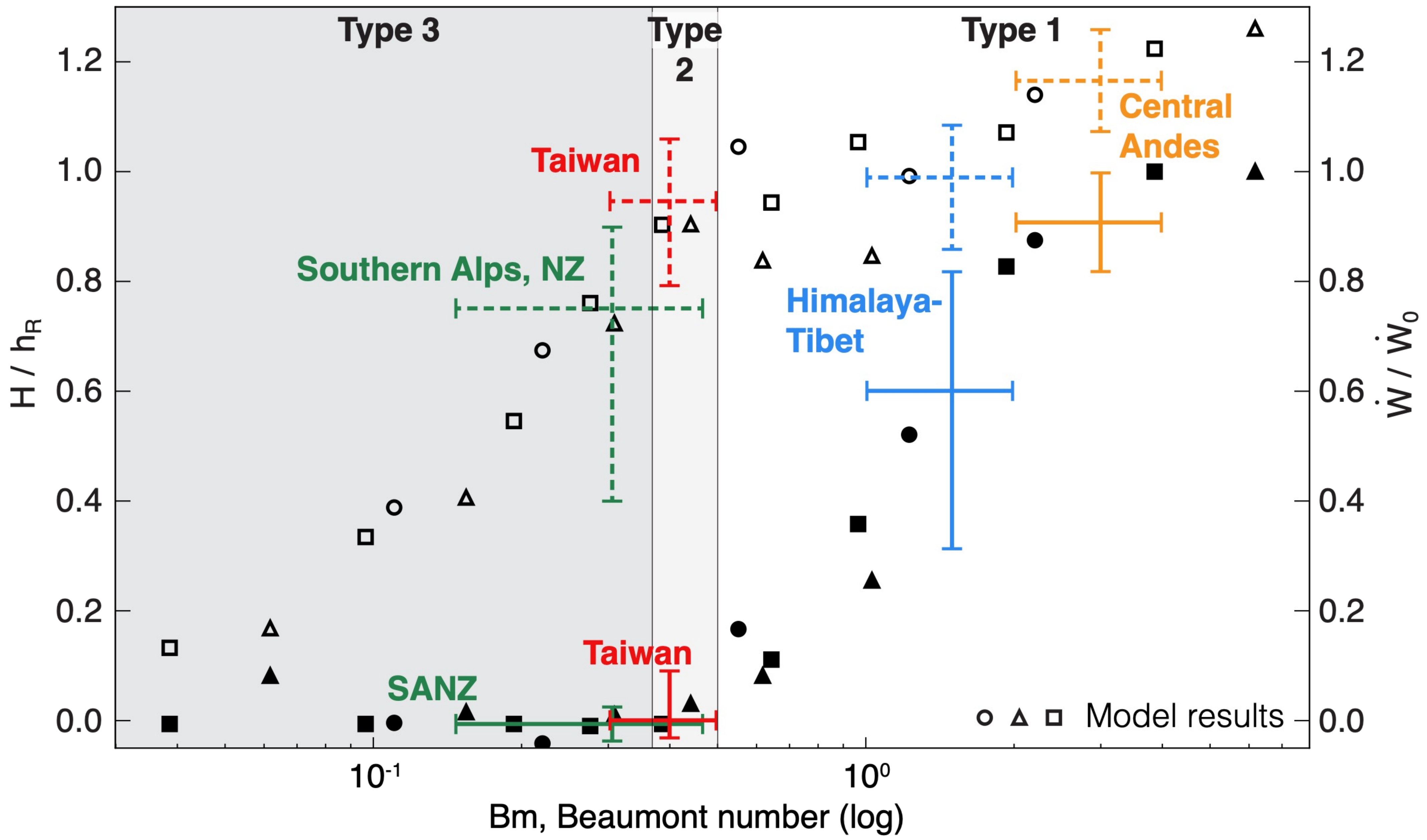


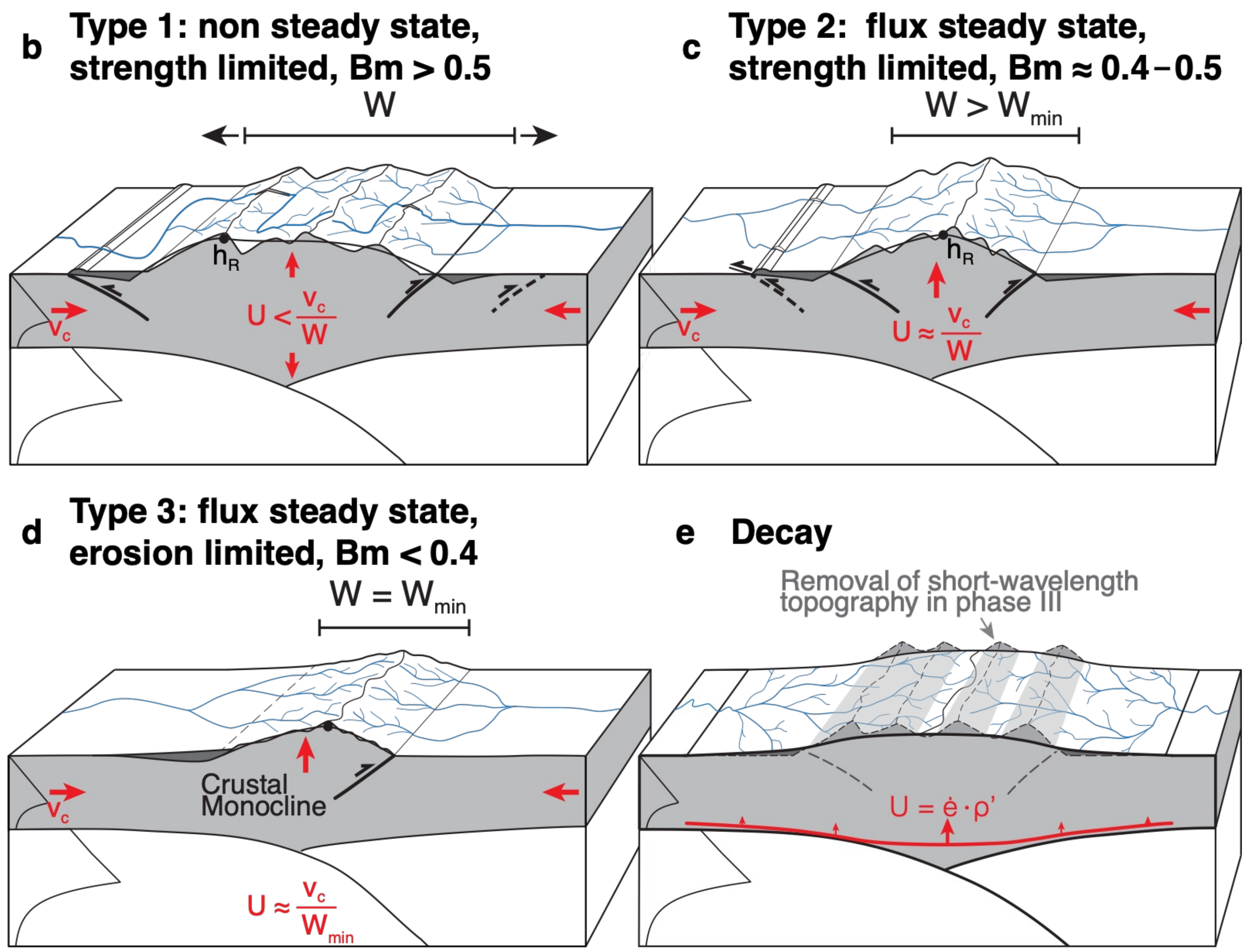
- Type 1: Himalaya-Tibet and Central Andes
- Type 2: Taiwan
- Type 3: Southern Alps of New Zealand.

- Crustal strength varies only by a factor 2-3.

- Convergence rate and fluvial erodibility primarily determine orogen type.

Conclusions





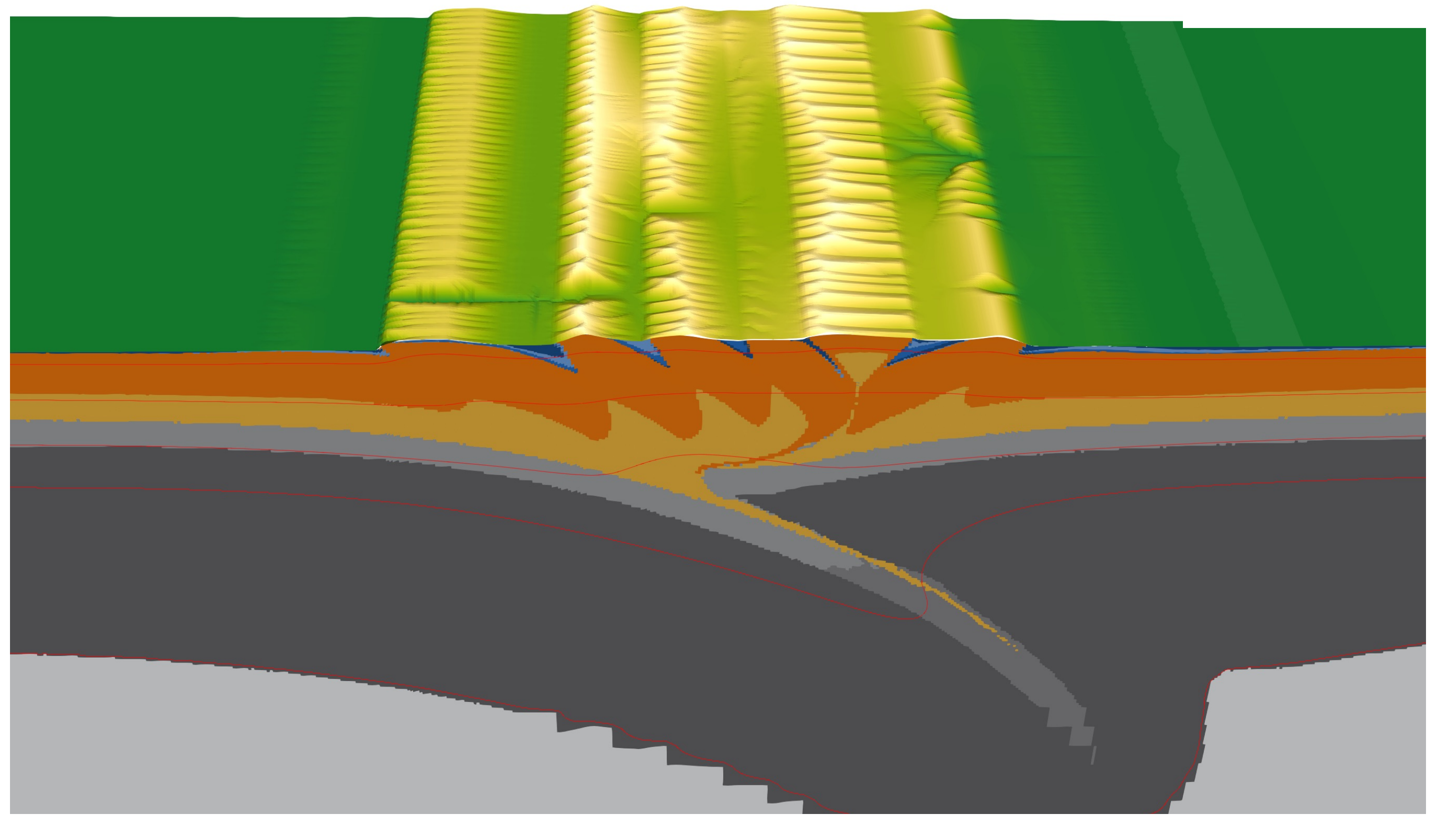
1) We investigate the interplay between surface processes and tectonics during collisional mountain building.

2) We define a new non-dimensional number, the Beaumont number, Bm, that quantifies the interaction between surface processes and tectonics.

3) Bm allows estimation of crustal strength and fluvial erodibility.

4) Based on Bm and model results, we define three types of mountain belts.

5) We classify 4 different orogens, find their controlling factors, and their crustal strength and fluvial erodibility



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