The fate of orogens –

How do exhumation processes scale across time?

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thanks to Kalin McDannell

The road to flat

Thermochron perspective:

- Processes
- Rates

This is not an apatite grain

Working across time scales: technical considerations

Diffusion is a blunt tool

Time masks interesting features

Uncertainties mask signal

Our tools have chunky ranges that alias signals

apatite U-He ages of 5 and 50 Ma do <u>not</u> tell you the same thing

Working across time scales: technical considerations

Dachsund of Time, courtesy of Bike Snob NYC

Sampling, 1/t, and things like the Sadler effect...

Thermochron perspective:

- Processes
- Rates

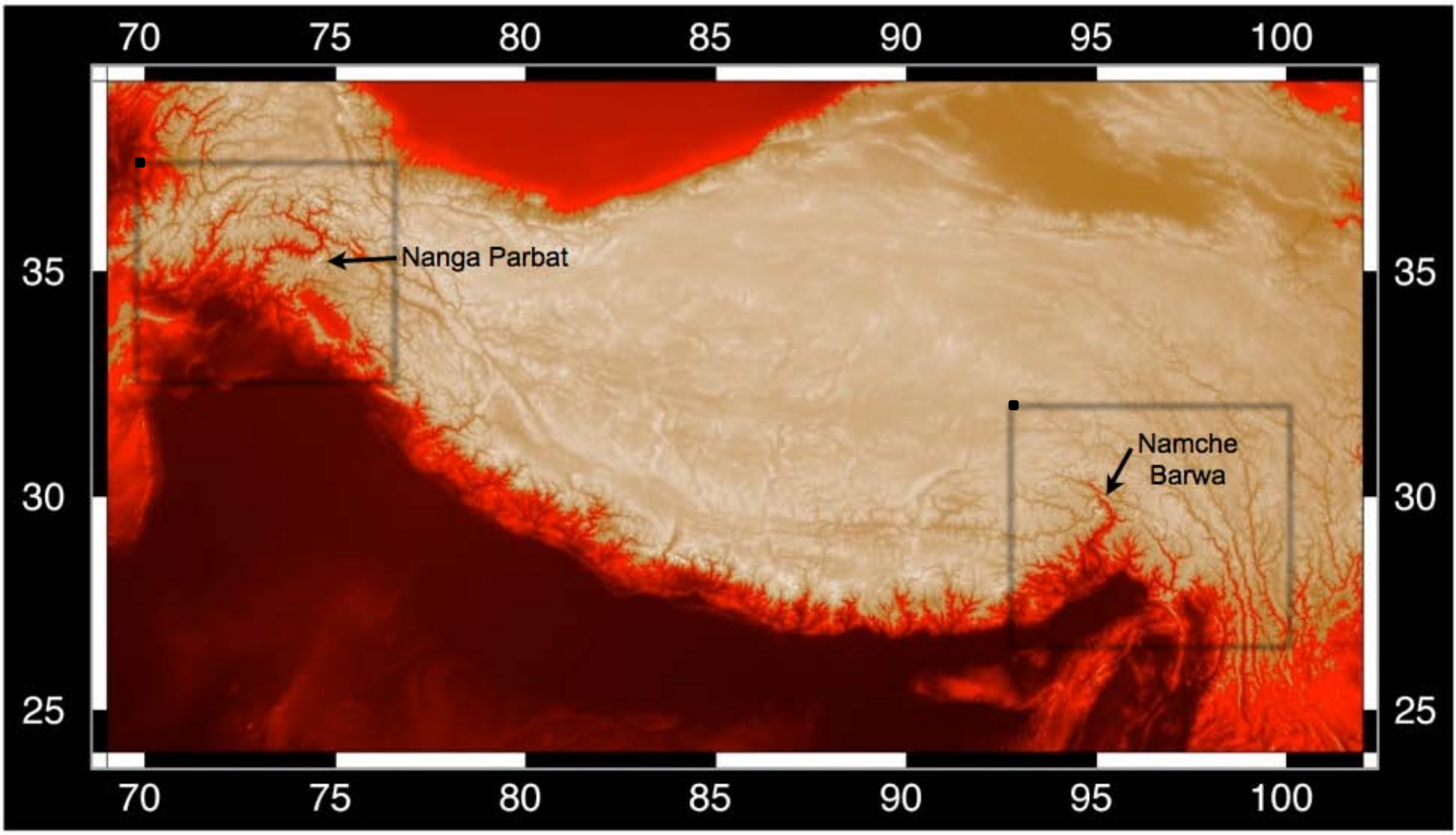
Thermochron perspective:

- Processes
- Rates

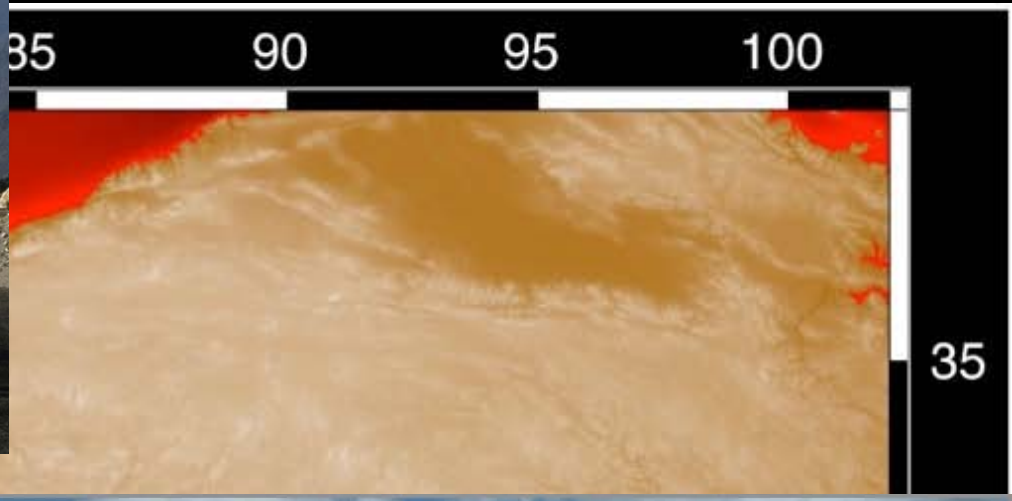
Thermochron perspective:

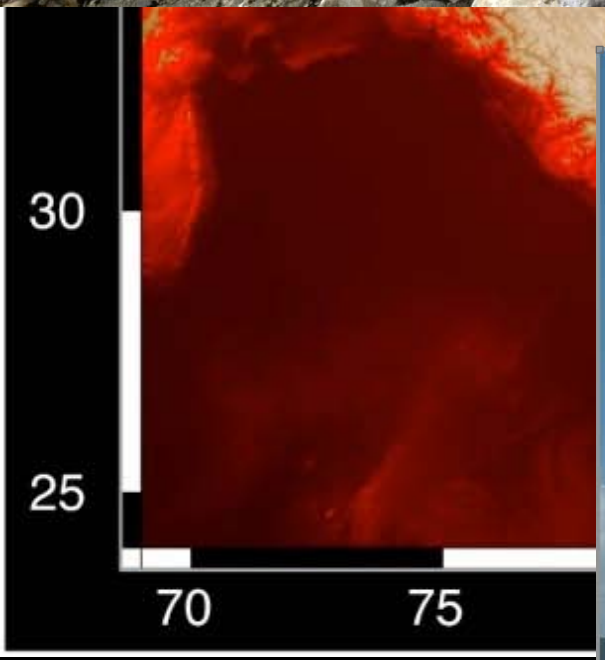
- Processes
- Rates

Active system

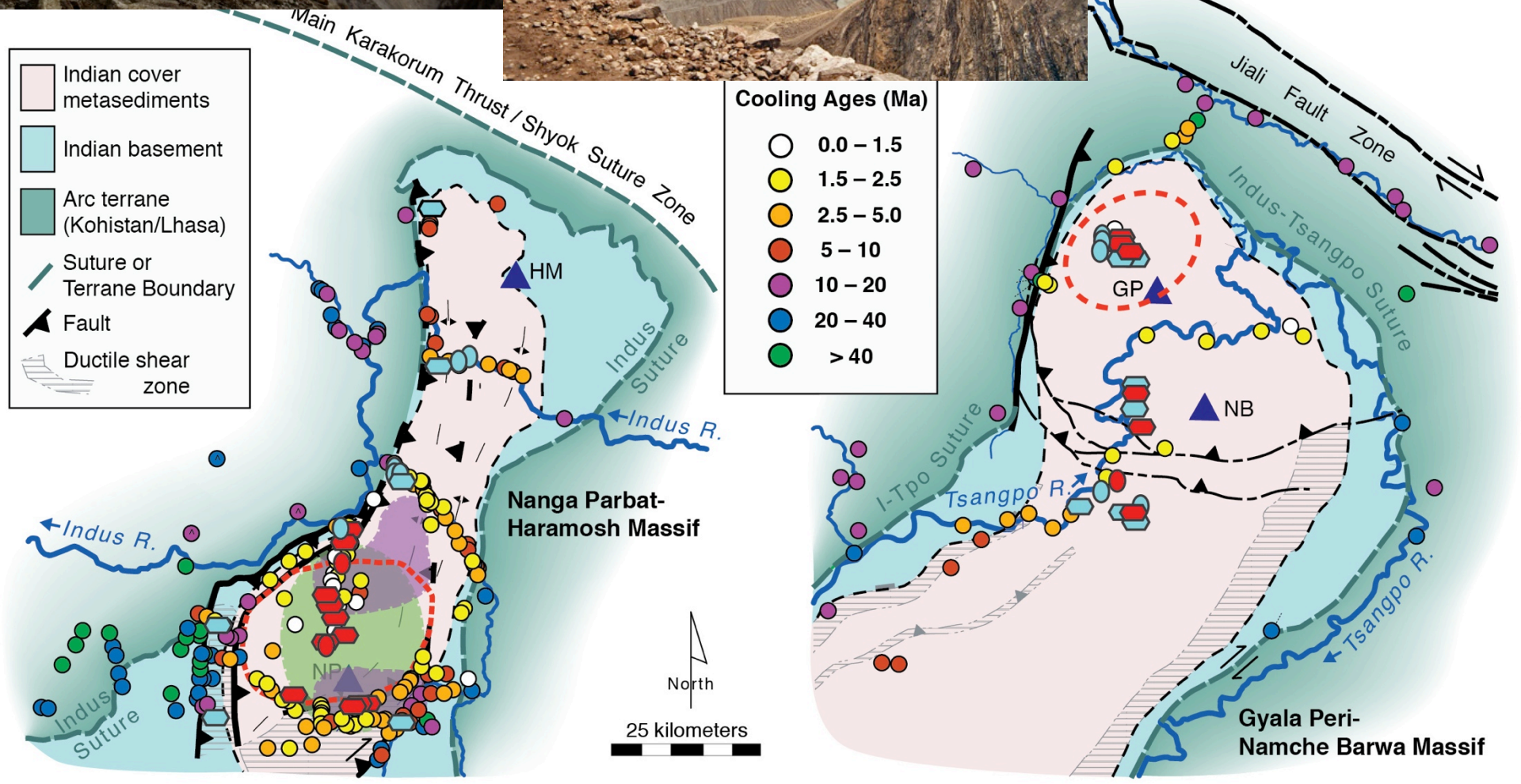


Active system

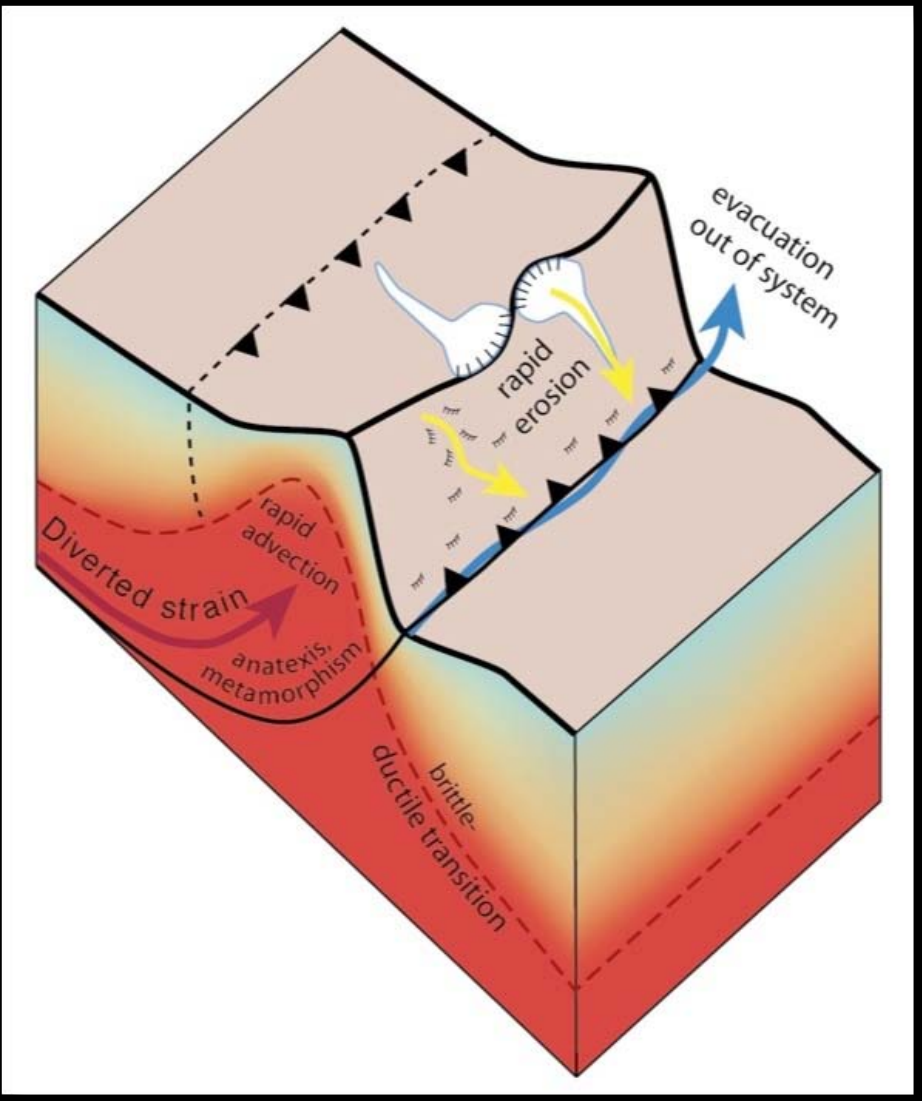


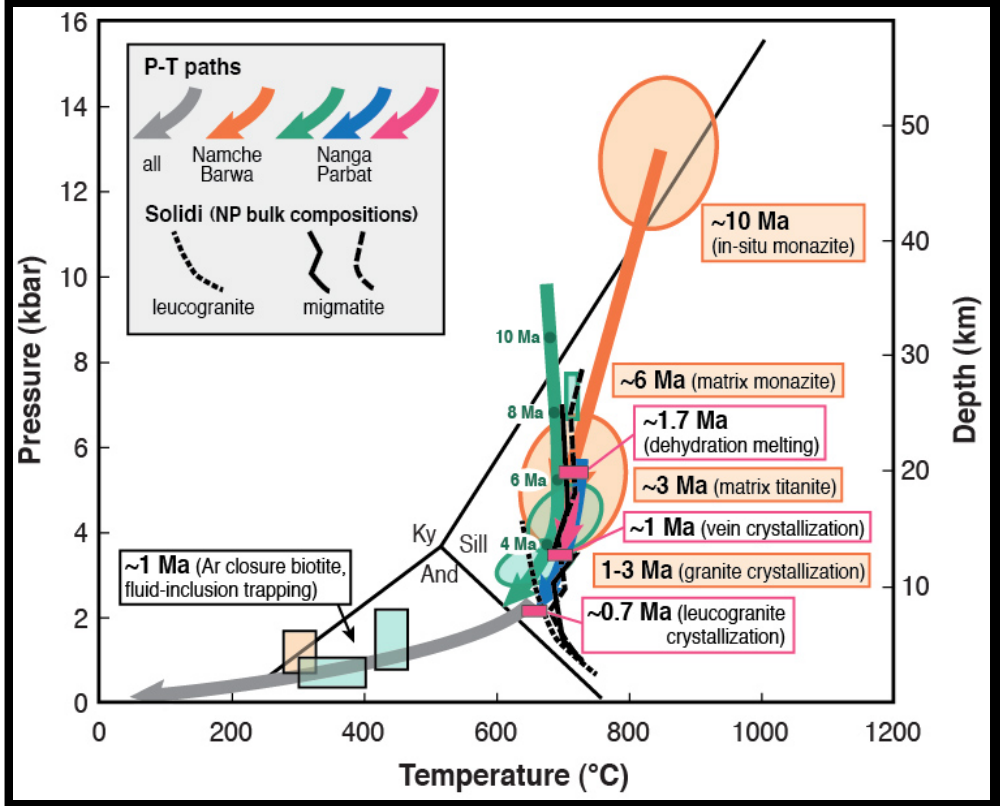


Syntaxial metamorphic massifs

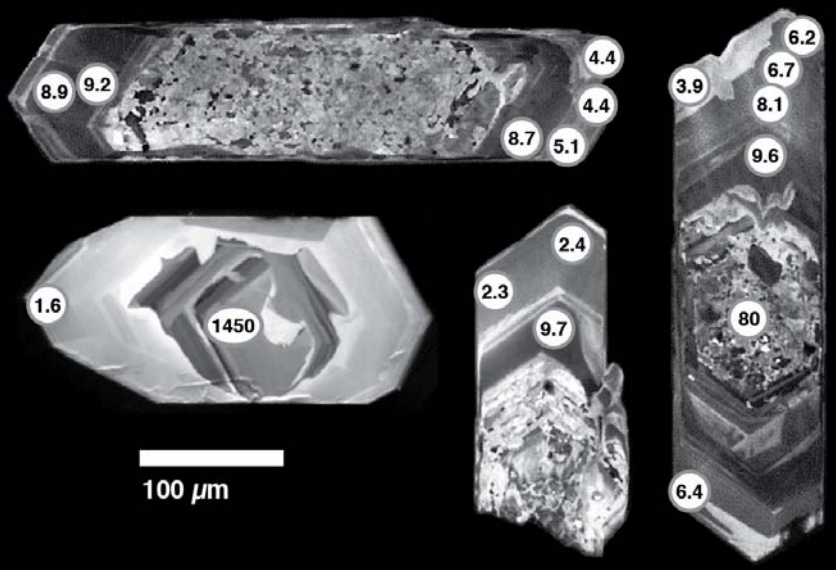


Tectonic aneurysm*

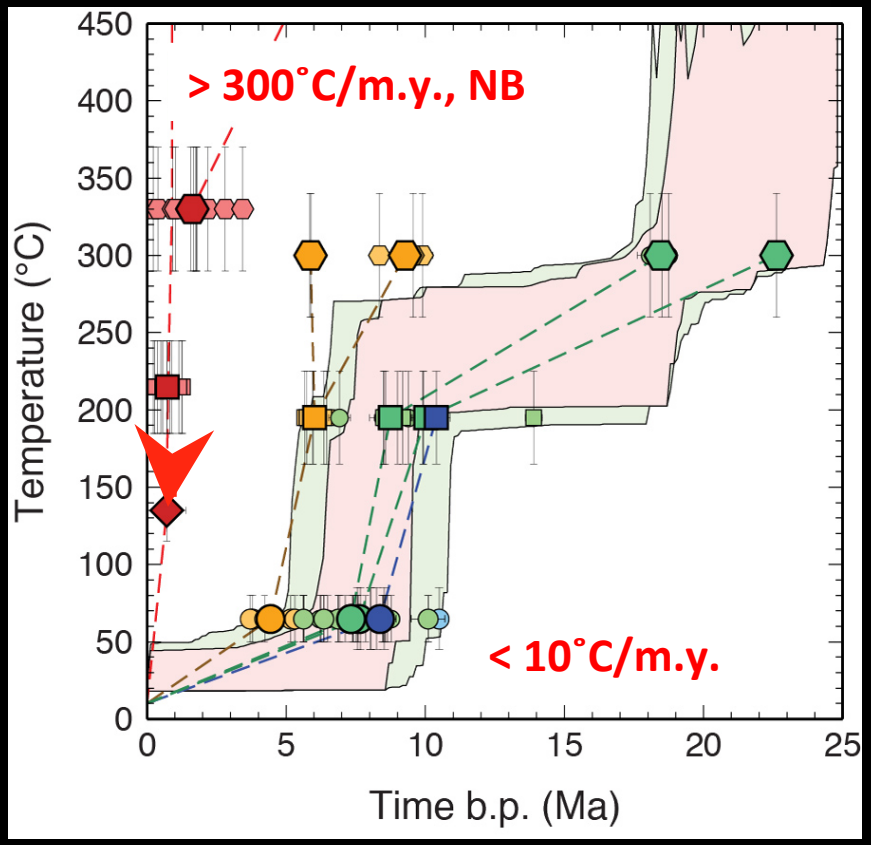


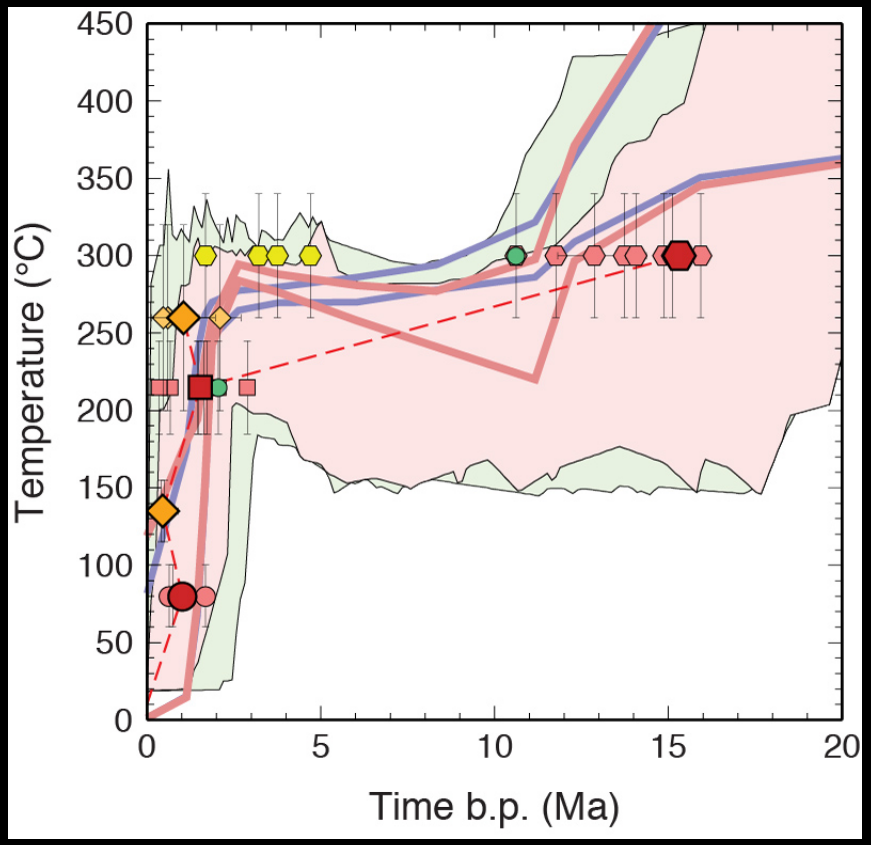


* feedbacks through erosional-kinematic-rheological coupling

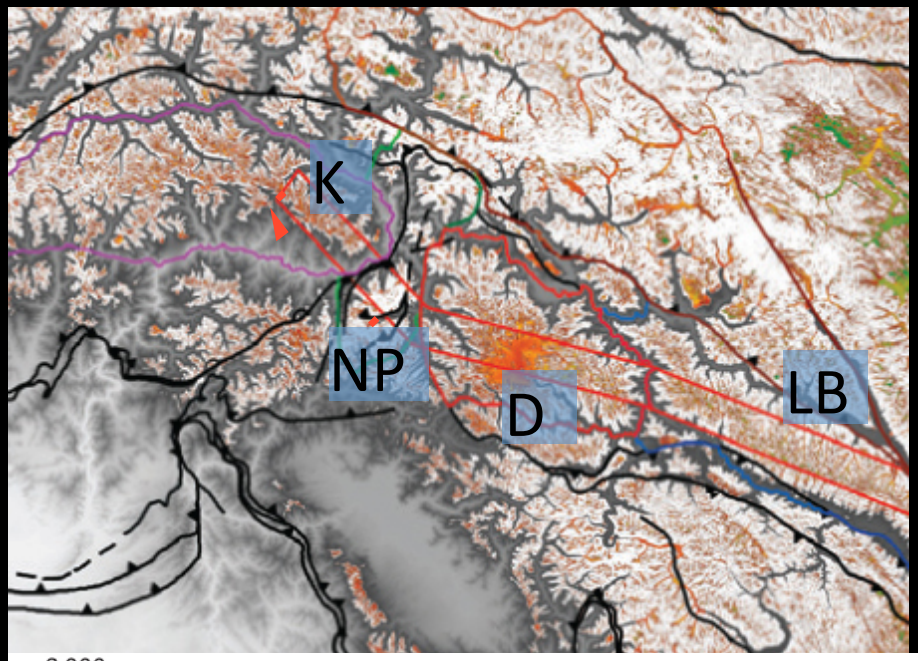


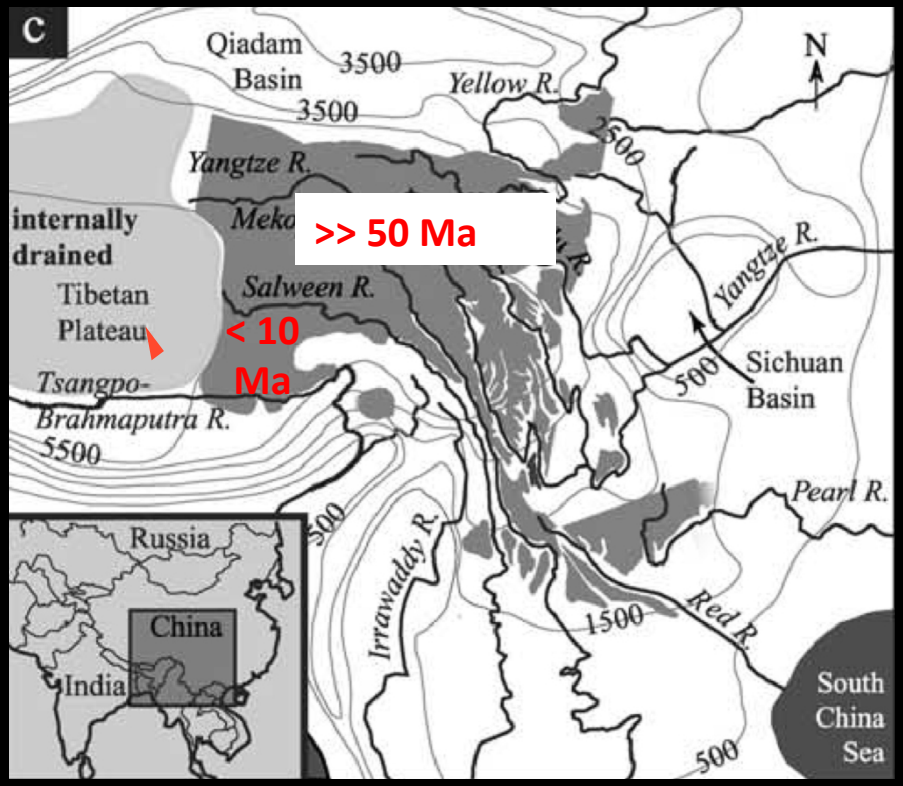
Rates and tempo



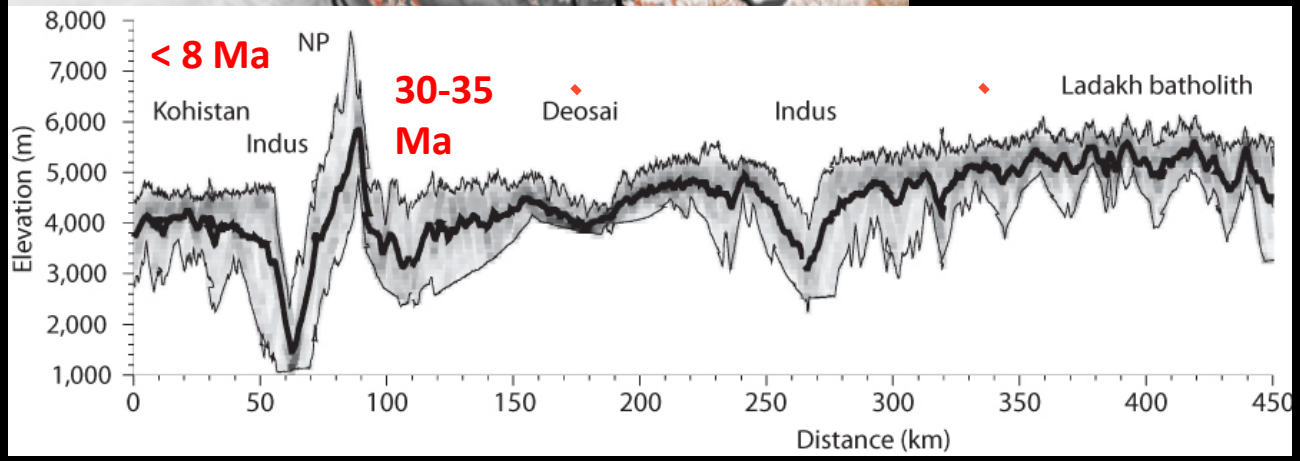


Low-relief landscapes are common in and near Tibet…



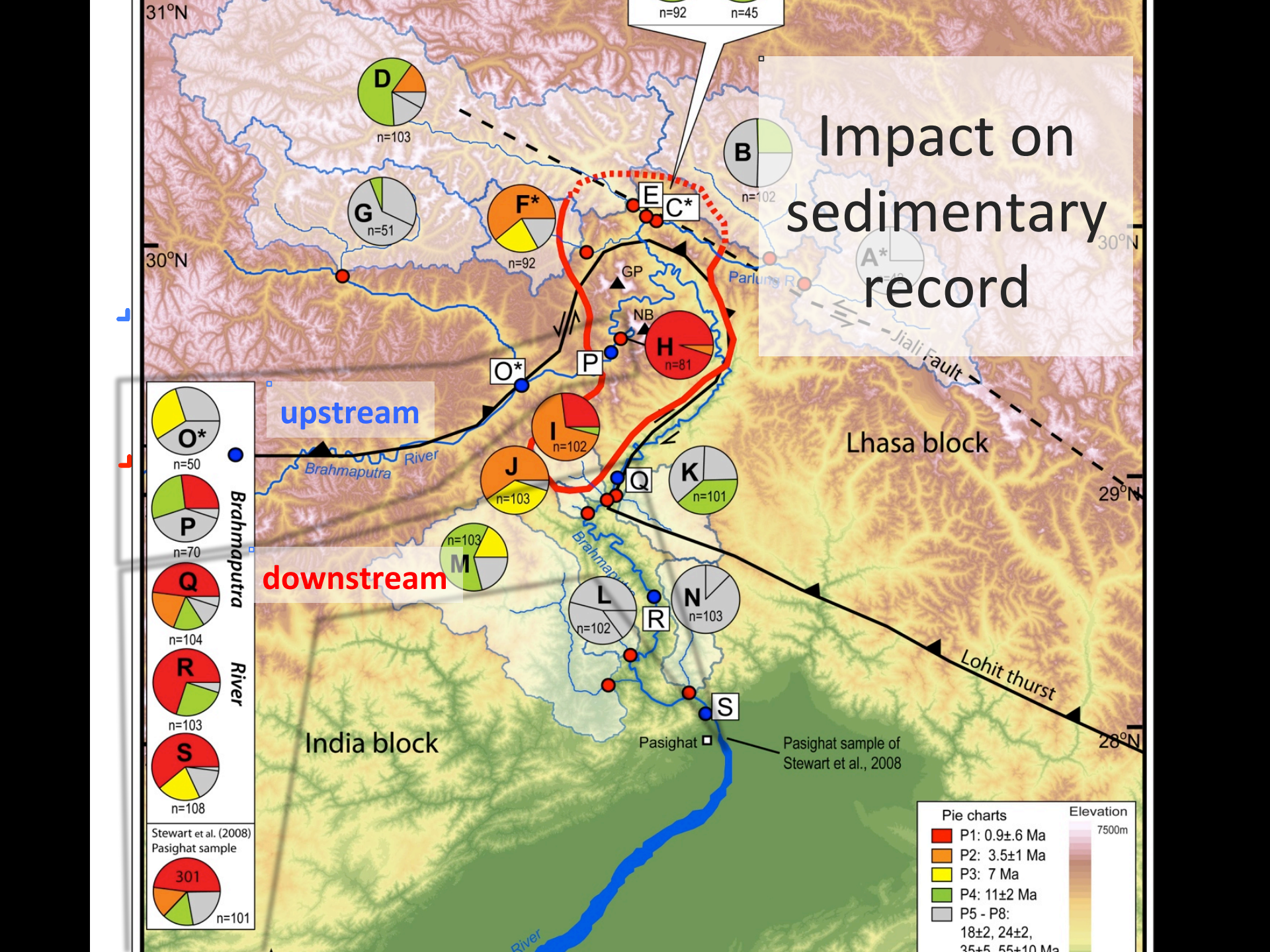


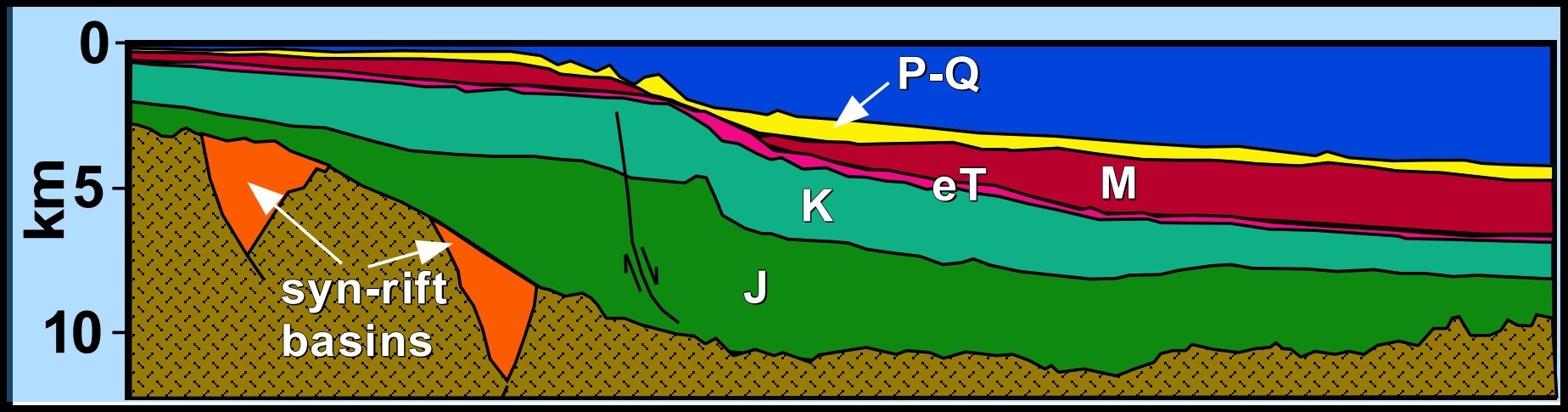
Clark et al. (2004), Tectonics 23: TC1006

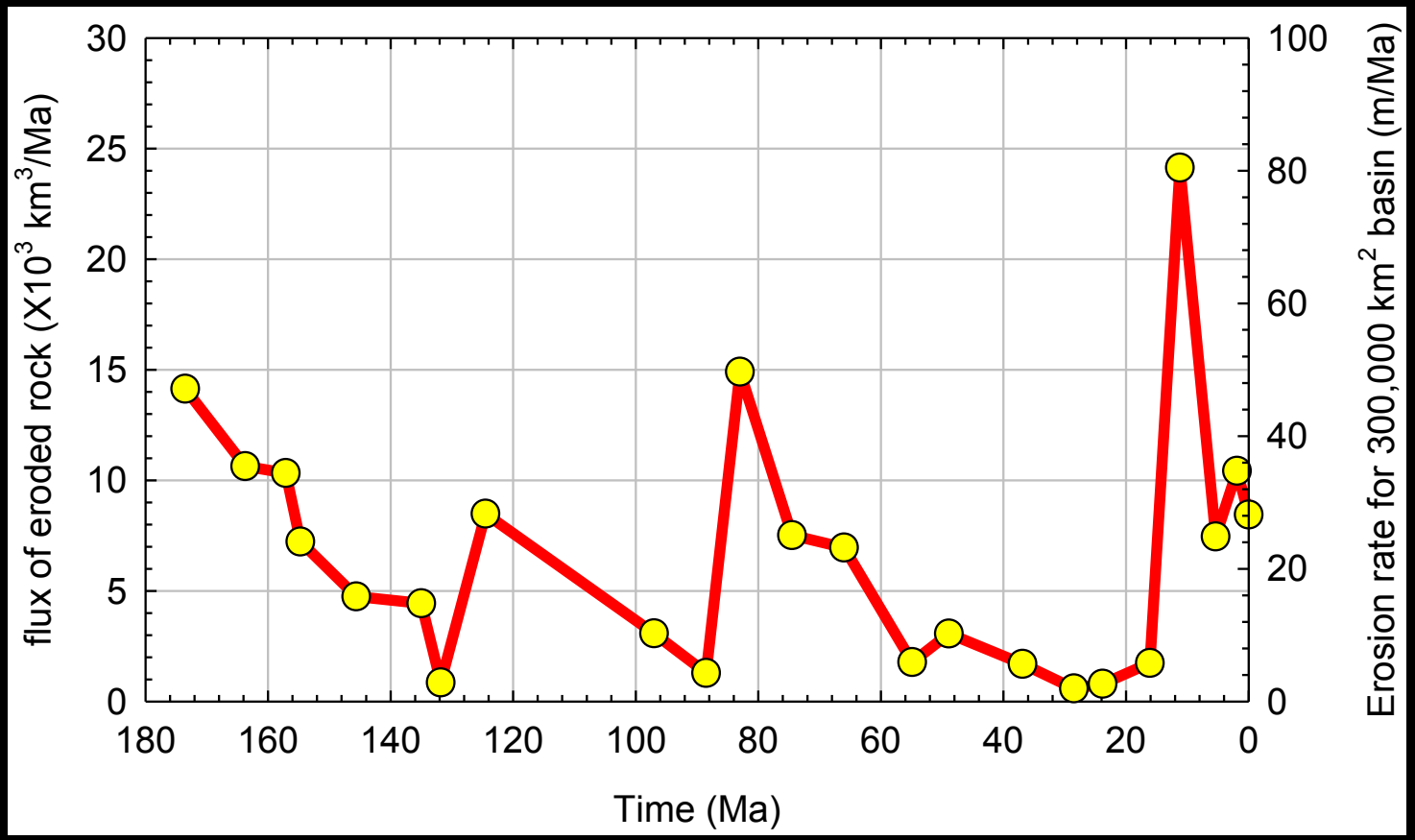


van der Beek et al. (2009), Nature Geoscience 2: 364

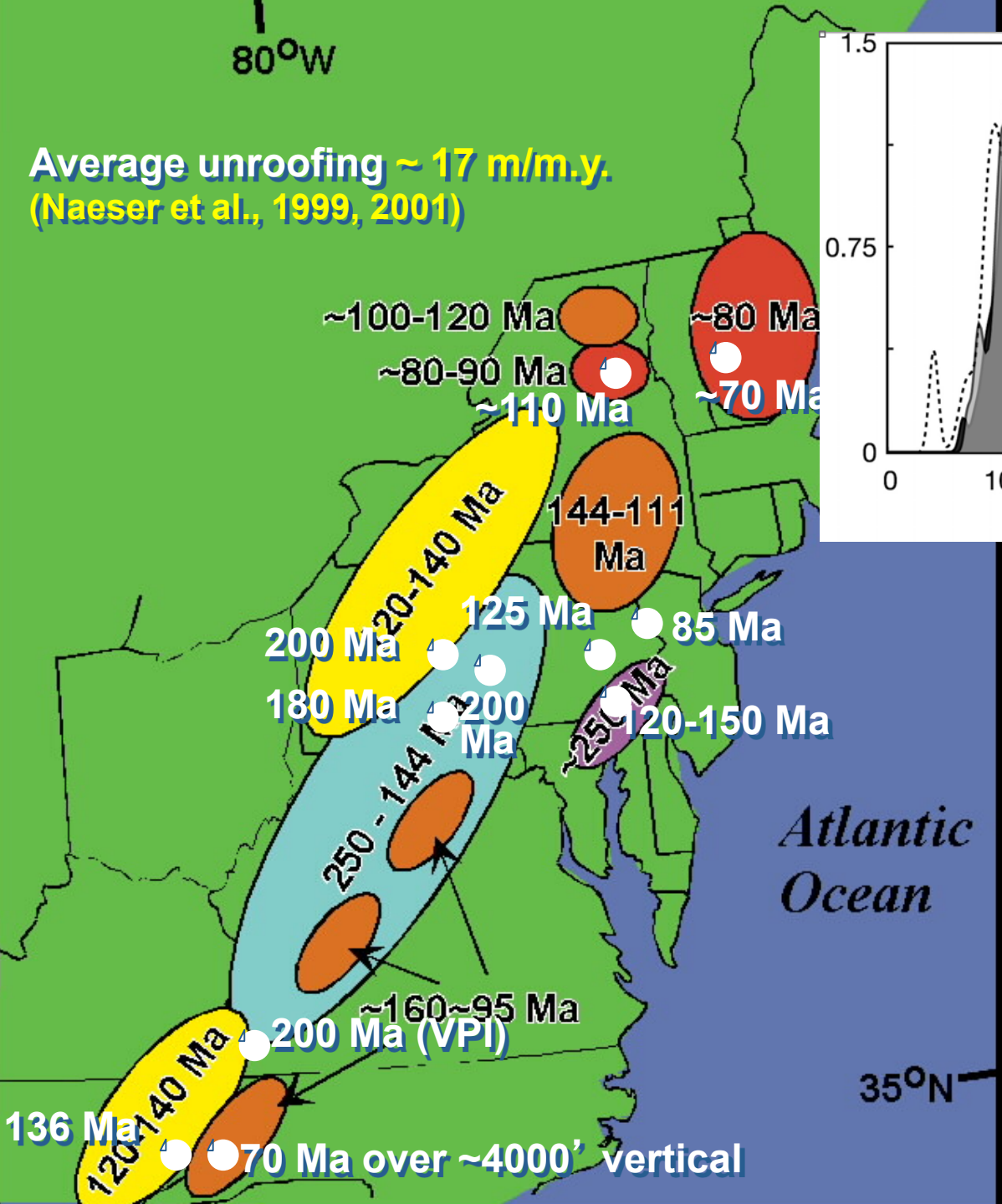
…but many are **NOT** old and they have <u>different</u> ages

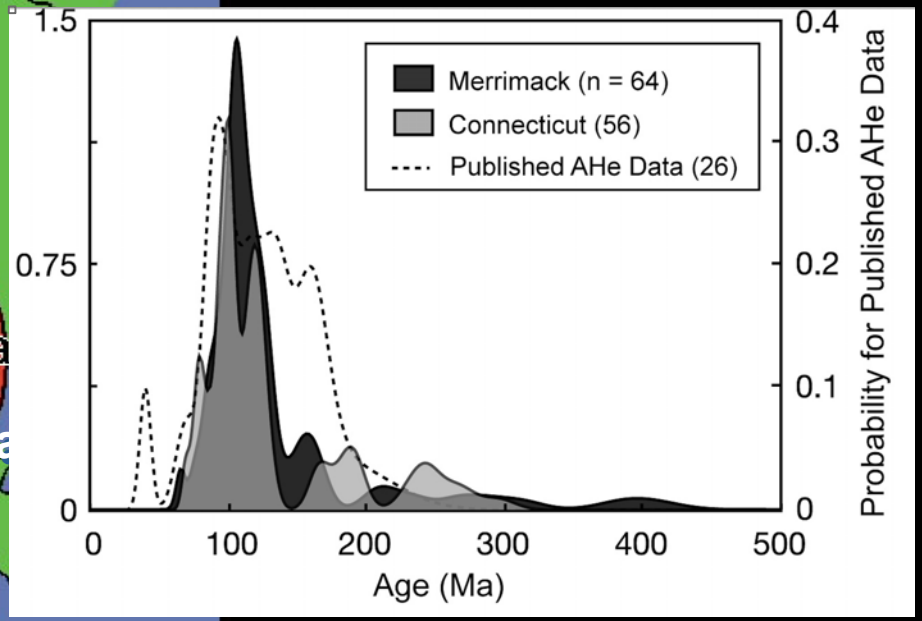

Impact on sedimentary record
upstream
downstream
Brahmaputra River
Lhasa block
India block
Lohit thurst
Jiali Fault
Pasighat
Pasighat sample of Stewart et al., 2008
GP
NB
Pie charts
P1: 0.9±.6 Ma
P2: 3.5±1 Ma
P3: 7 Ma
P4: 11±2 Ma
P5 - P8: 18±2, 24±2,
Elevation
7500m
Stewart et al. (2008) Pasighat sample
31°N
30°N
29°N
28°N





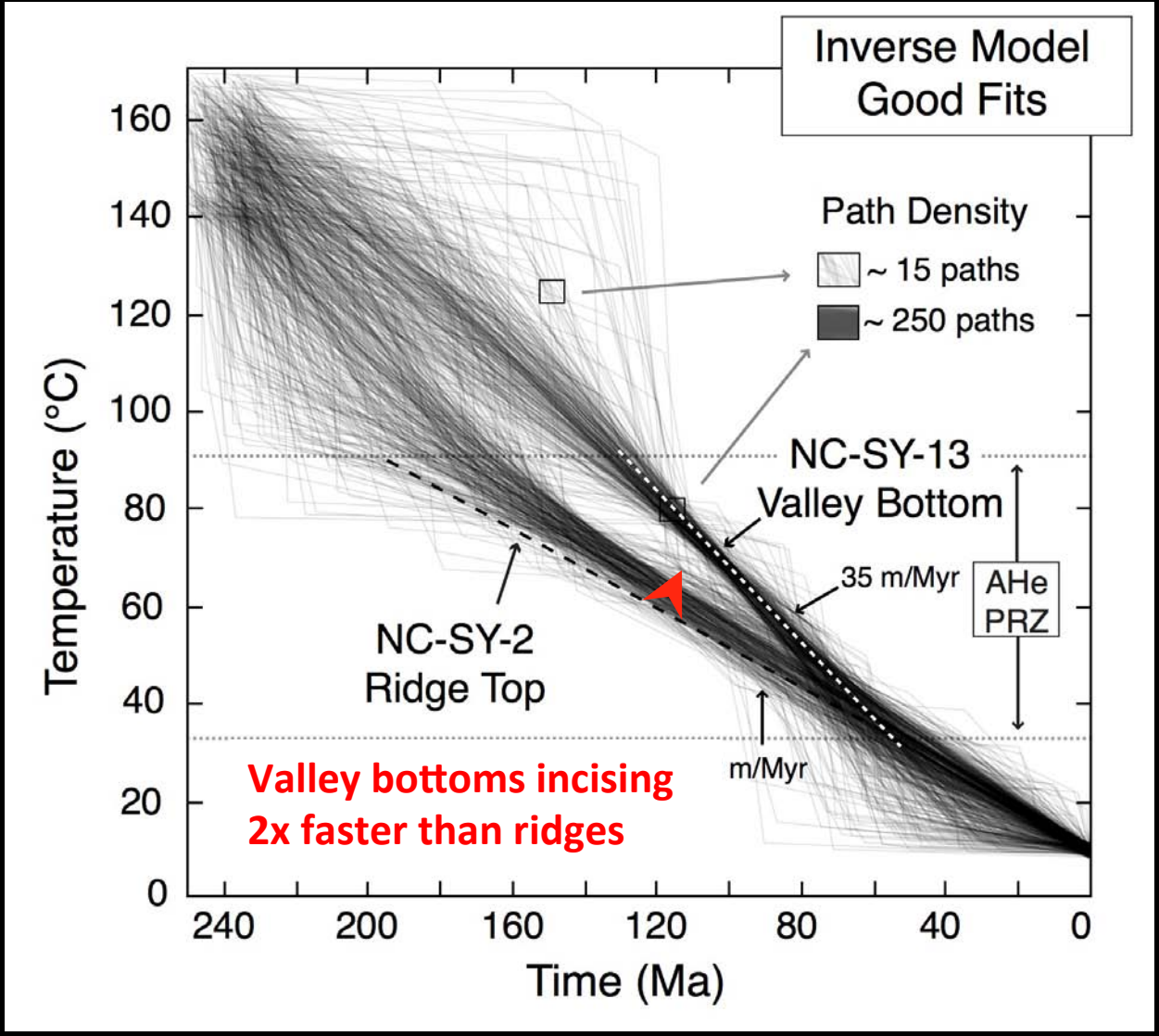
Pazzaglia and Brandon, 1996, Basin Research, 8, 255-278





Appalachian thermochronology

Rates and tempo



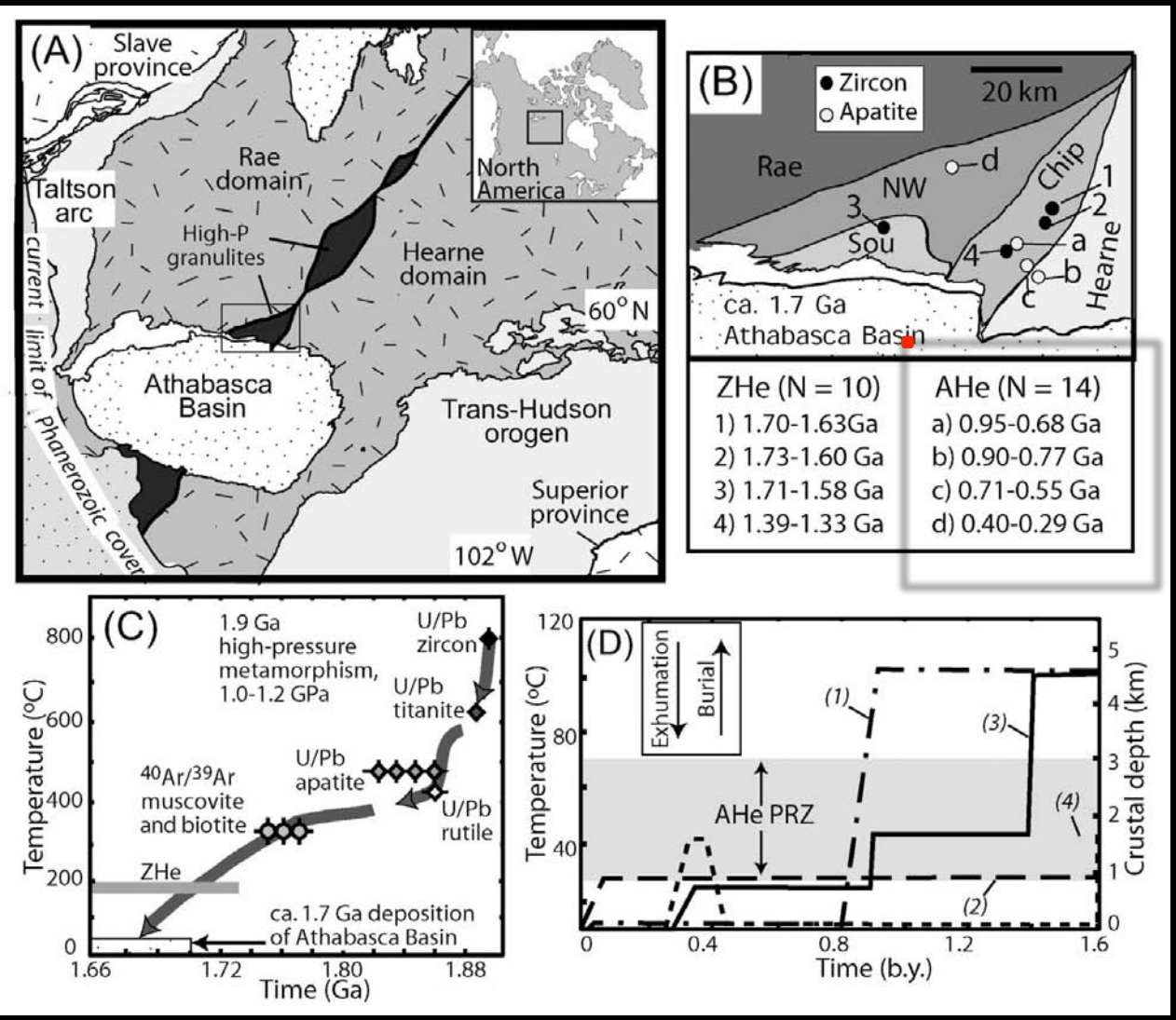
Lots of rates, 10-30 m/m.y. (long term and short term)

But other data suggest unsteady behavior

Not just steady post-orogenic topo decay?

Rifting? Climate and landscape evolution? Deeper mantle? Changes to root?

Cratons



Apatite U-Th/He ages 500 to 900 Ma

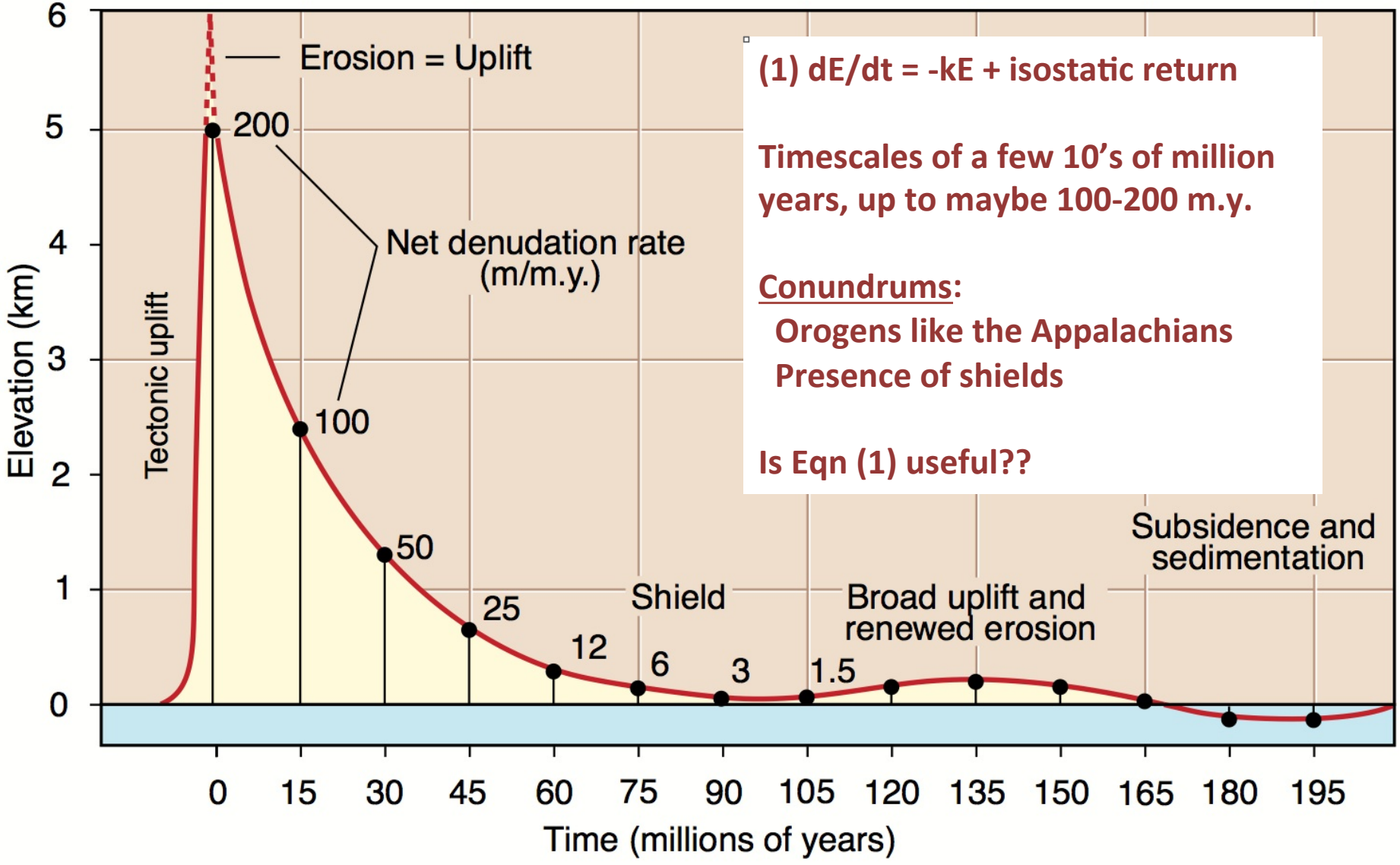
Exciting… stability!

< 50˚C and 2 km burial for past 500 to 1000 m.y.

Ages would not survive greater burial or erosion

Flowers et al., 2006, *Geology,* 34: 925-928

Post-orogenic decay



(1) dE/dt = -kE + isostatic return

Timescales of a few 10's of million years, up to maybe 100-200 m.y.

Conundrums:

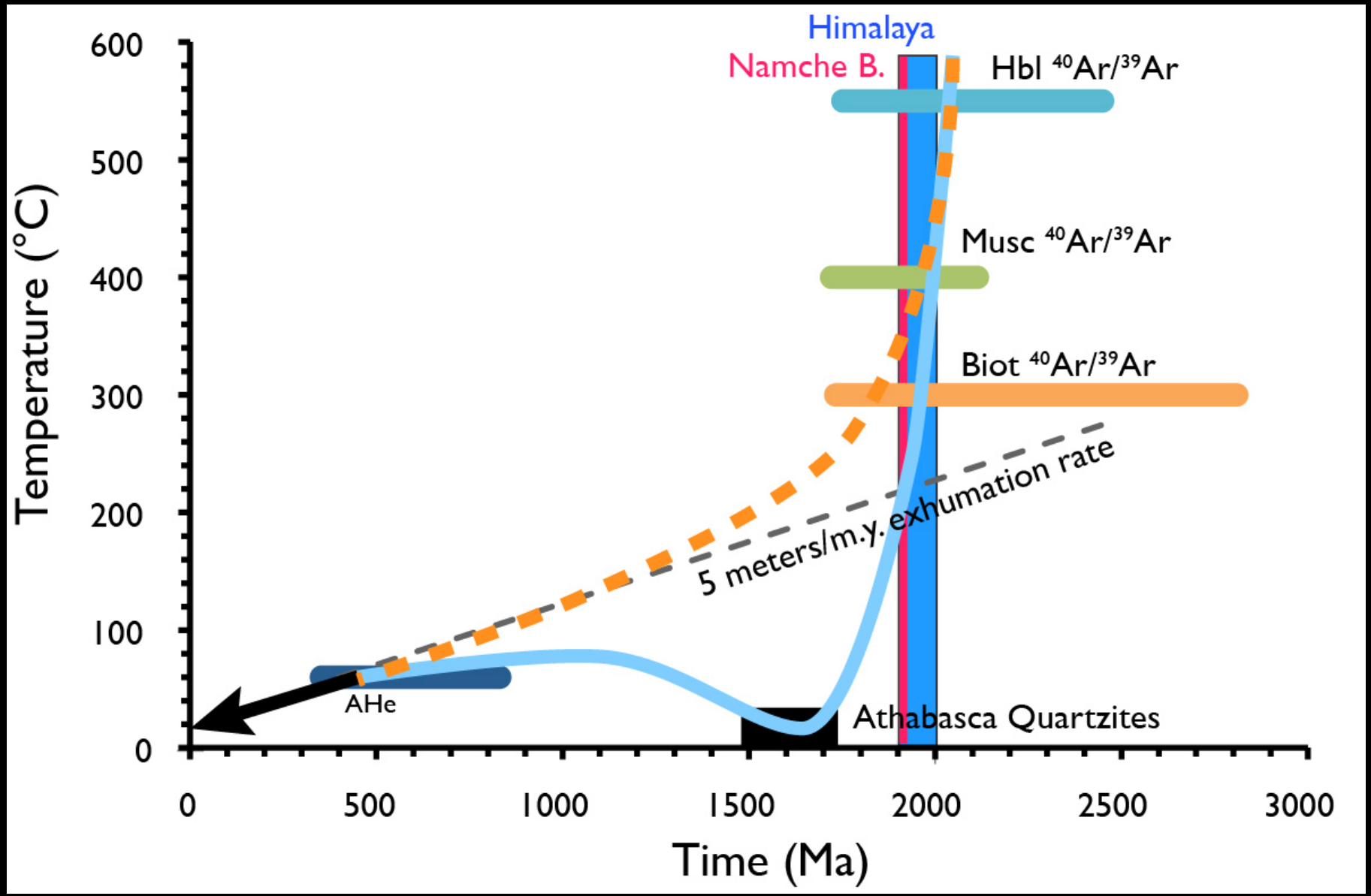
Orogens like the Appalachians

Presence of shields

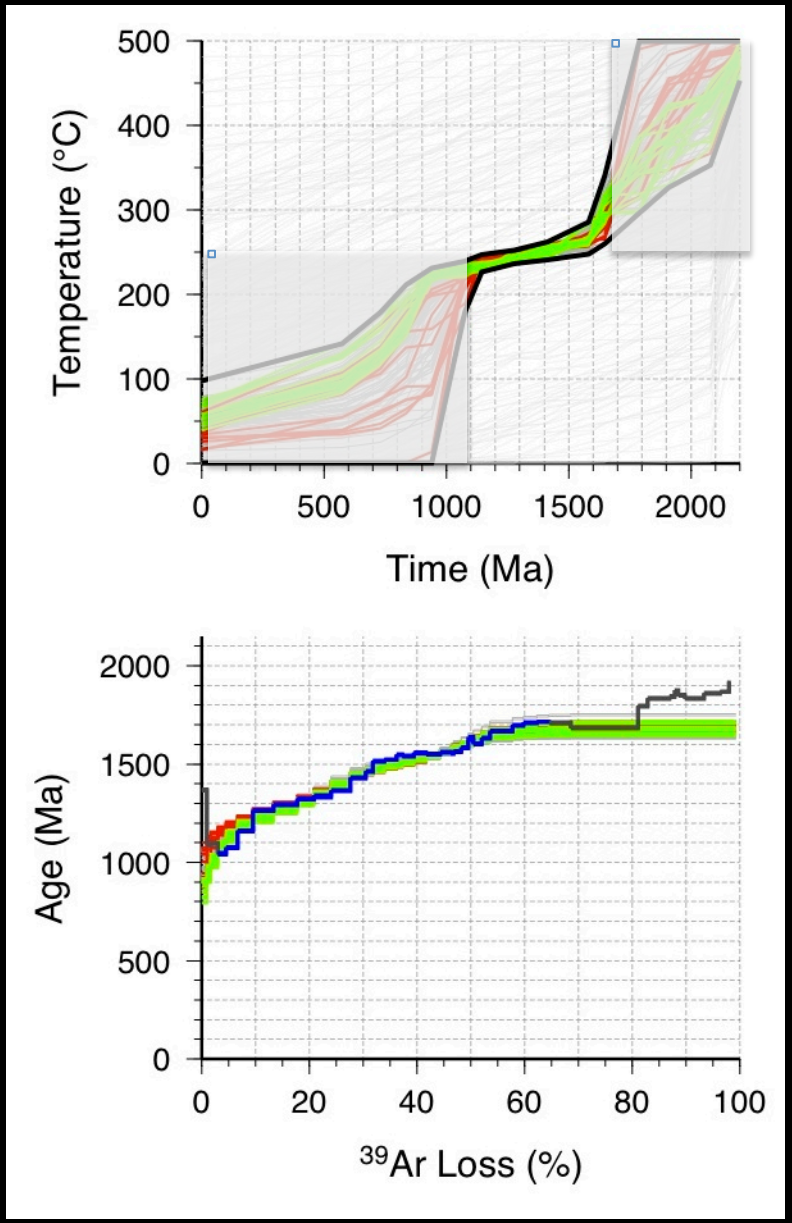
Is Eqn (1) useful??

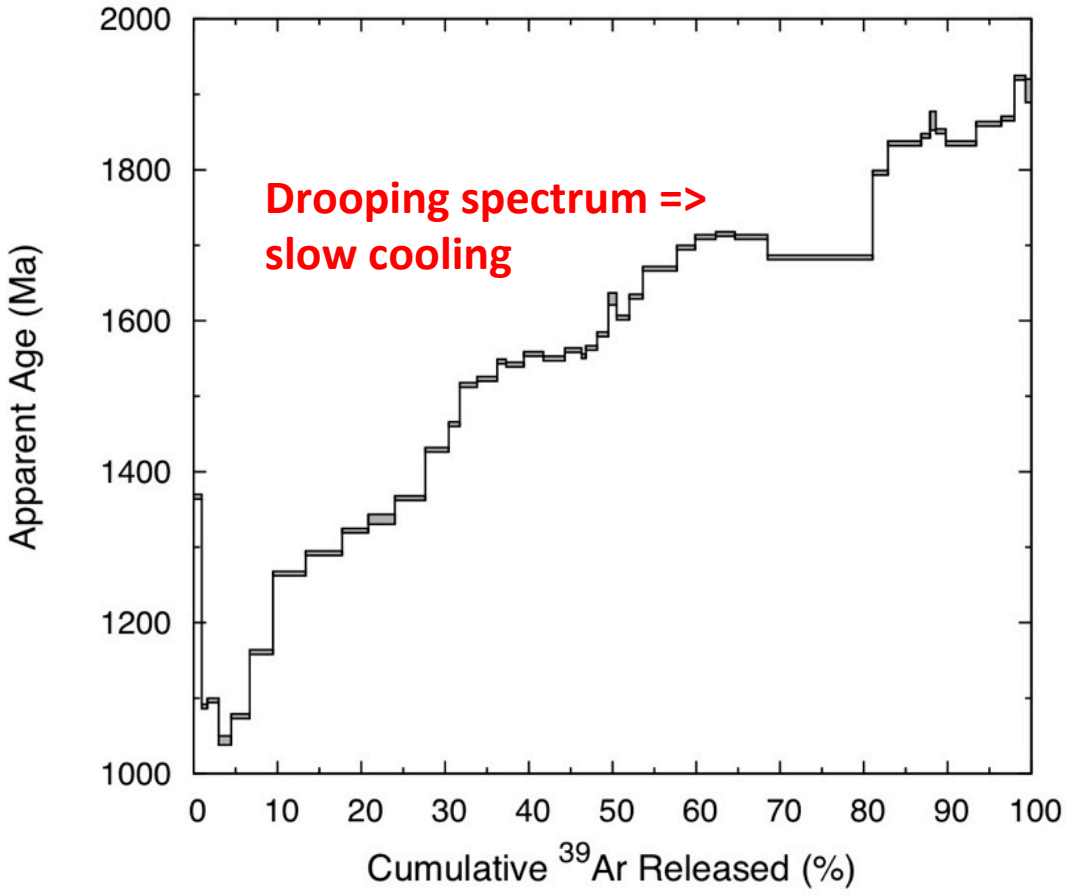
Christiansen and Hamblin, *Earth's Dynamic Systems,* 10th ed.

Long-term post-orogenic stabilization



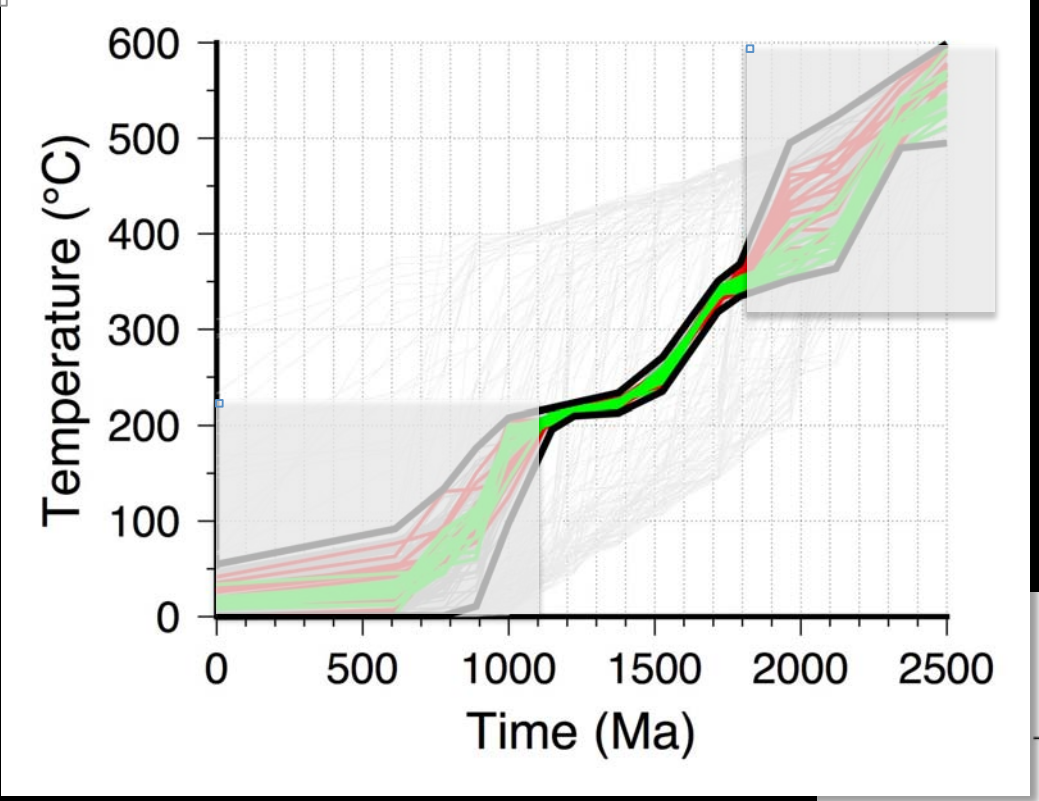
Inversion of K-feldspar age spectra

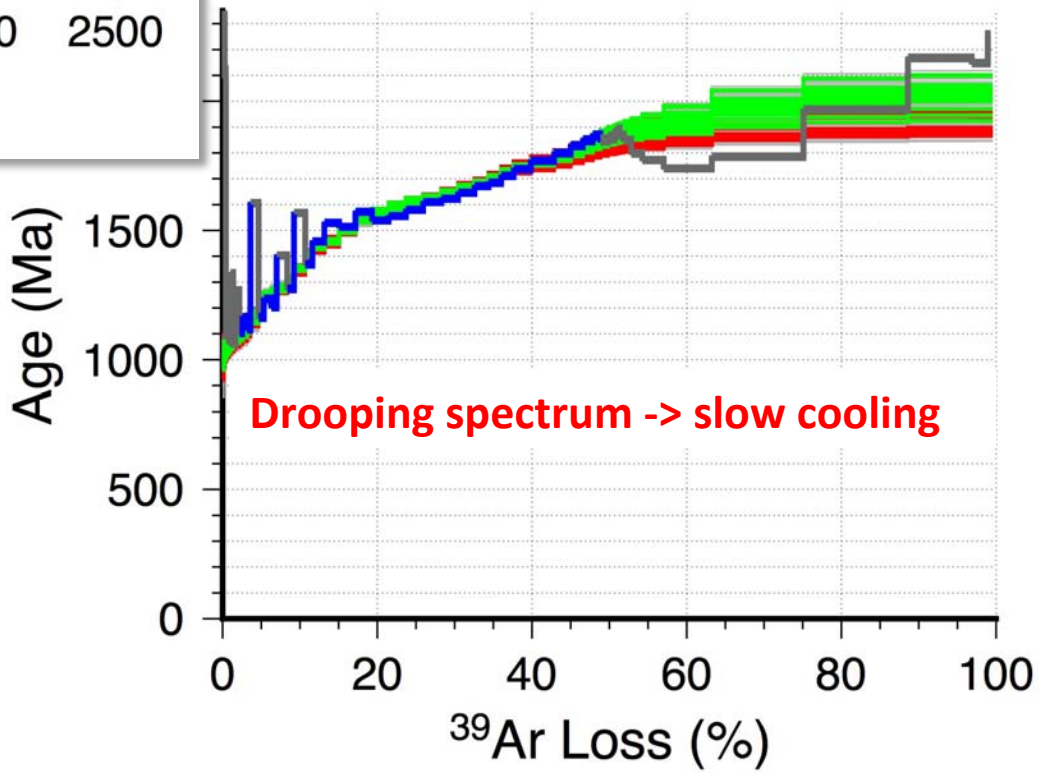




Chris Roddick, unpub. data

Inversion of K-feldspar age spectra





Kalin McDannell, unpub. data

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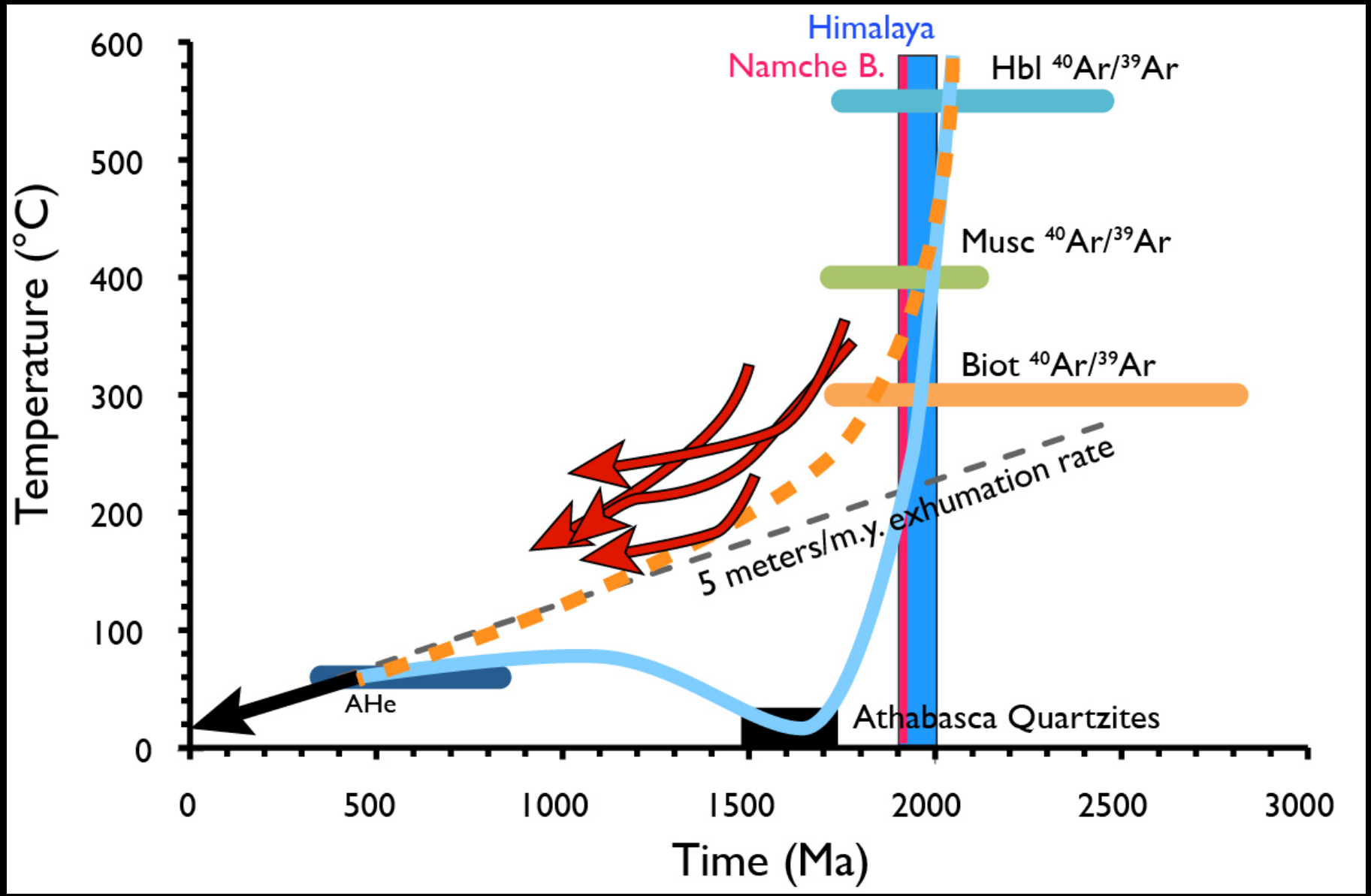
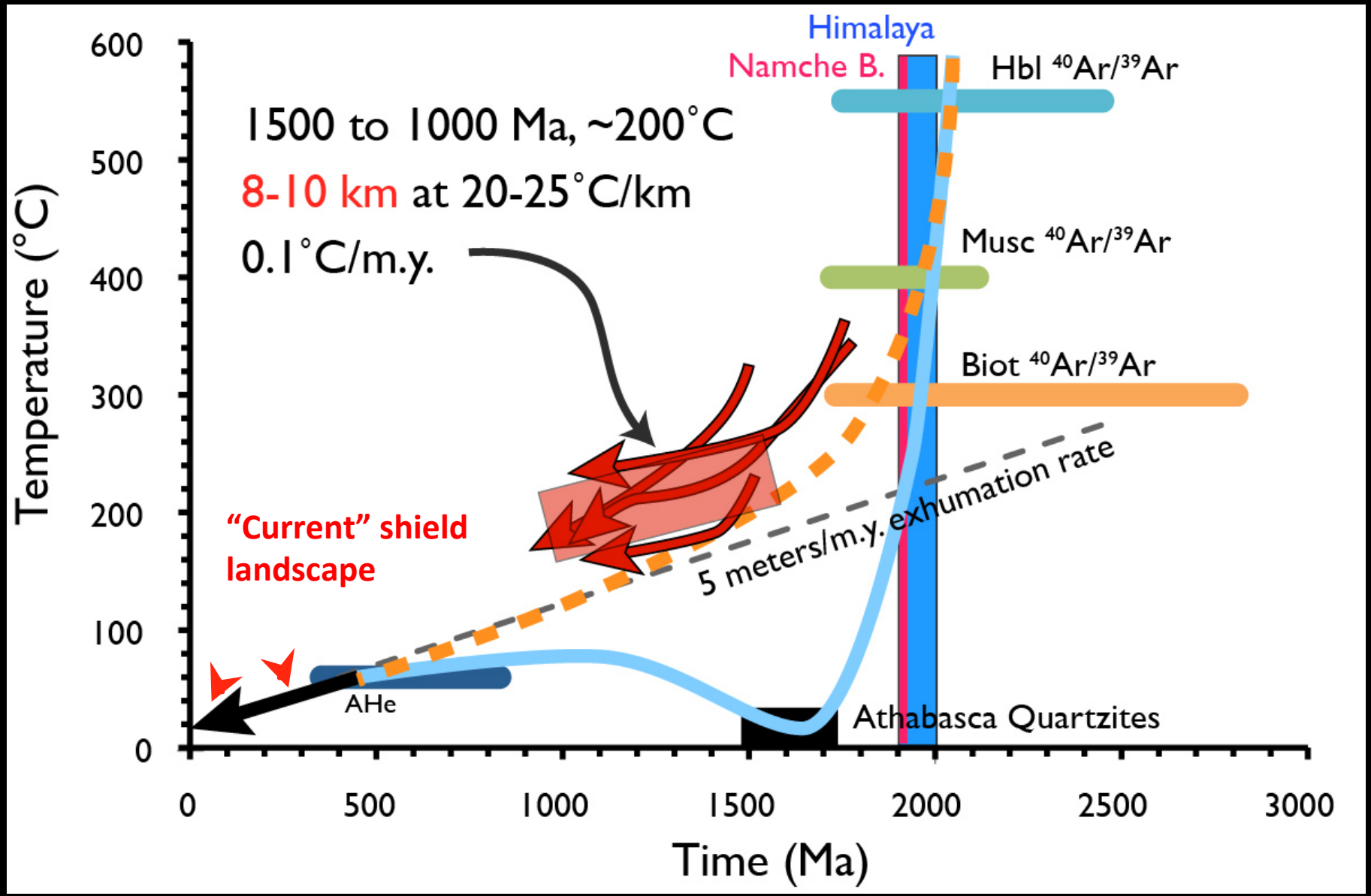
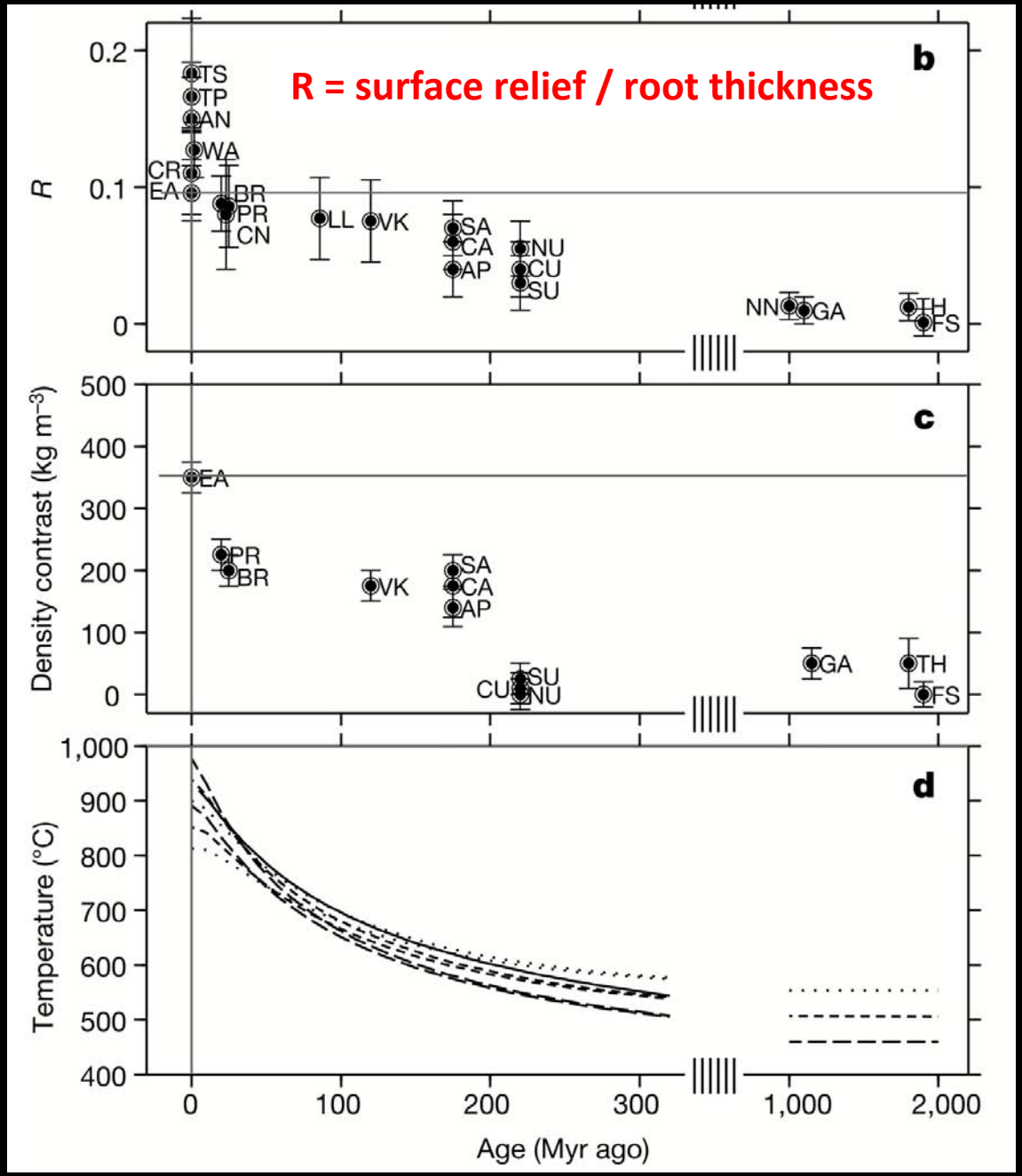


How and when did the shield surface?





Fischer, 2002, *Nature,* 417: 933-936

Roots

Waning buoyancy over 200-300 m.y.

Effective density contrast of root seems to decay with time

Gravity data suggests changes in nature of root itself (retrograde reactions during cooling)

How do processes and rates scale?*

Active: Surface a dynamic boundary condition; a major player involved with several feedbacks; active crustal and mantle drivers at many scales

(Post)-Mature: Surface importance for landscapes; coupling is mostly via isostasy; deeper drivers are more important (deeper mantle, changes in root)

Cratons: Operation of isostasy in face of: tectosphere, altered roots, strong lithosphere? Exhumation processes very different?

BUT, does it become one-way? If exhumation processes change, could they impact evolution of deeper lithosphere?

* I don't know