Quantifying Phanerozoic Km-Scale Vertical Movements in Morocco*

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Abstract

Low-T geochronology and time-T modelling studies conducted in Morocco document significant pre-, syn- and post-rift km-scale vertical movements. However, time-T modelling studies failed to reconstruct a unique time-constrained geological history for the Phanerozoic at the scale of the margin. Offshore Morocco, numerous wells located on the shelf encounter a nearly complete syn- and post-rift succession. The offshore basins have potential petroleum systems; however, to date hydrocarbon exploration has mostly been unsuccessful. To address this, source-to-sink systems need to be better defined and quantified. A key is to constrain when, where, and with what amplitude the exhumation events occurred in the hinterland to quantify potential volumes of eroded sediments. We used available time-T modelling results and dynamic geotherms for T to depth conversion. This allows calculation of denudation rates, presented in a series of contour maps. Similar models are grouped into three distinct regions, distinguished by timing and magnitude of exhumation: the Meseta (including the High Atlas Massif Ancien de Marrakech), Anti-Atlas and Reguibat Shield. The presently outcropping Variscan rocks in the Meseta were close to the surface during the Permian/Late Triassic, followed by subsidence until the Middle Jurassic, exhumation in the Late Jurassic/Early Cretaceous (0.01-0.09km/Ma), renewed subsidence during the Late Cretaceous and a final exhumation in the Cenozoic (0.01-0.21km/Ma). The sampled Anti-Atlas basement rocks were deeply buried in the Permian, exhuming from Triassic to Middle Jurassic (0.01-0.16km/Ma), subsiding during the Late Jurassic/Early Cretaceous, and were exhuming from Late Cretaceous onwards (0.01-0.05km/Ma). The Reguibat Shield is marked by subsidence from the Permian to Triassic, and exhumation from Jurassic onwards for most of the massif (0.01-0.06km/Ma). High denudation rates compare with values typical of rift flank, domal or structural uplifts and are only obtained in the Anti-Atlas during the Early to Middle Jurassic and in the High Atlas during the Neogene. The mean value of 0.04km/Ma compares with weathering/peneplain rates. Estimates of eroded volumes from Permian onwards are 2x106, 0.6x106, and 0.2x106 km^3 in the Reguibat Shield, Anti-Atlas and Meseta respectively. The results provide several source-to-sink qualitative and quantitative maps for selected periods in Phanerozoic times.

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ISES
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Why focusing on vertical movements?

Source-to-sink/Petroleum system

Geodynamics

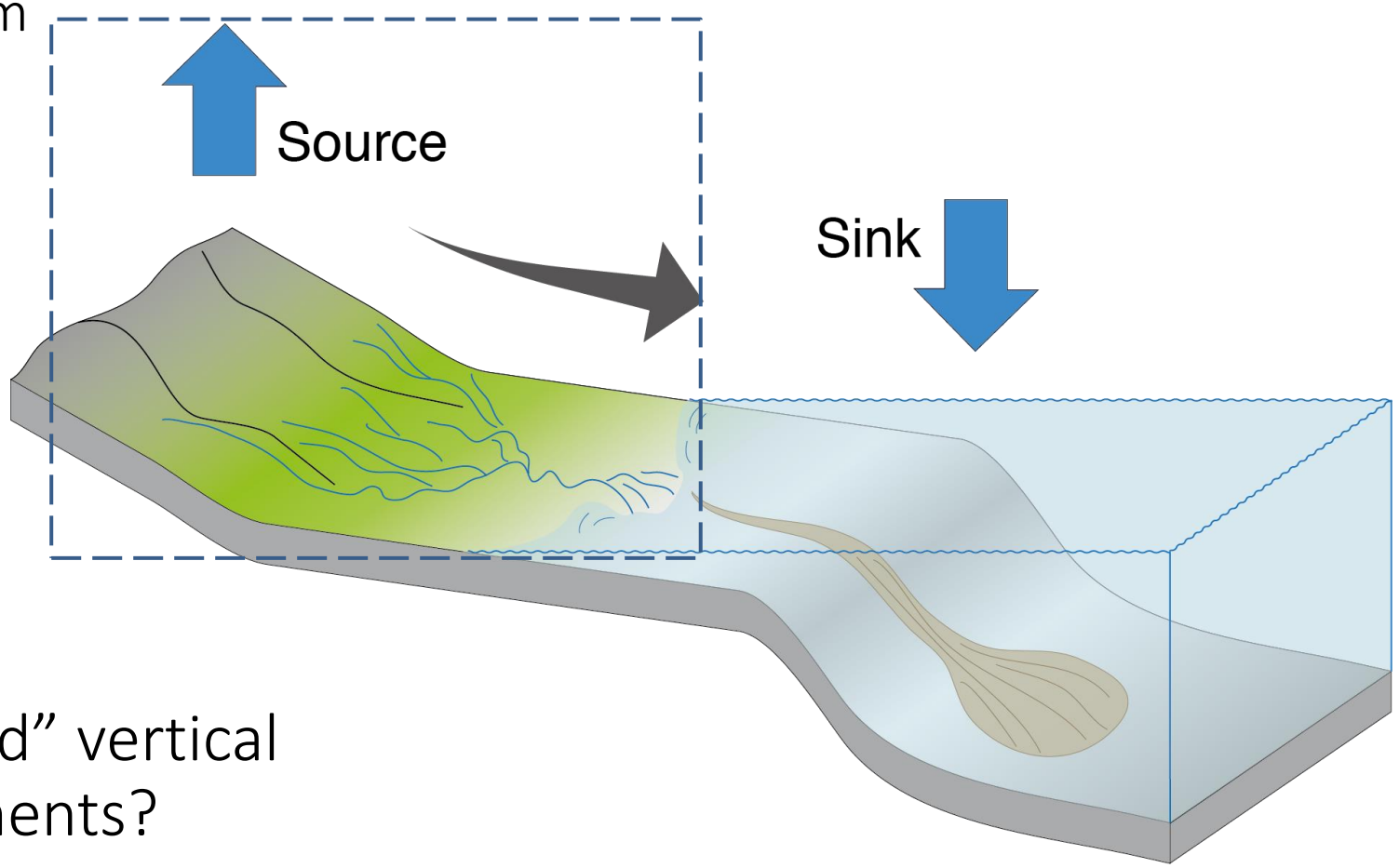
Knowns

Wavelength and hinge

Where and when

Unknowns

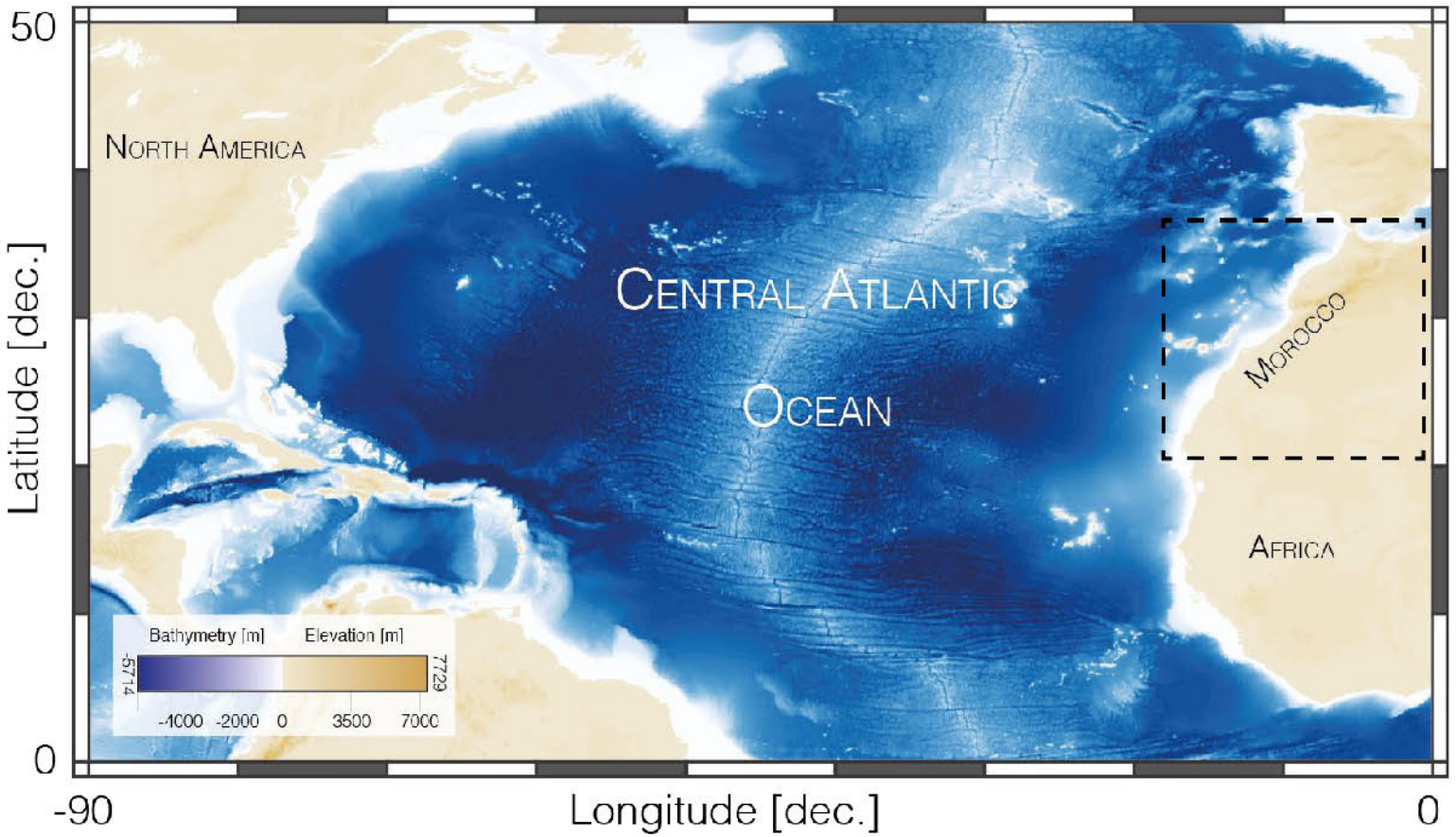
Rates and volumes?

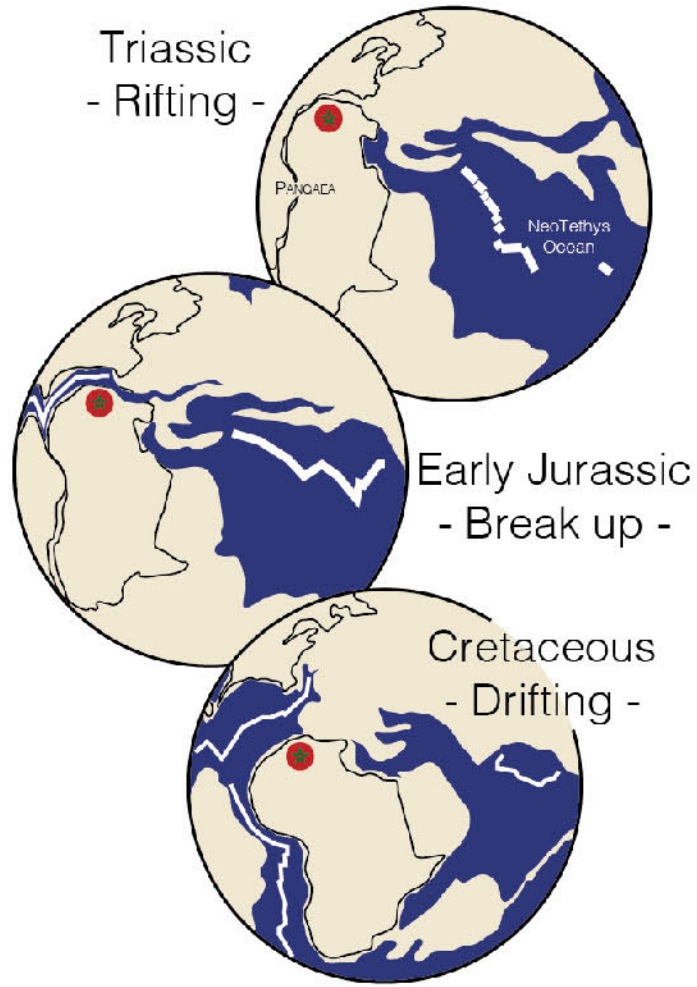


“unexpected” vertical movements?

after Helland-Hansen et al., 2016

Central Atlantic



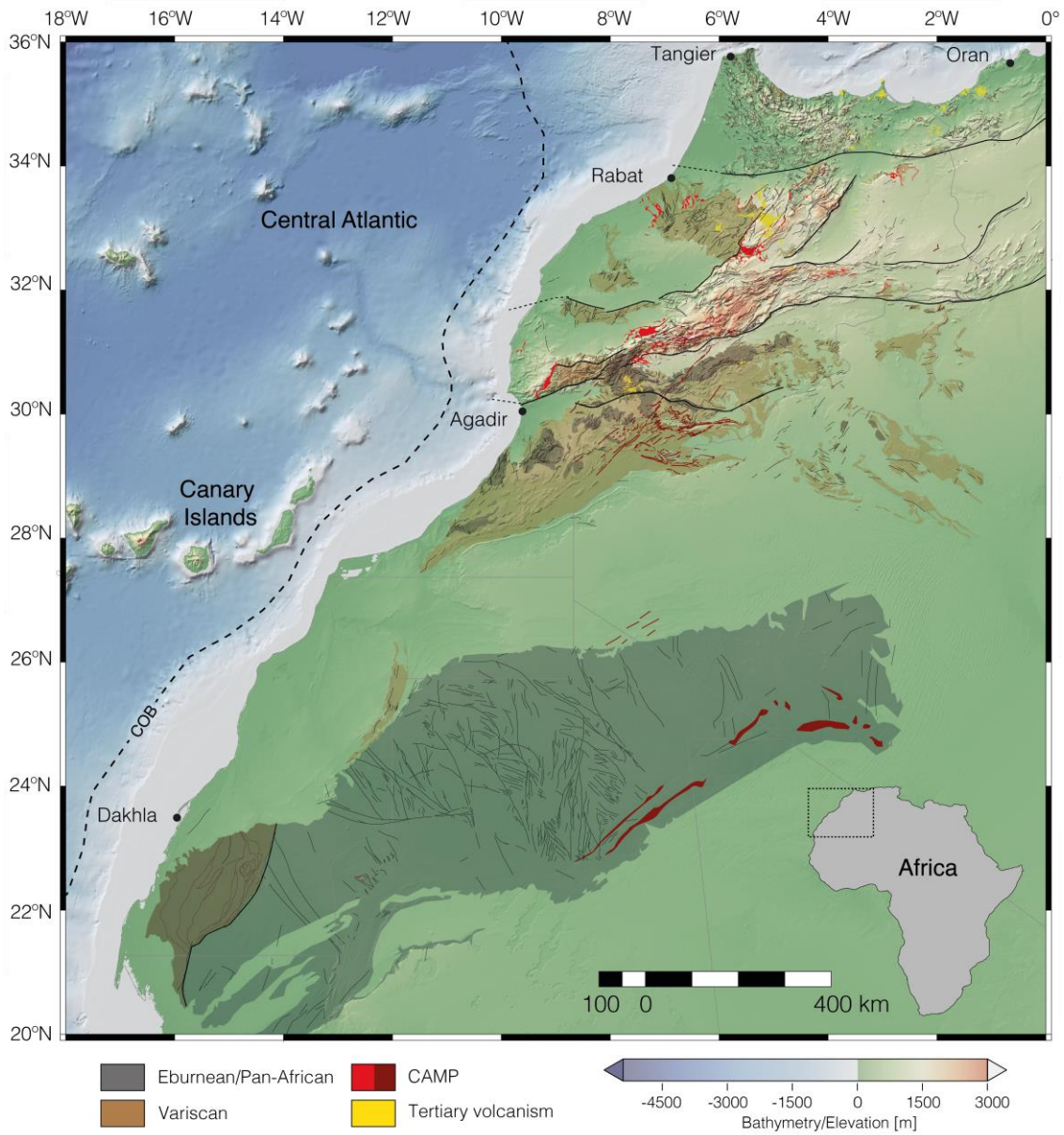


after Stampfli and Borel, 2002

Why Morocco?

Low-Temperature Thermochronology

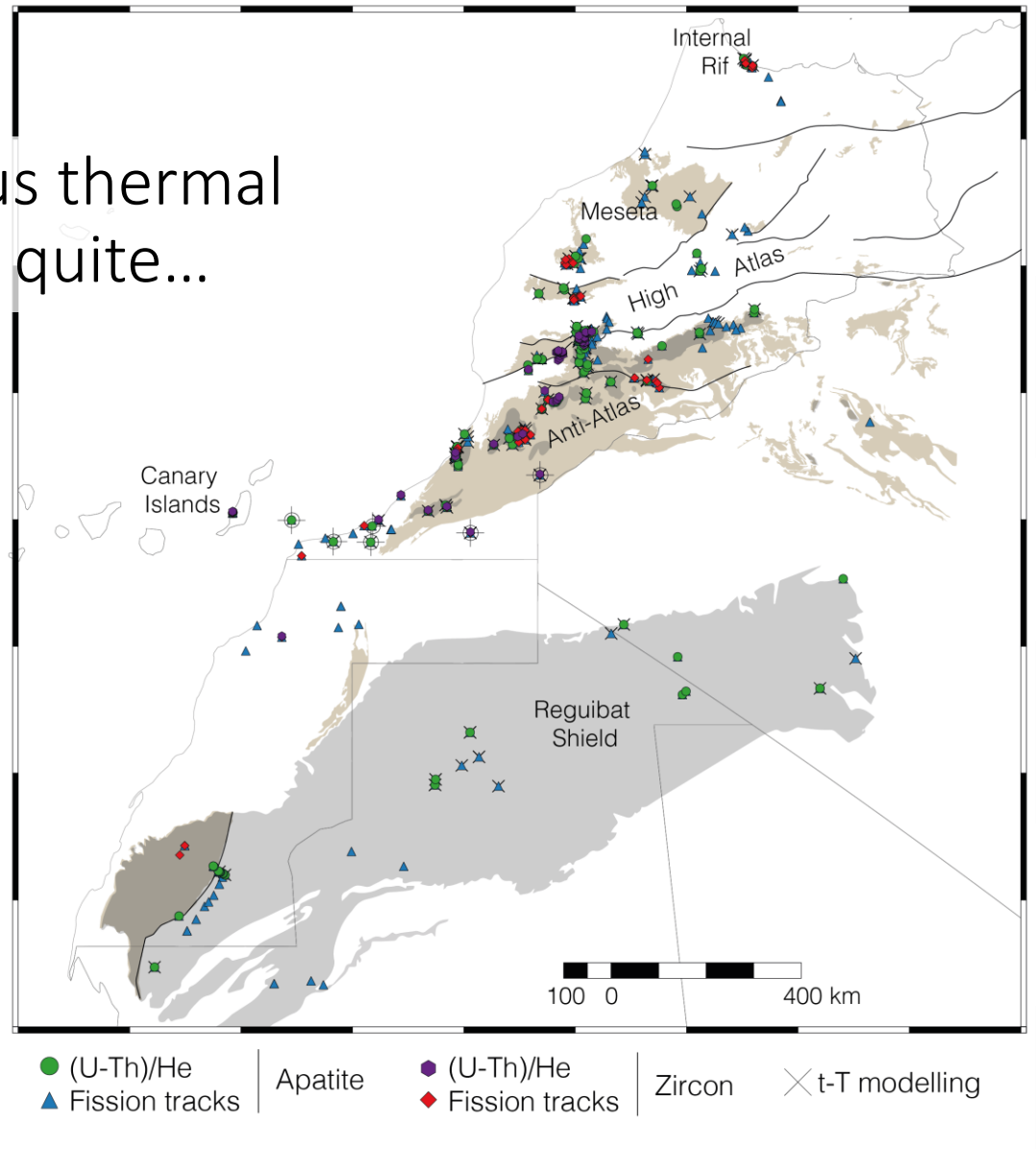
Great exposure



COB: Continental Ocean Boundary

Low-Temperature Thermochronology

A homogeneous thermal history? Not quite…



A large database

529 AHe
312 AFT
225 ZHe
59 ZFT

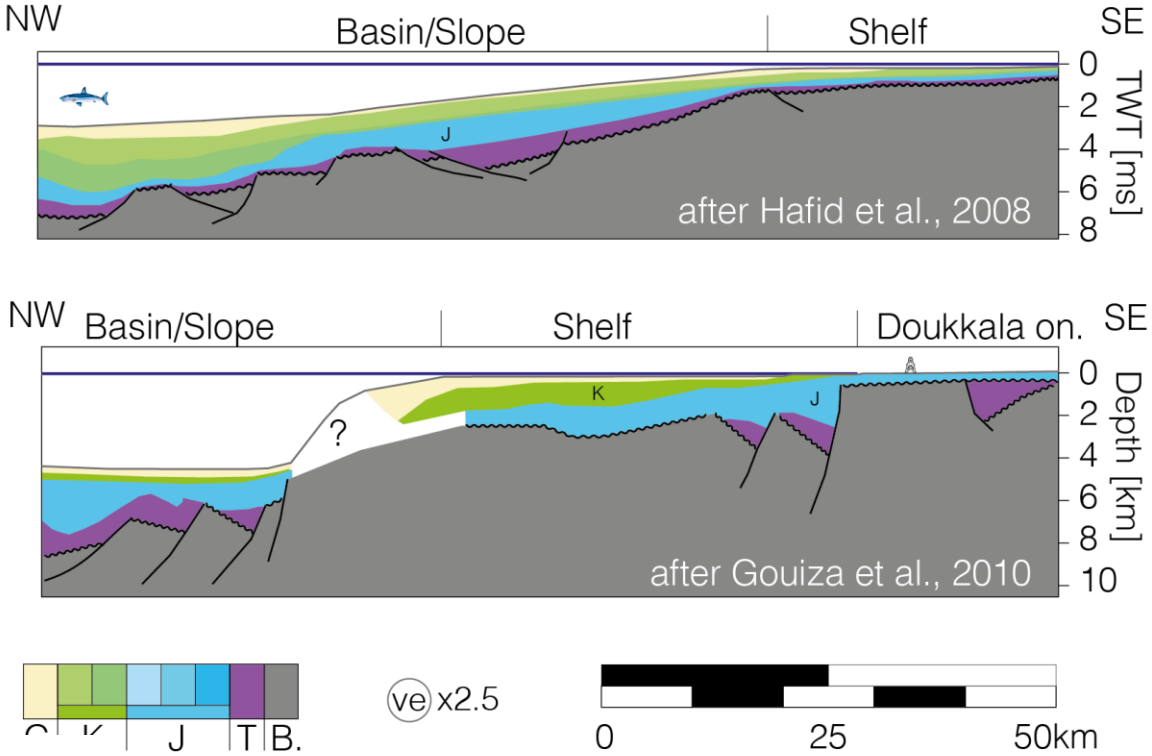
Documenting vertical movements

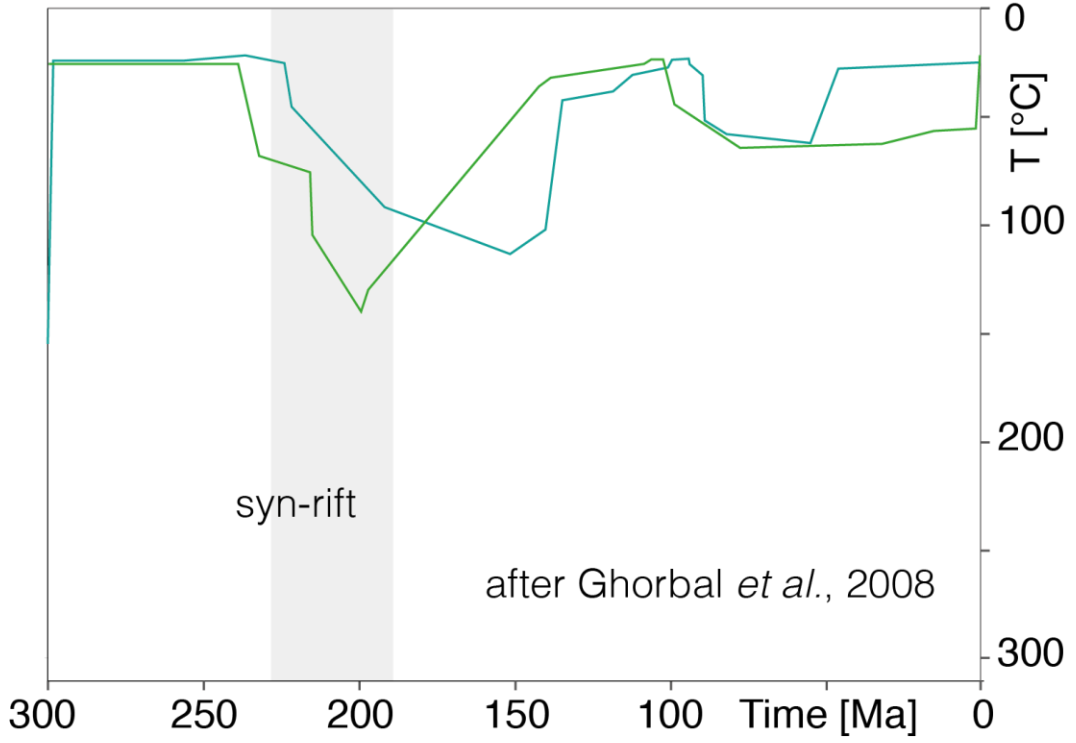
COB: Continental Ocean Boundary

The Moroccan rifted margin

Meseta

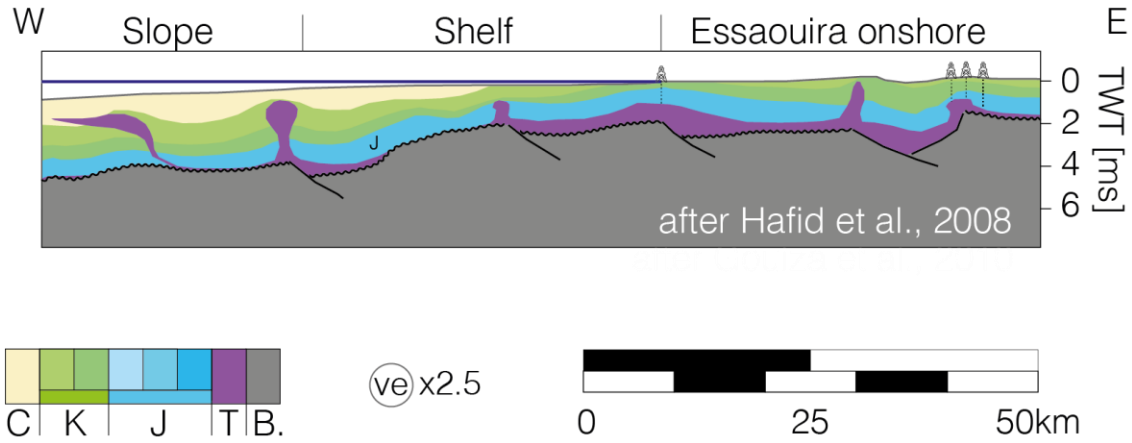
Profile and sample location

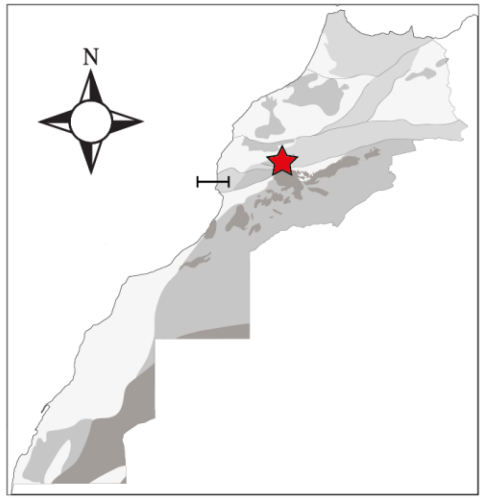




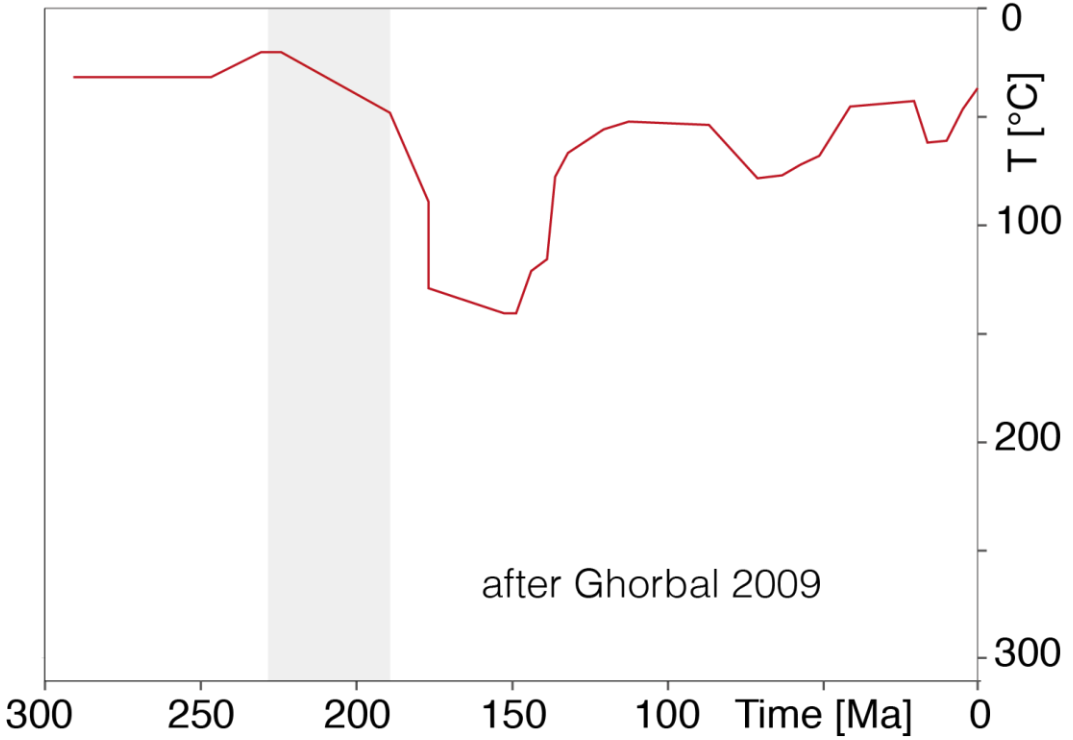
The Moroccan rifted margin

High Atlas



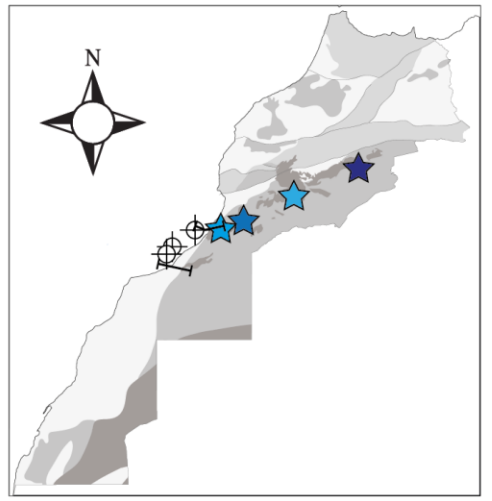


Profile and sample location

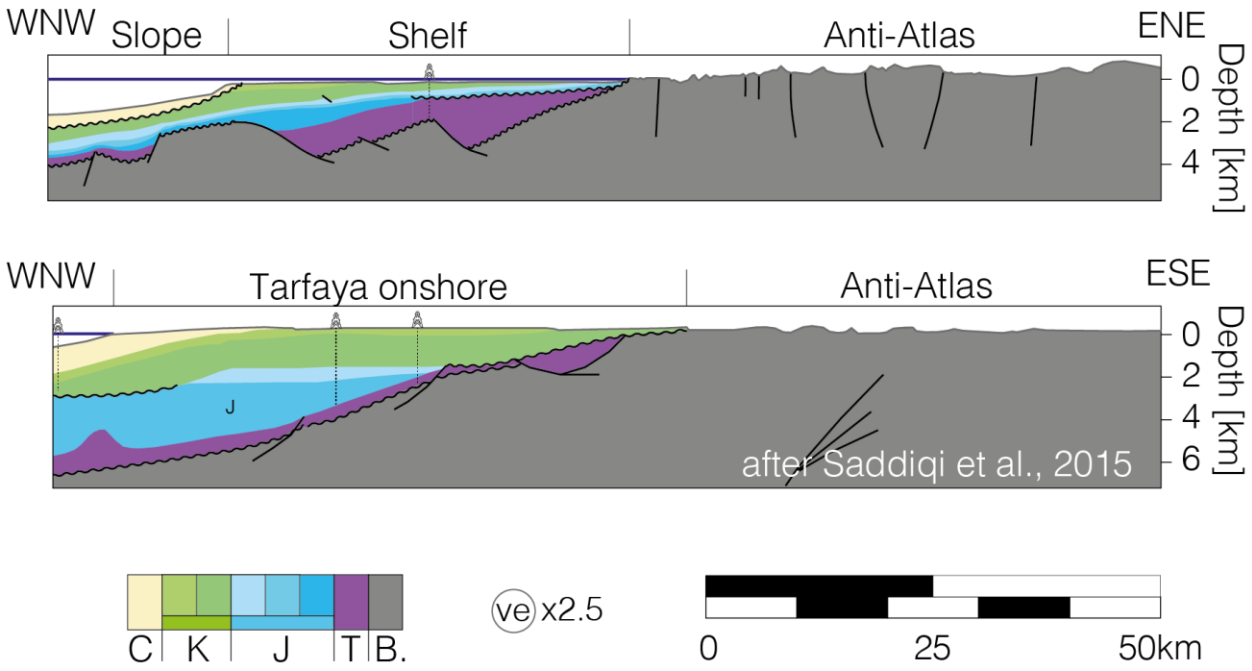


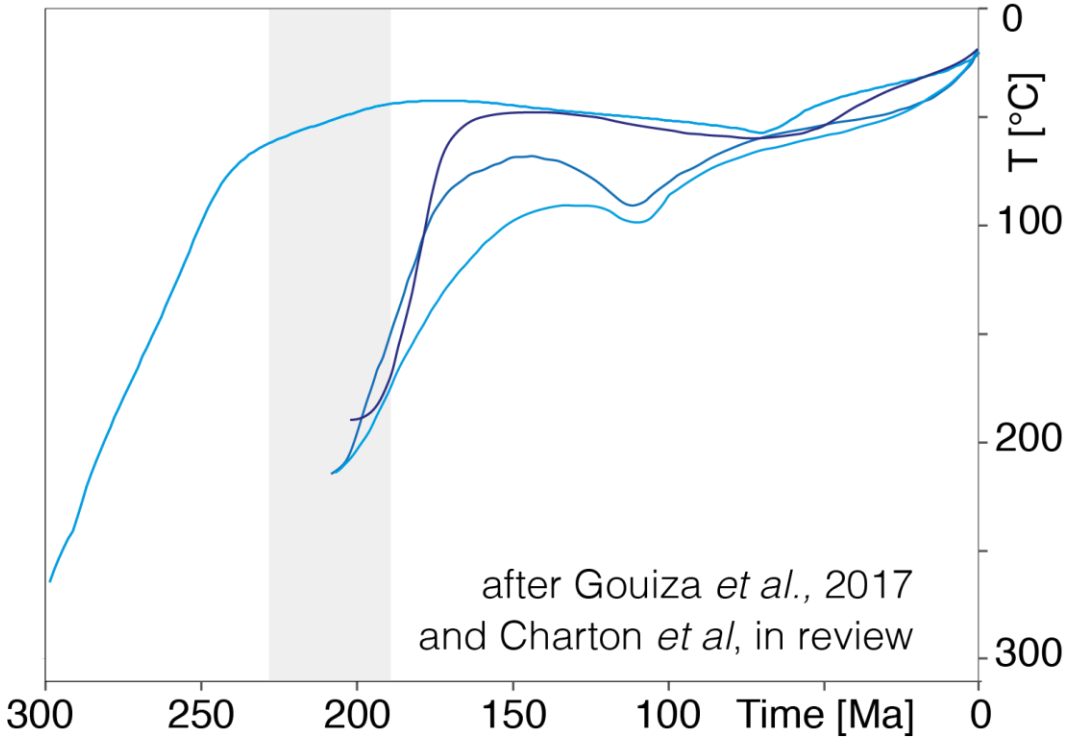
The Moroccan rifted margin

Anti-Atlas



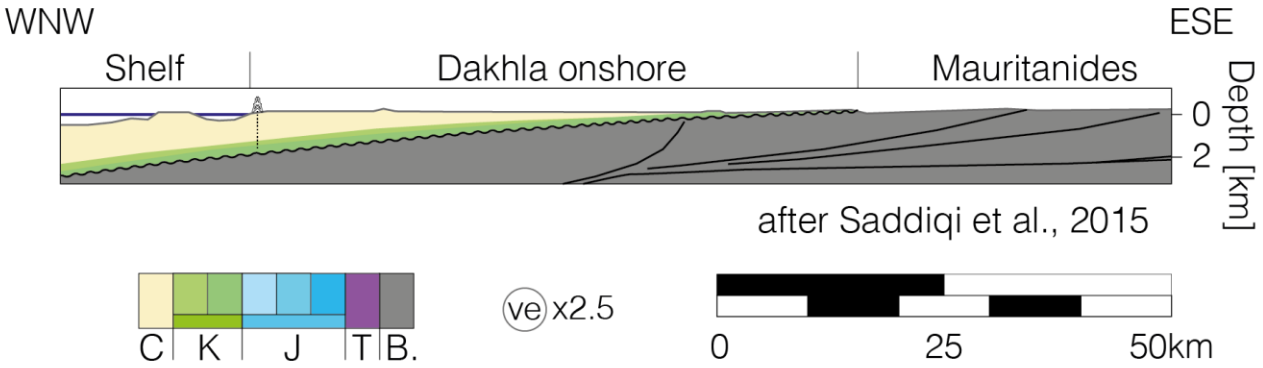
Profile and sample location





The Moroccan rifted margin

Reguibat Shield



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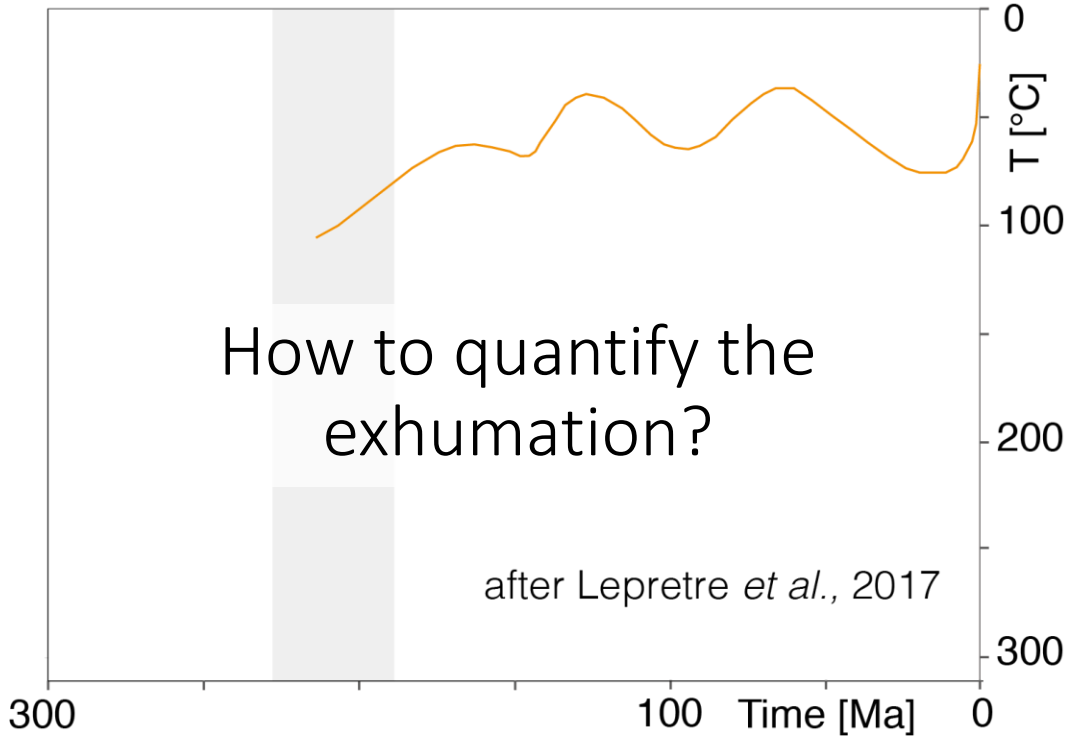
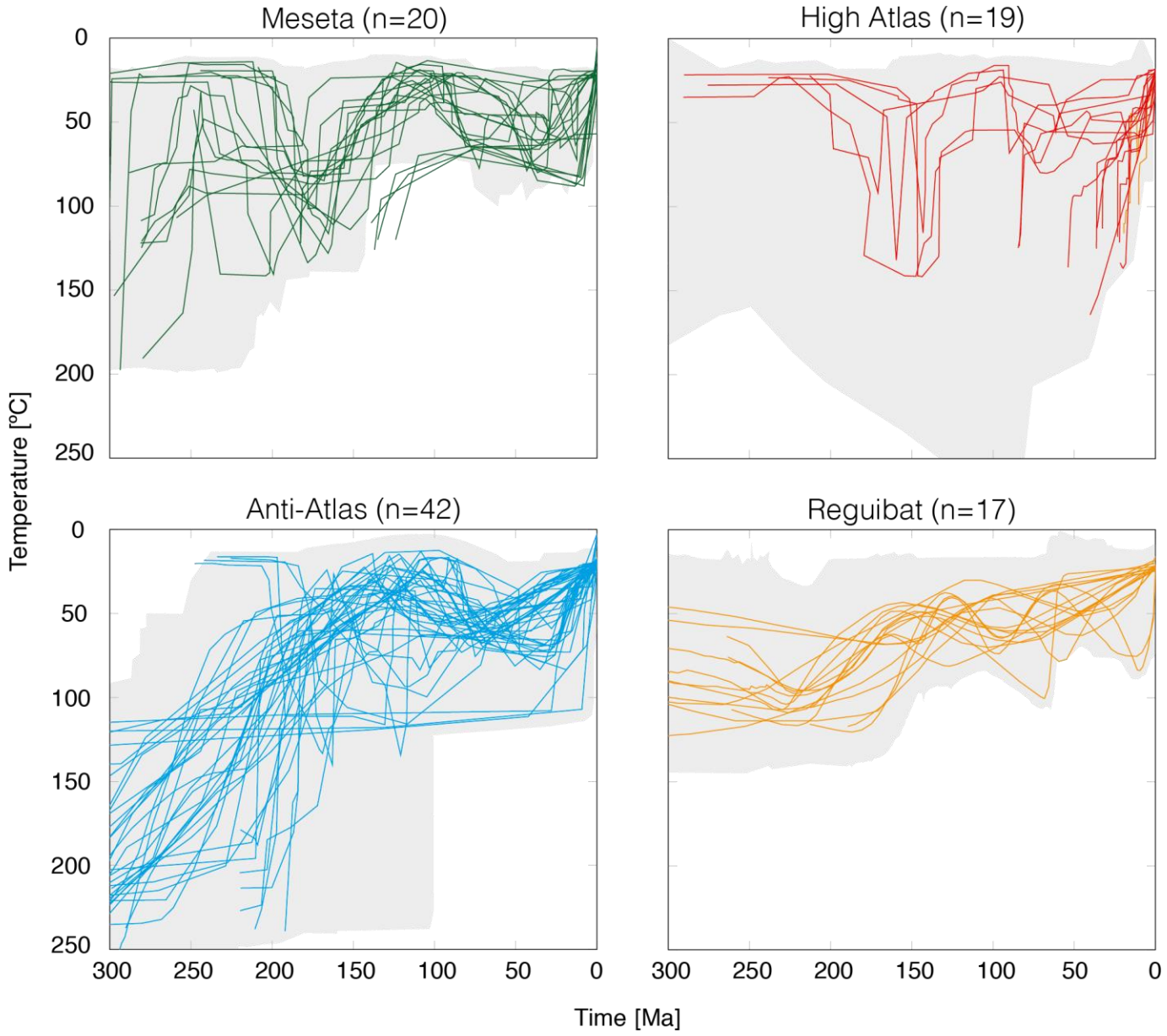
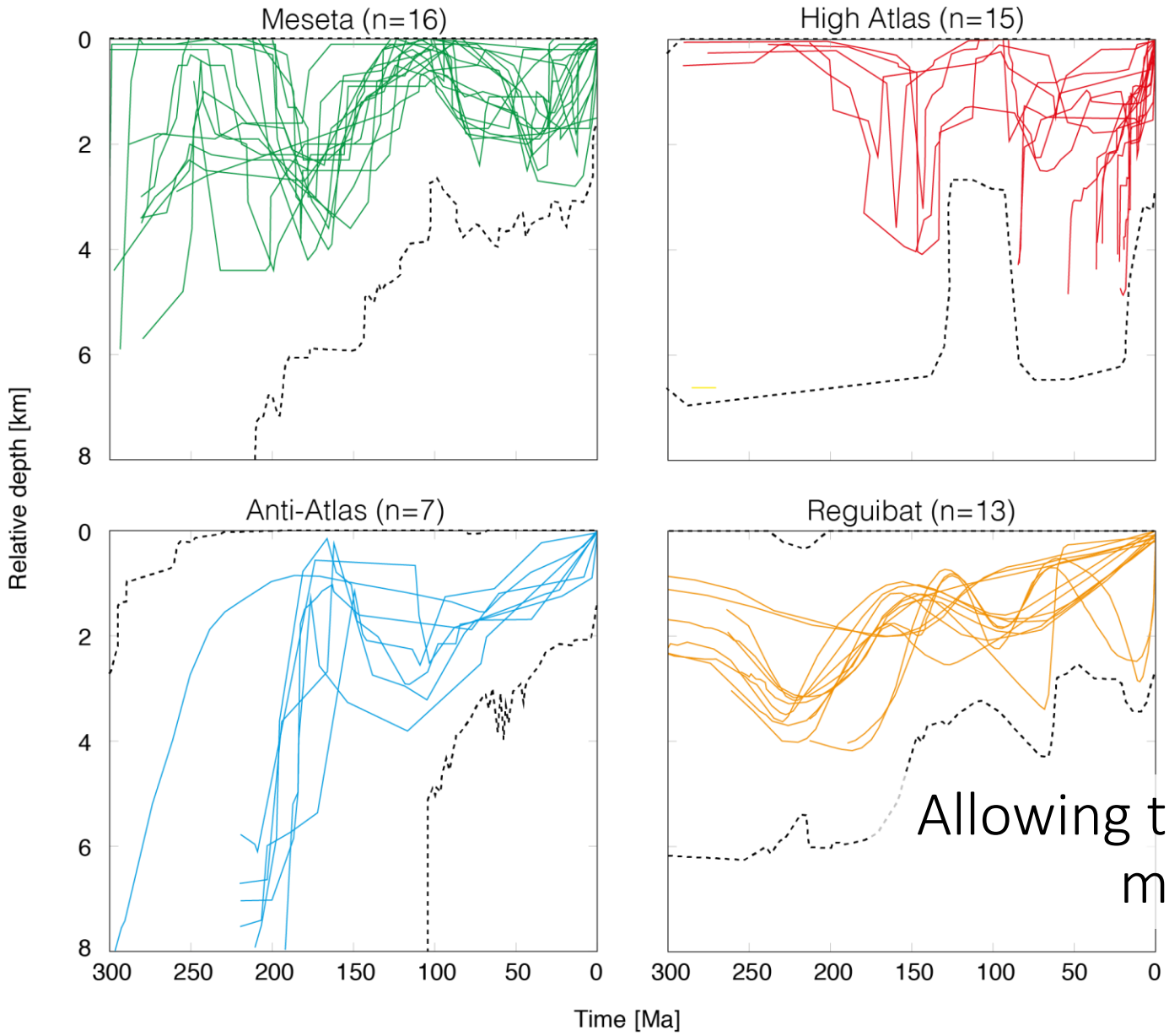


Time-Temperature modelling … to depth

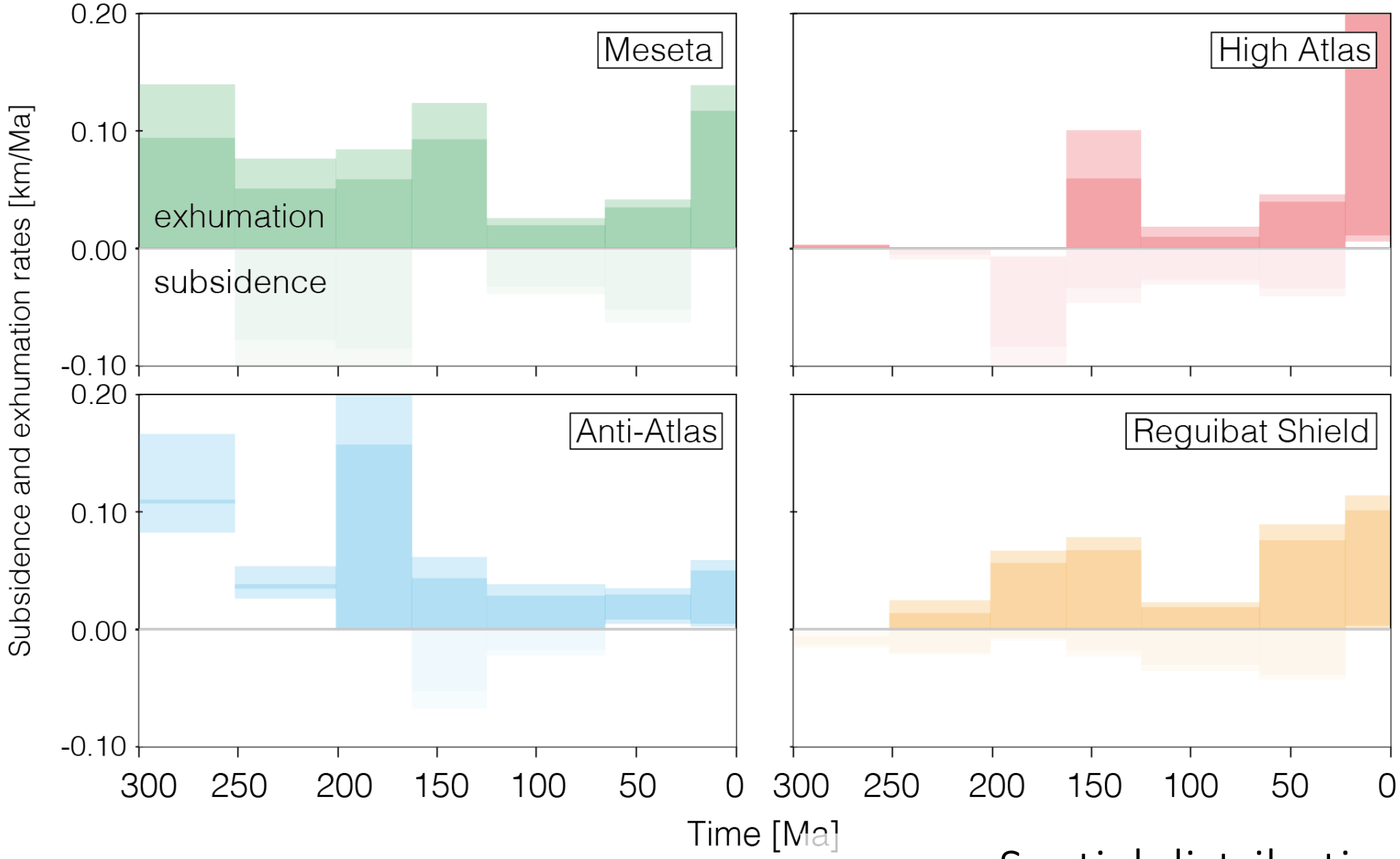


Time-Temperature modelling … to depth



Allowing to quantify vertical movements

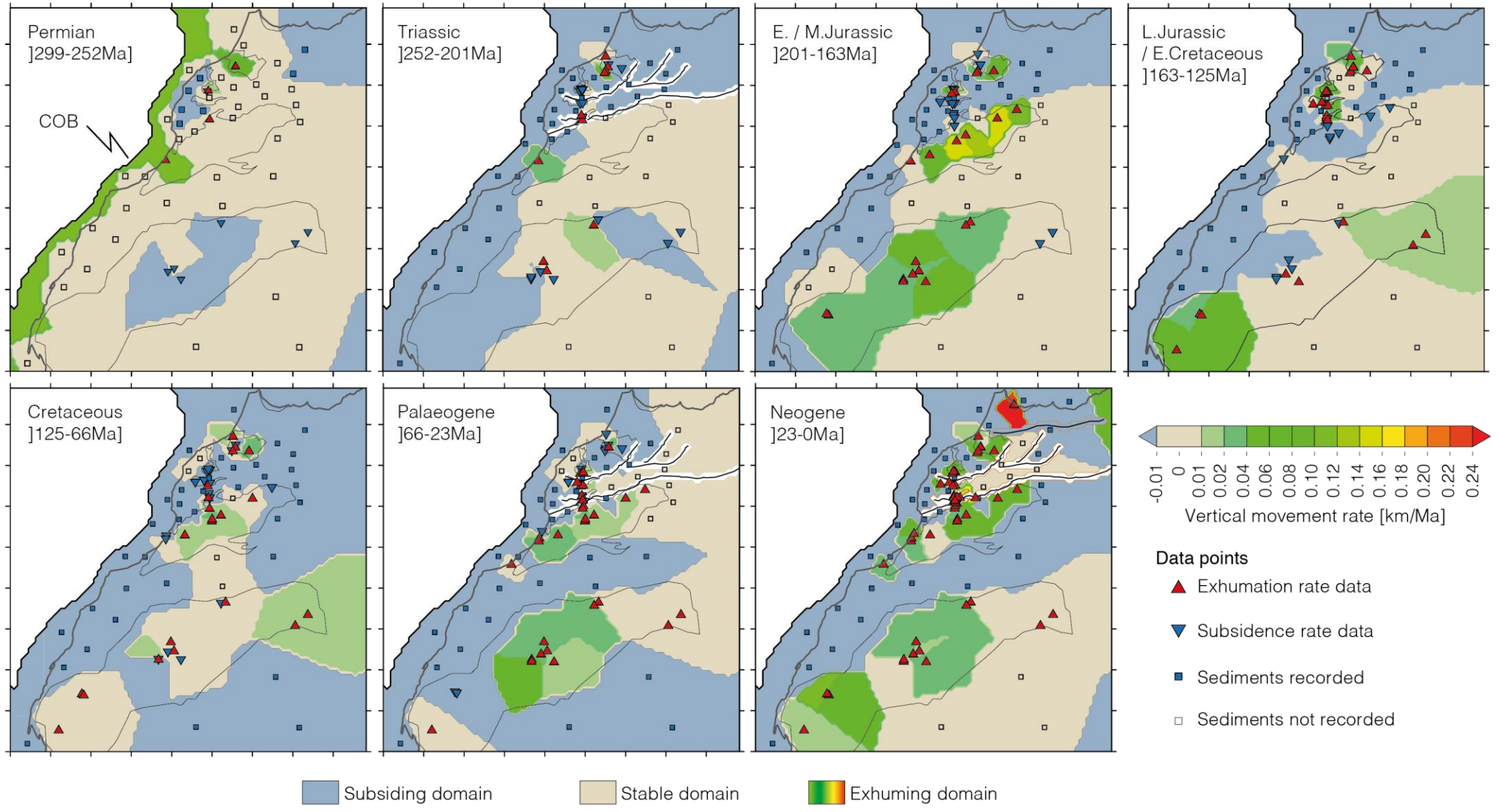
Vertical movement rates [km/Ma]



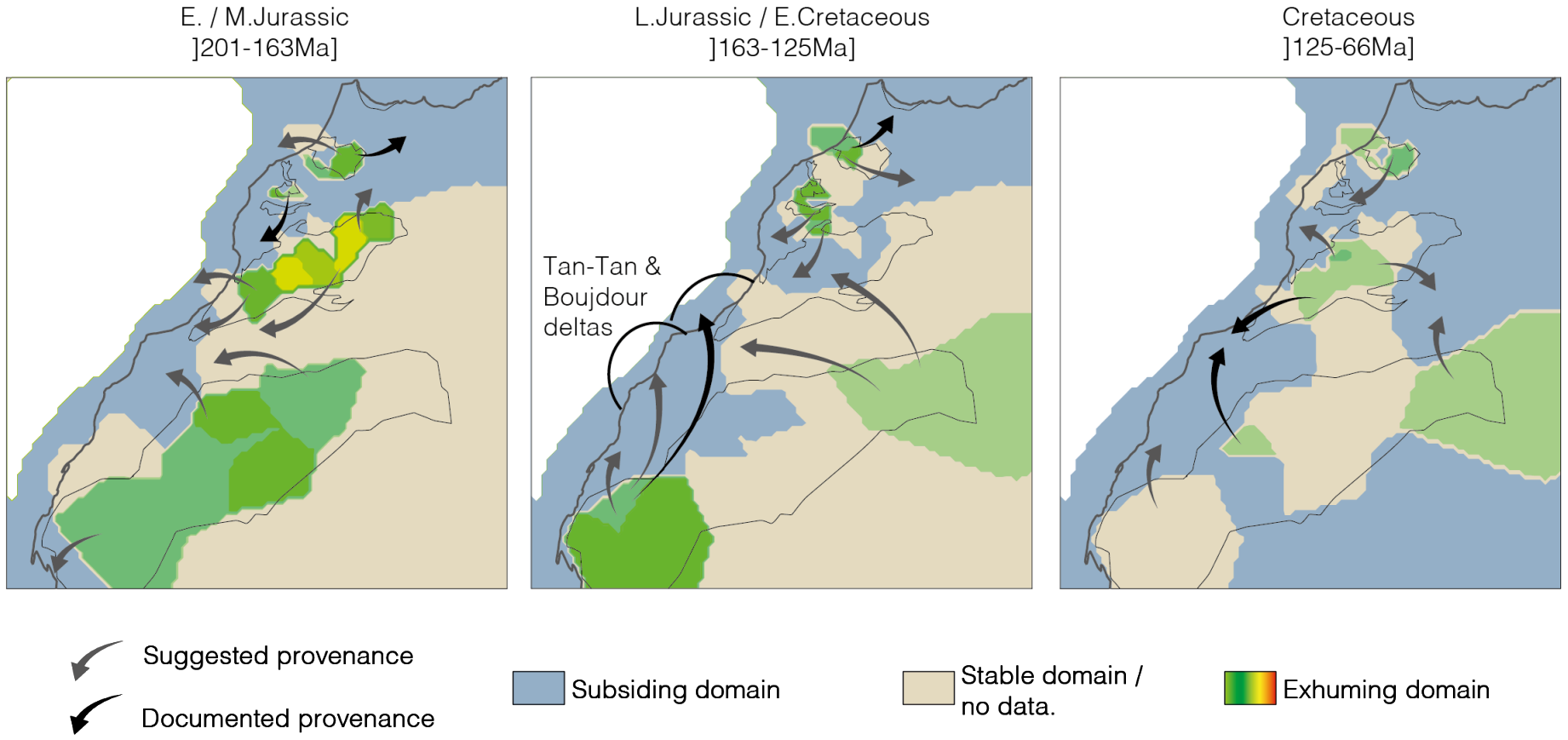
Spatial distribution?

Exhumation maps

Shifts in source areas?

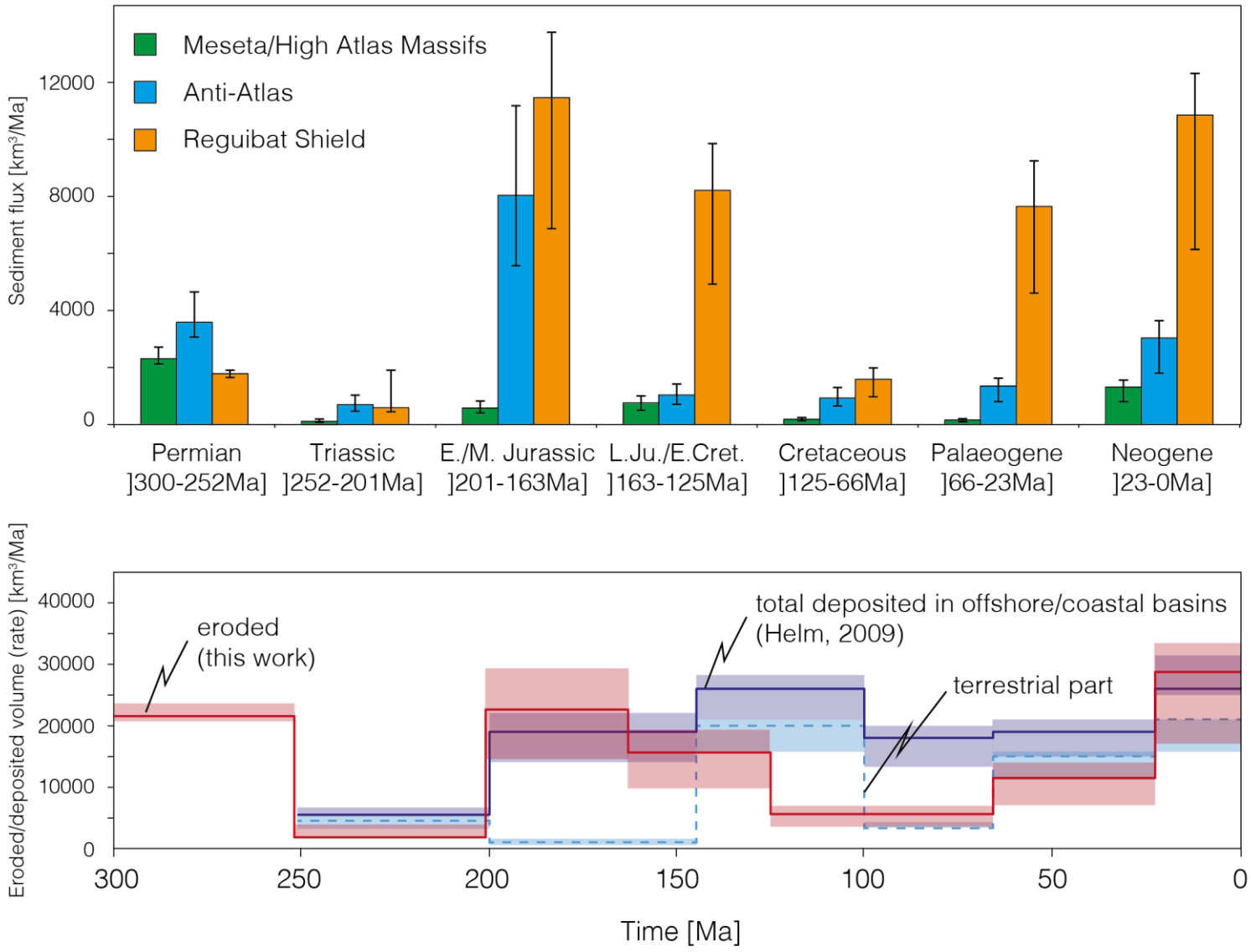


Implications for source-to-sink systems



How much was eroded?

Volumes of eroded material per Ma



Conclusions

Exhumation…

- patterns mapped for the first time
- rates up to 0.2 km/Ma
- volumes up to 12,000 km^3/Ma

Sediment Provenance

- Major **source shifts** in the Jurassic and Cretaceous
- **Cretaceous deltas** sourced from Reguibat only.

Thanks to…

Project

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Thank you

Thank you for your attention

Questions?

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