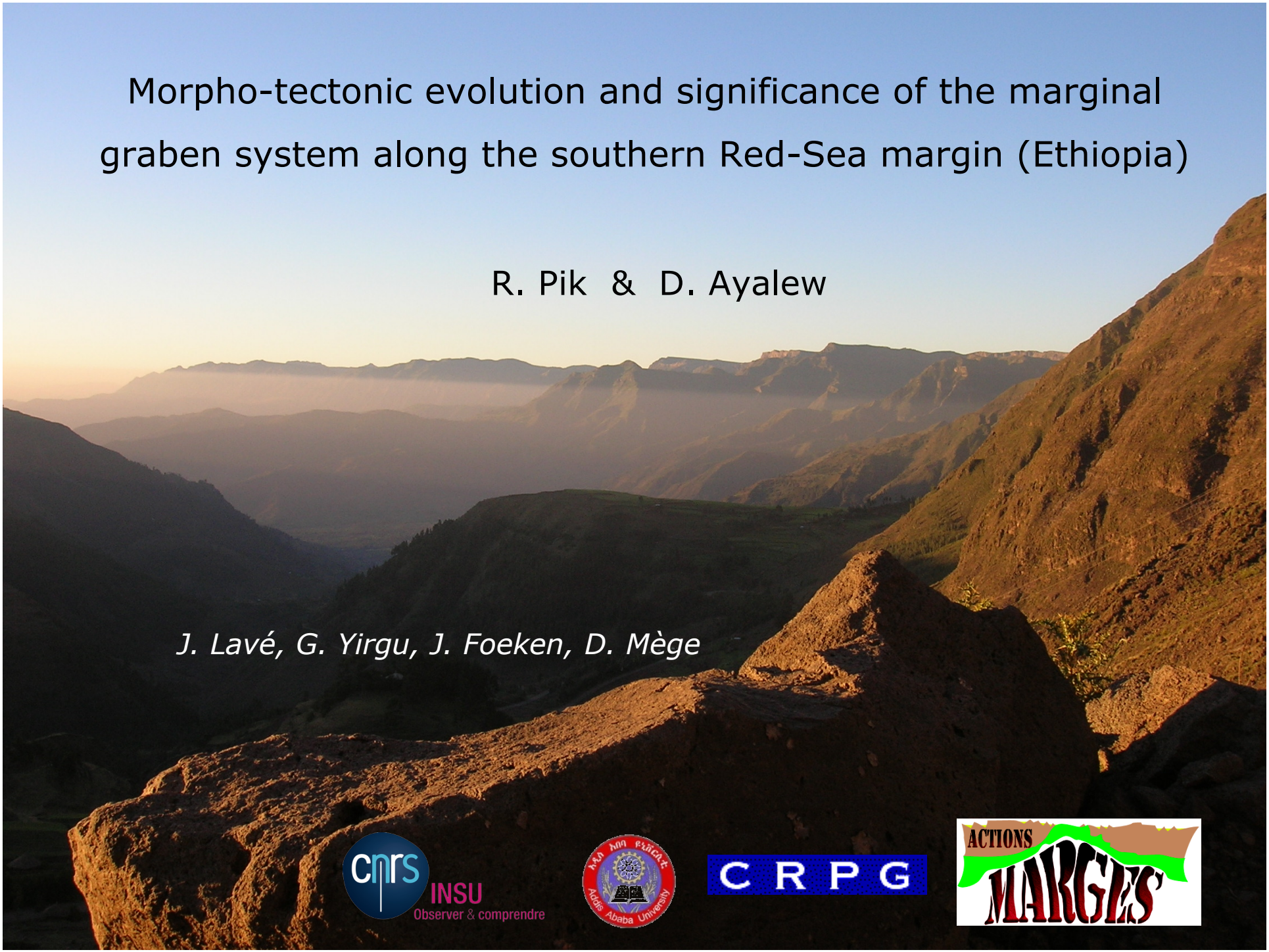
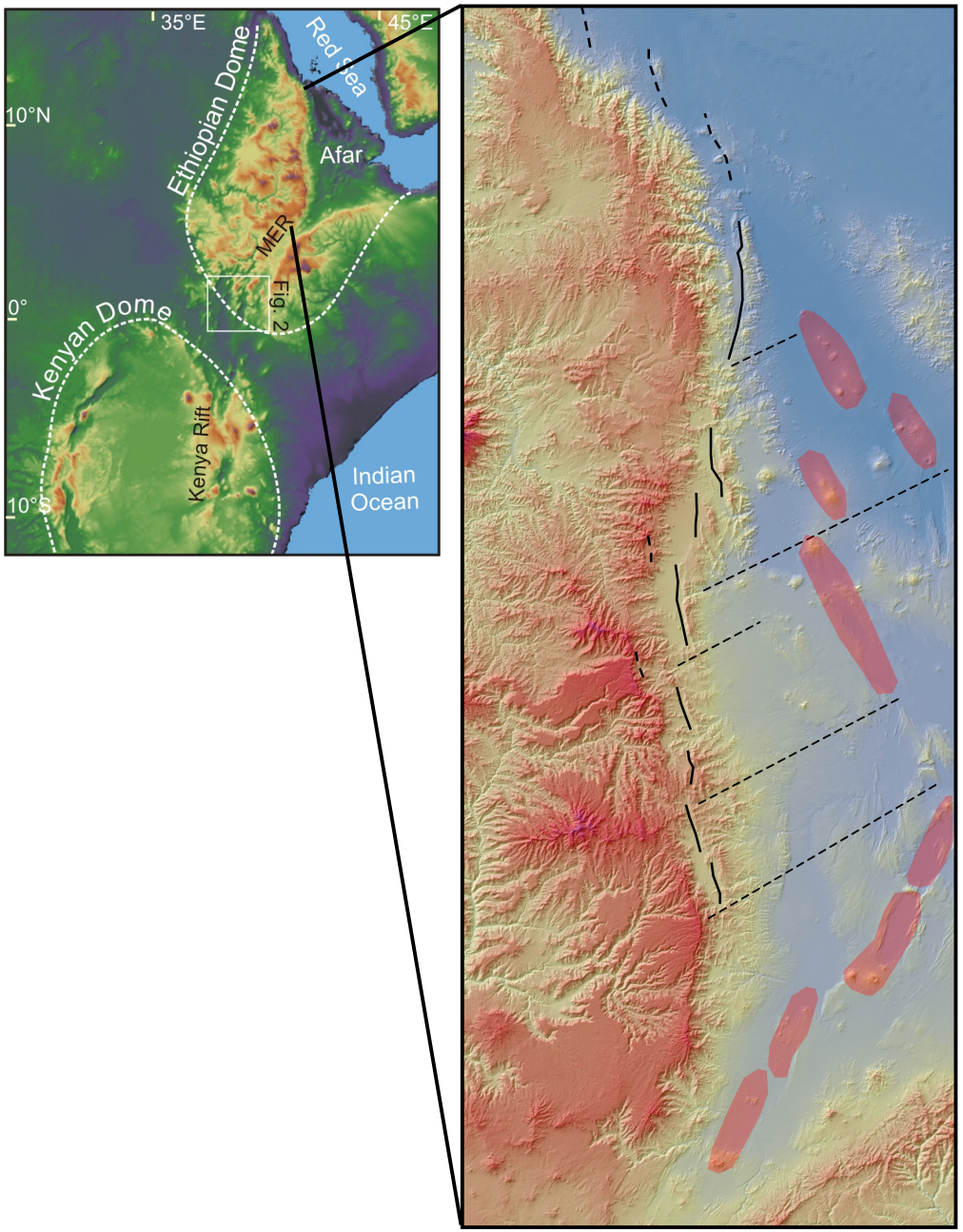
Morpho-tectonic evolution and significance of the marginal graben system along the southern Red-Sea margin (Ethiopia)

R. Pik & D. Ayalew

J. Lavé, G. Yirgu, J. Foeken, D. Mège

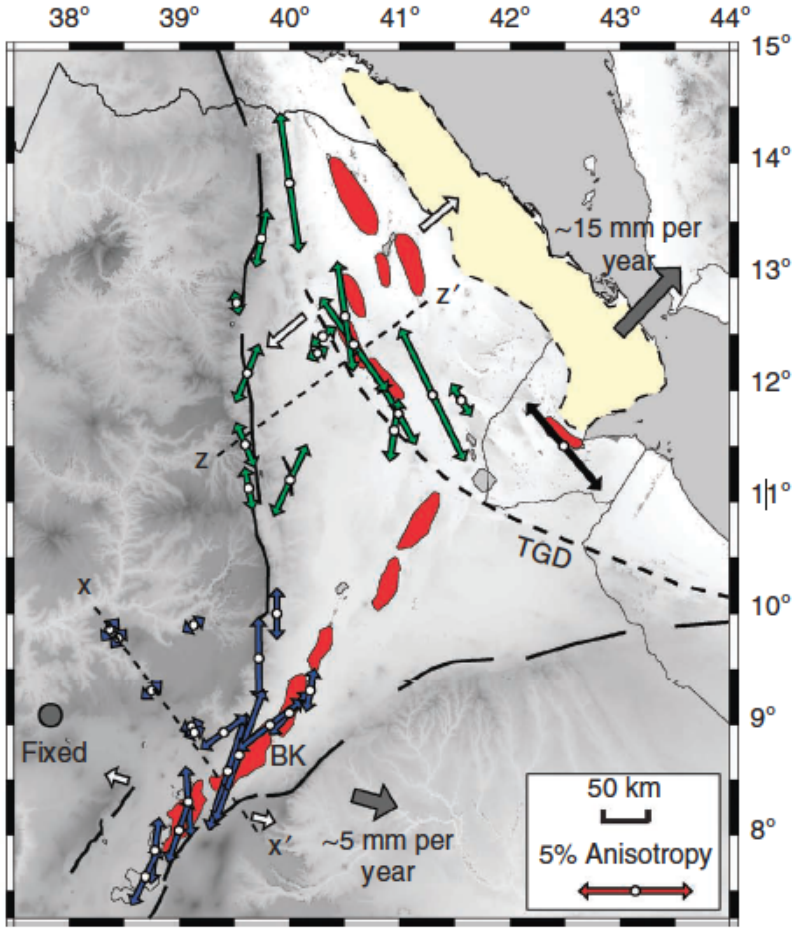


The southern Red Sea - West Afar marginal graben system

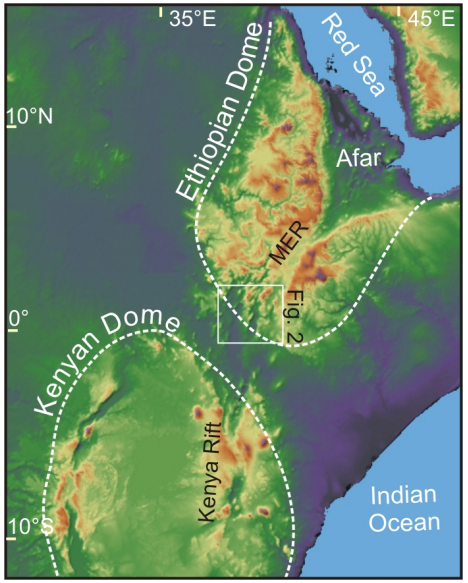


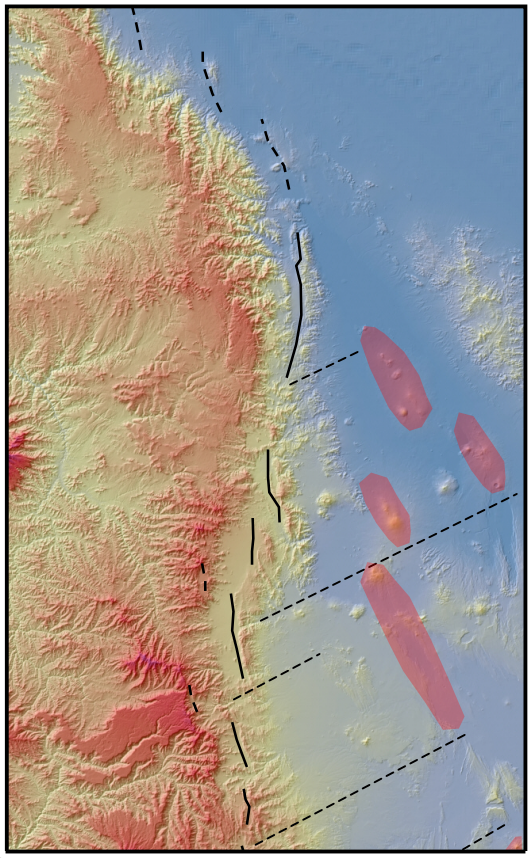
- developed all along the margin
- strongly segmented
- significant anisotropy

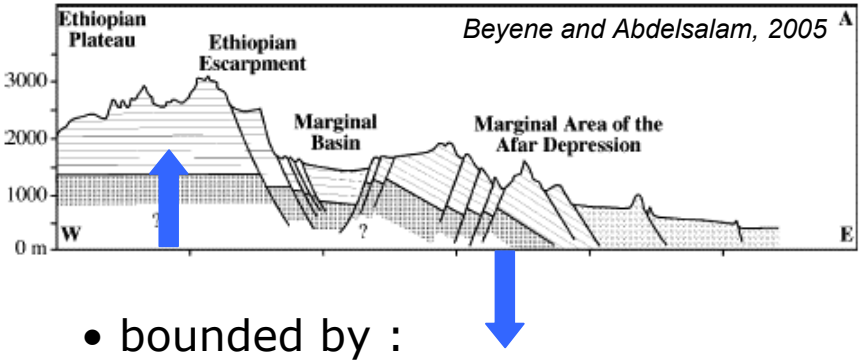
(shear wave splitting data / Keir at al., 2011)



The southern Red Sea - West Afar marginal graben system





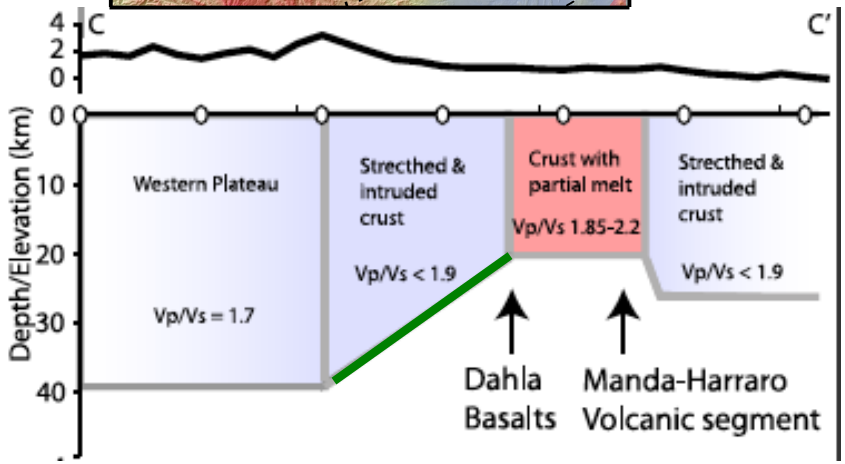


- bounded by :

  an uplifted plateau

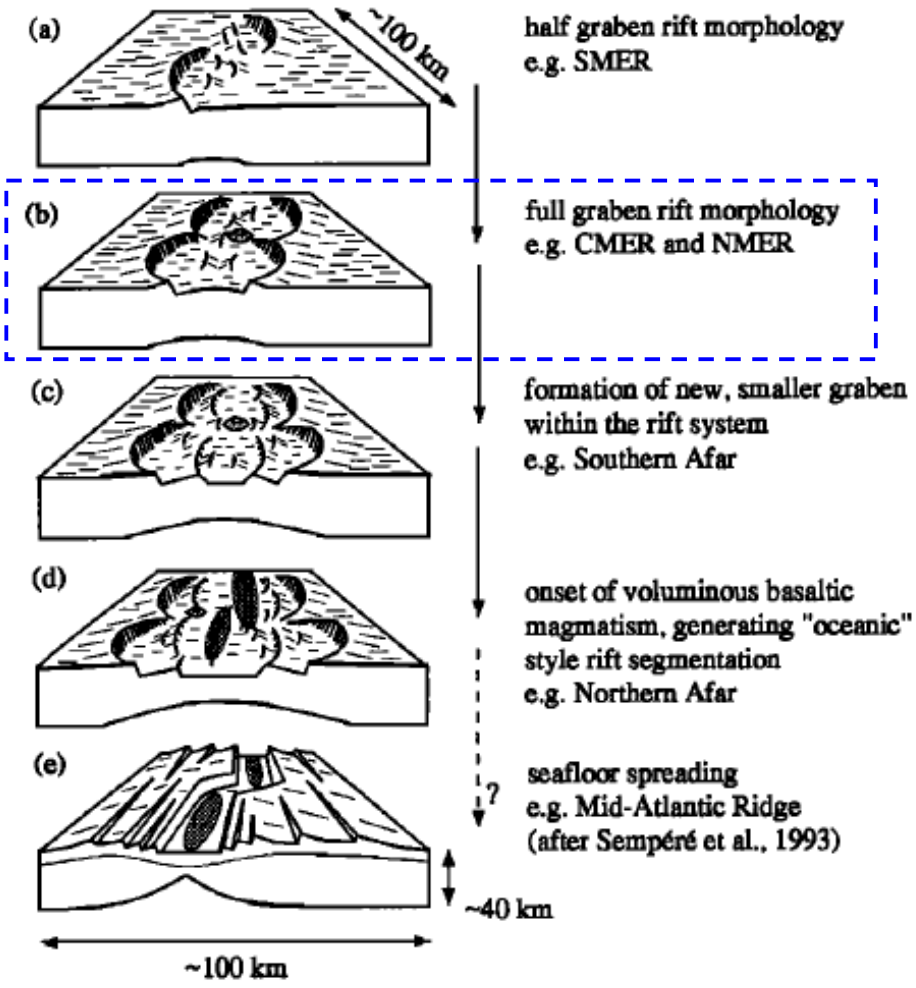
  a flexured margin

- topographic margin on top of the maximum gradient of crust attenuation

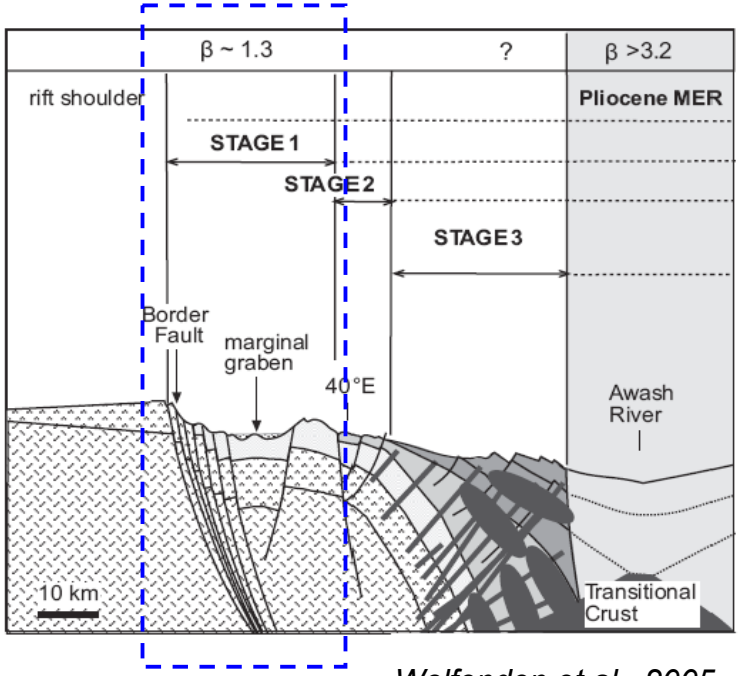


Hammond et al., 2011

Working models for the evolution of rifting



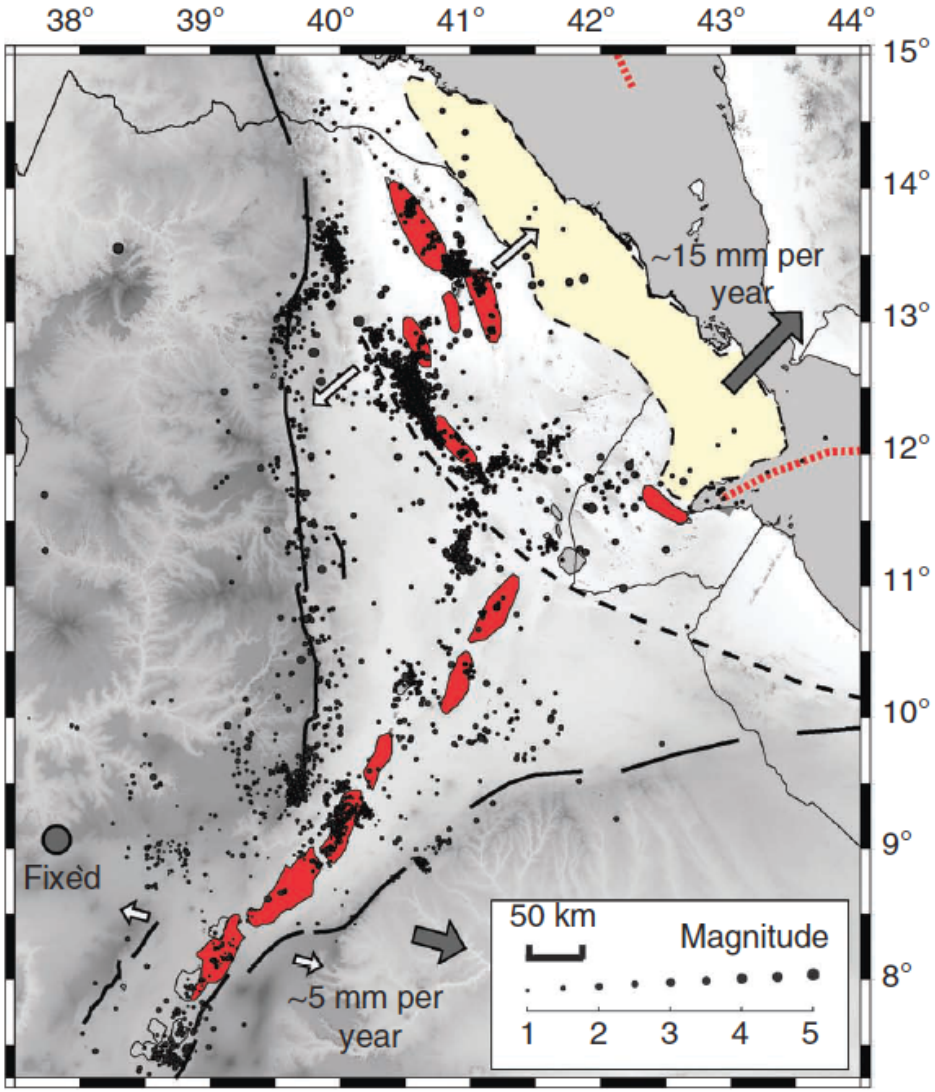
Hayward & Ebinger, 1996



Wolfenden et al., 2005

- Large offset border fault
- Initial rift stage
- "abandoned"

The southern Red Sea - West Afar marginal graben system



- still seismically active !

  Belachew et al., 2011 ; Keir et al., 2011

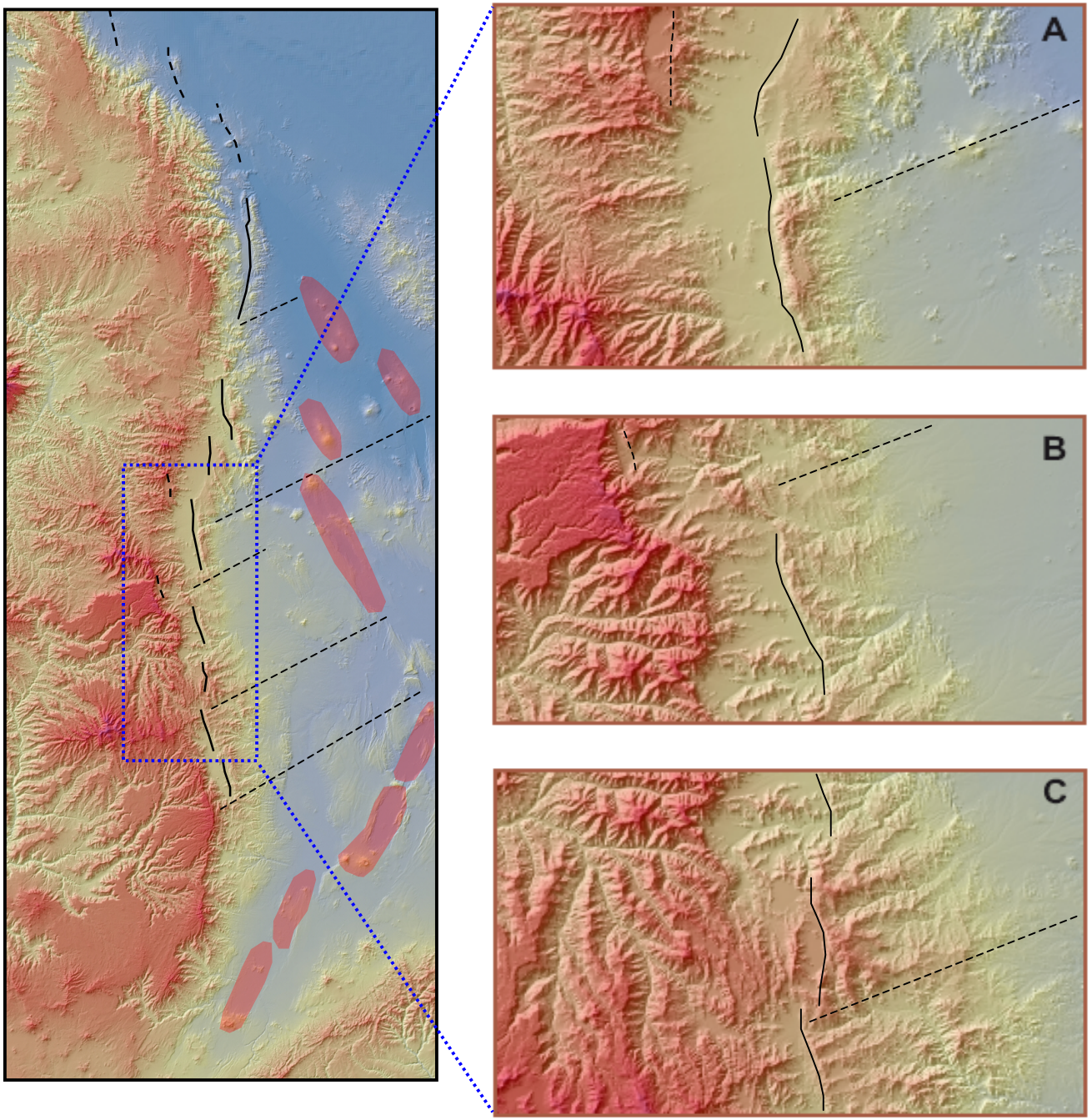
The aim of this study :

- study in detail the morpho-tectonic evolution of this system

  => *check if the structures are really abandoned*

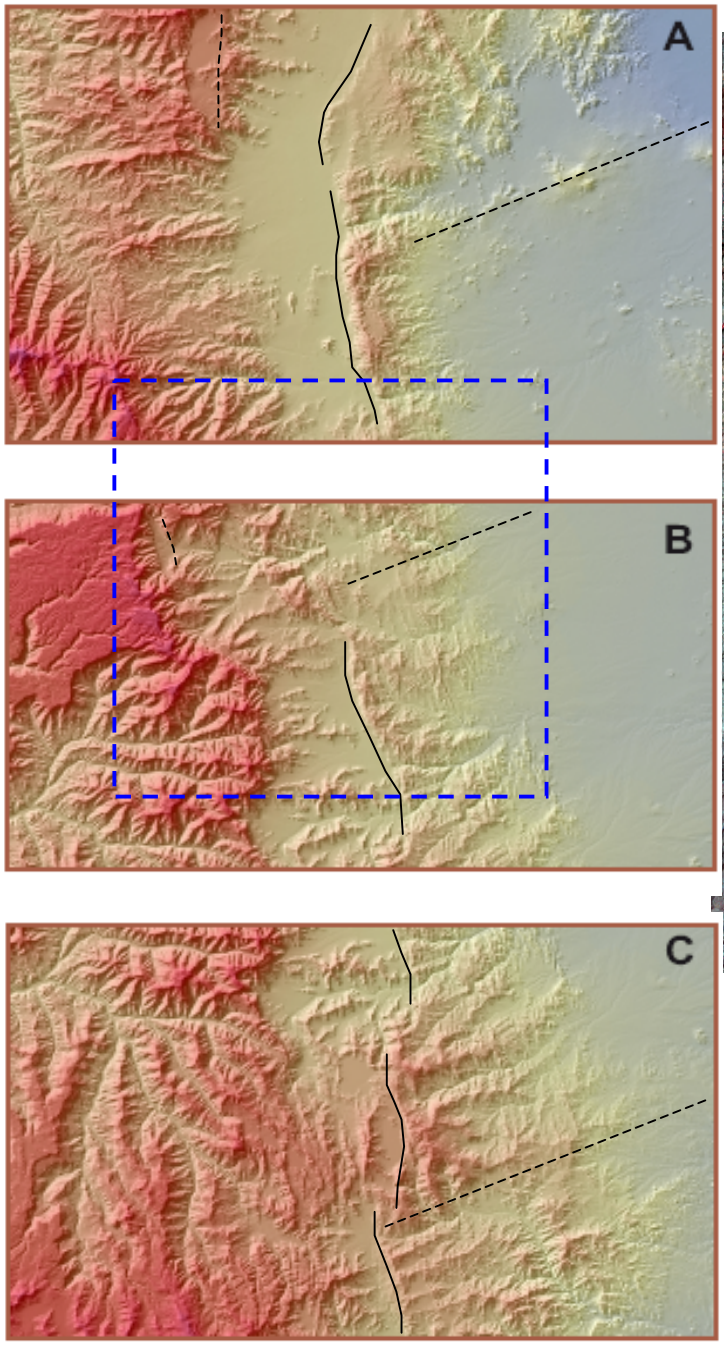
Ultimately :

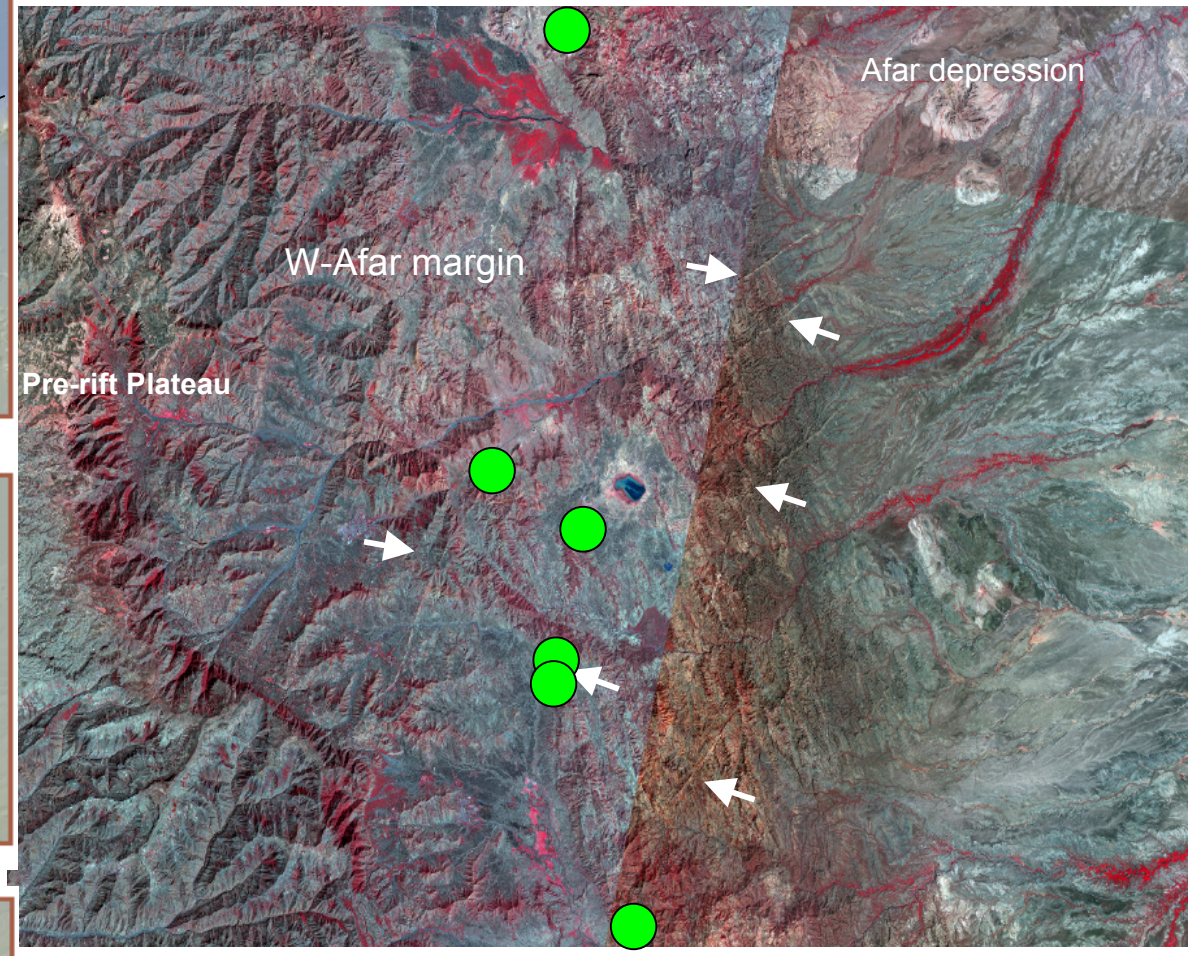
- investigate the partitioning of strain in space &time
- which type of structure accommodate extension & attenuation of the crust



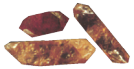
Focus zone

of this study



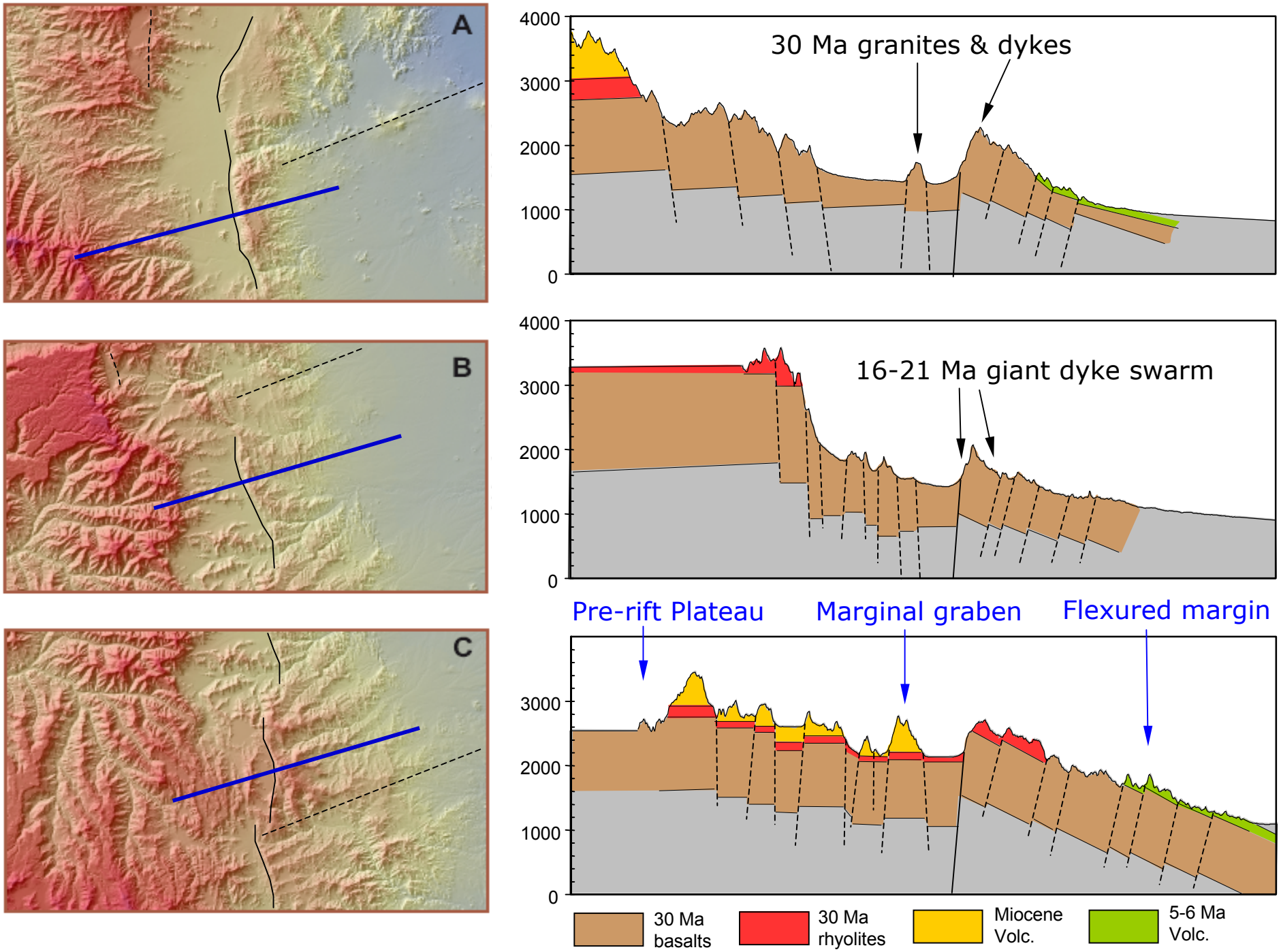


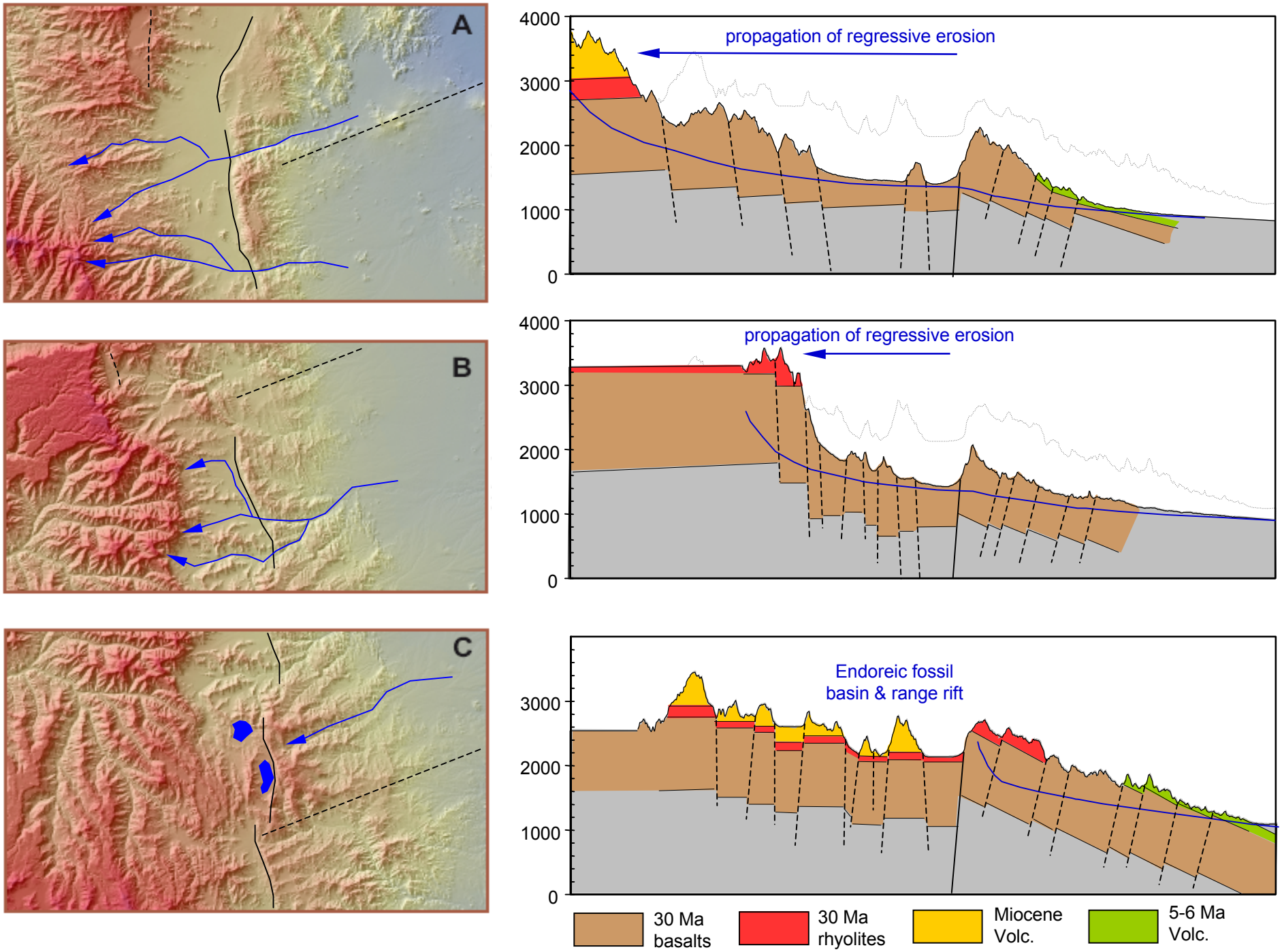
=> low-T (U-Th)/He thermochronology

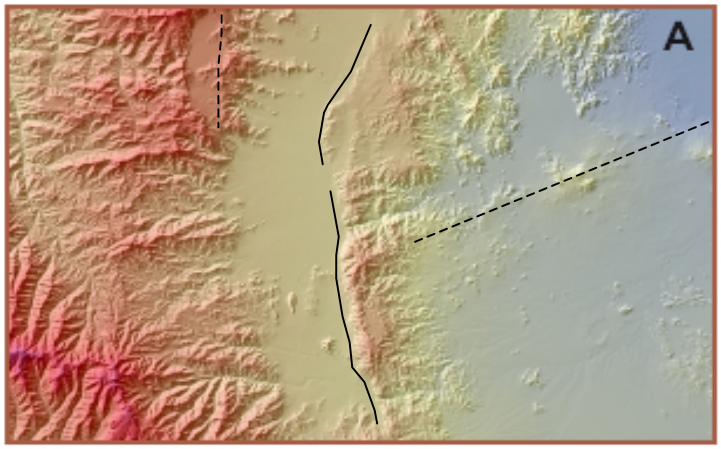


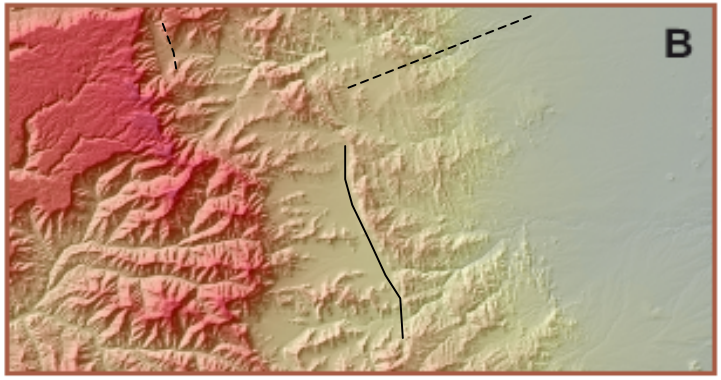
Zircon, Tc ~180 °C : age of dykes

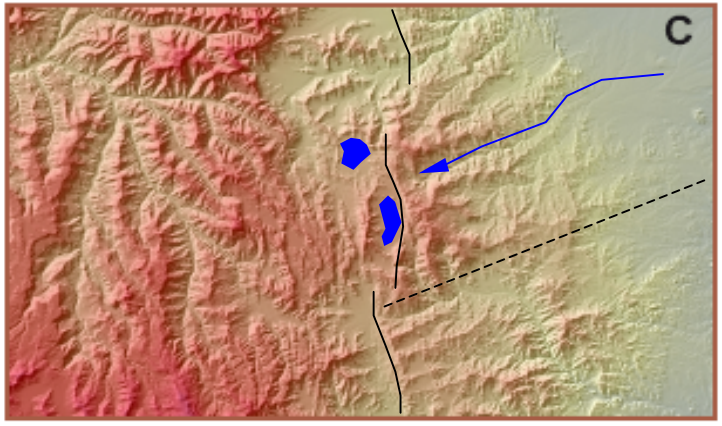
apatites, Tc ~ 70 °C : cooling history


A
B
C
4000
3000
2000
1000
0
30 Ma granites & dykes
16-21 Ma giant dyke swarm
Pre-rift Plateau
Marginal graben
Flexured margin
30 Ma basalts
30 Ma rhyolites
Miocene Volc.
5-6 Ma Volc.

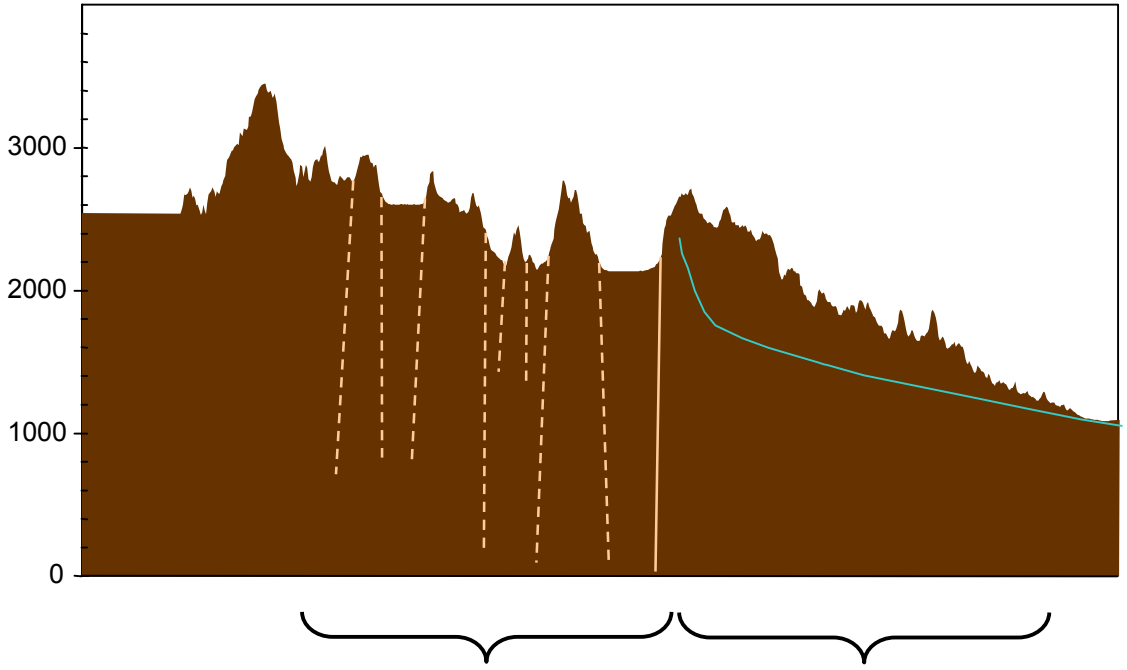

A
B
C
4000
3000
2000
1000
0
propagation of regressive erosion
propagation of regressive erosion
Endoreic fossil
basin & range rift
30 Ma
basalts
30 Ma
rhyolites
Miocene
Volc.
5-6 Ma
Volc.

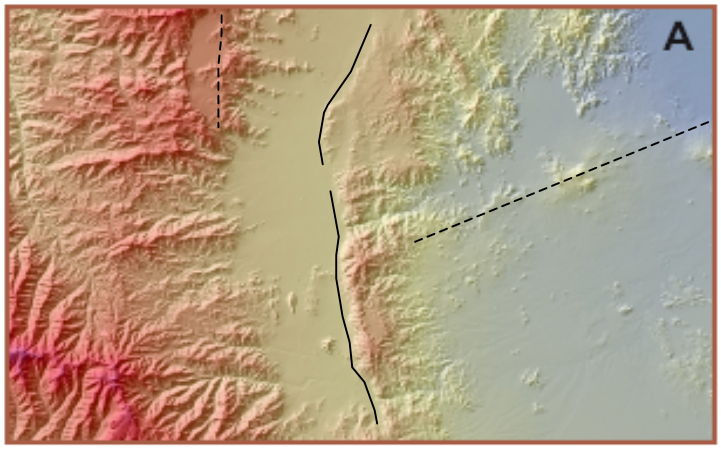


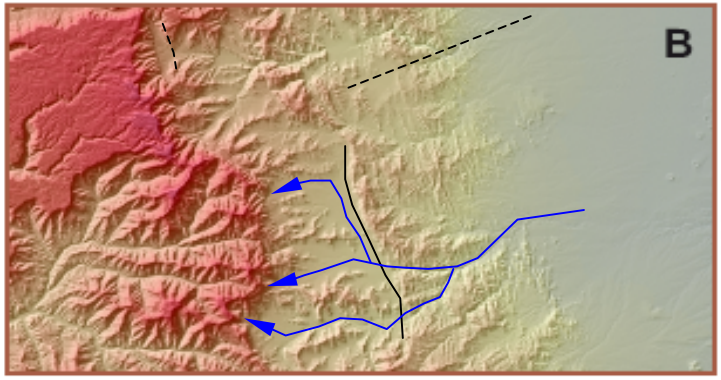


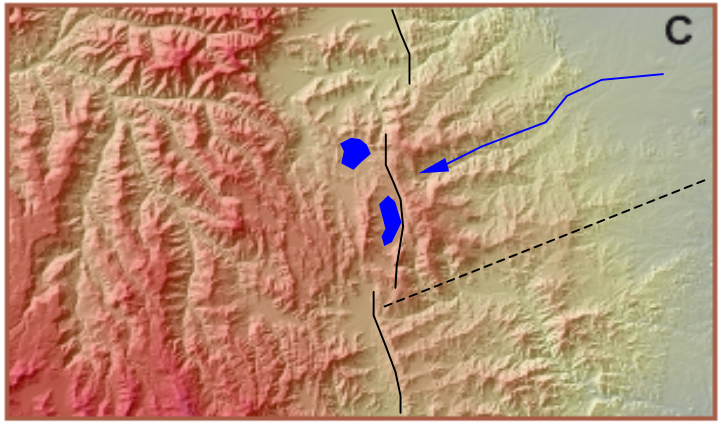


Propagation of the Erosion wave

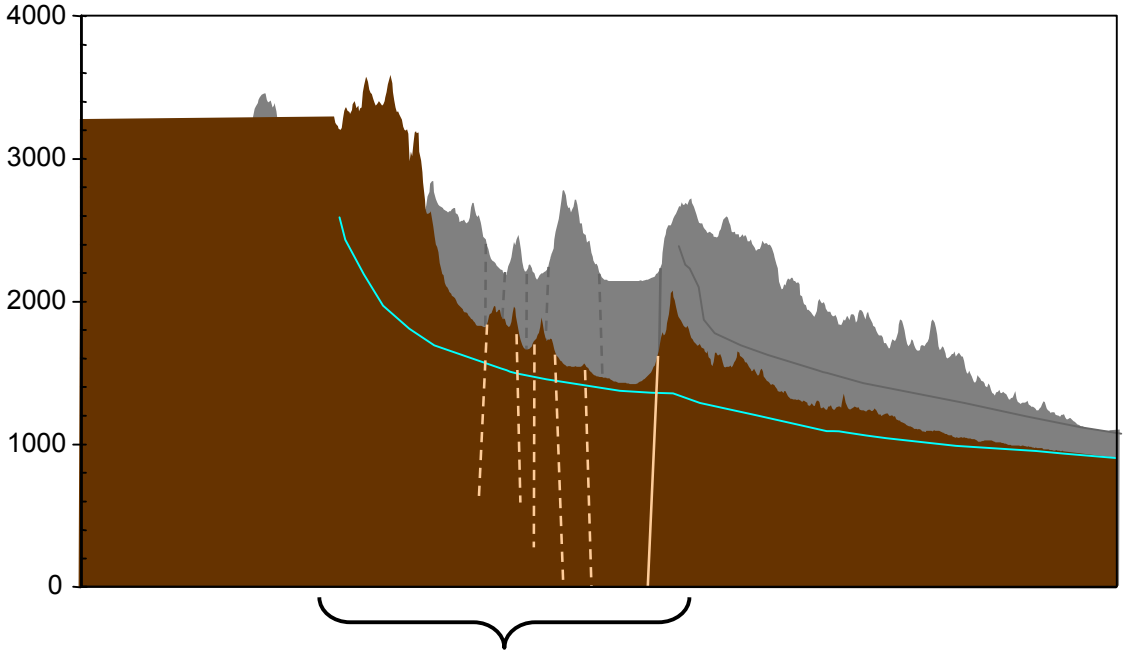




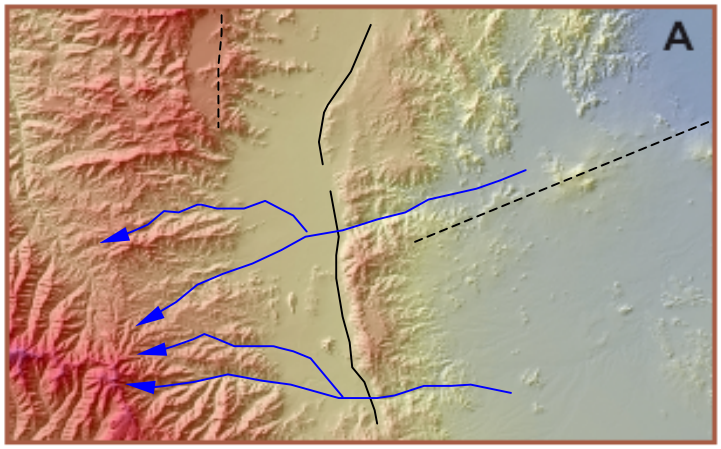


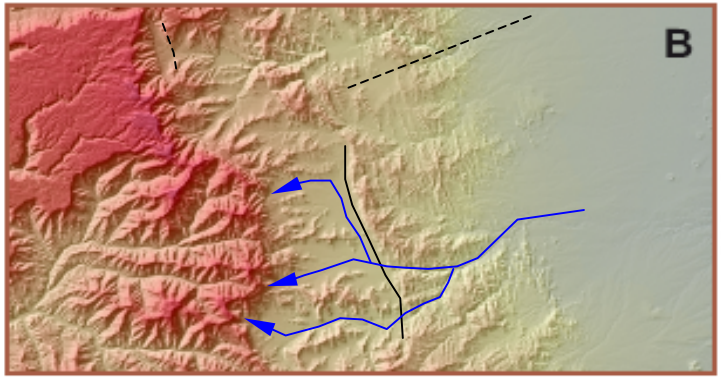


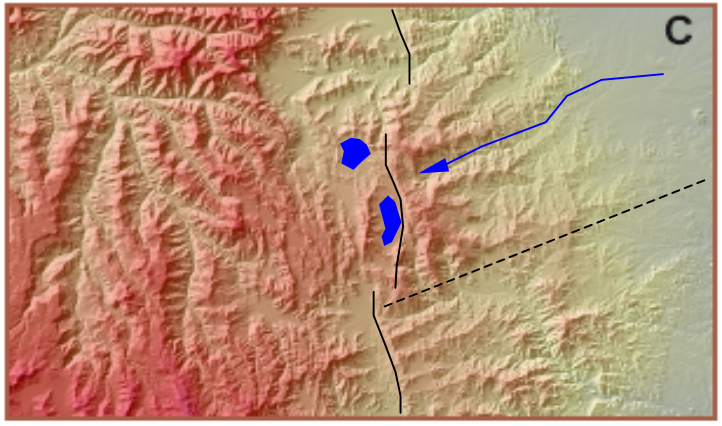
Propagation of the Erosion wave



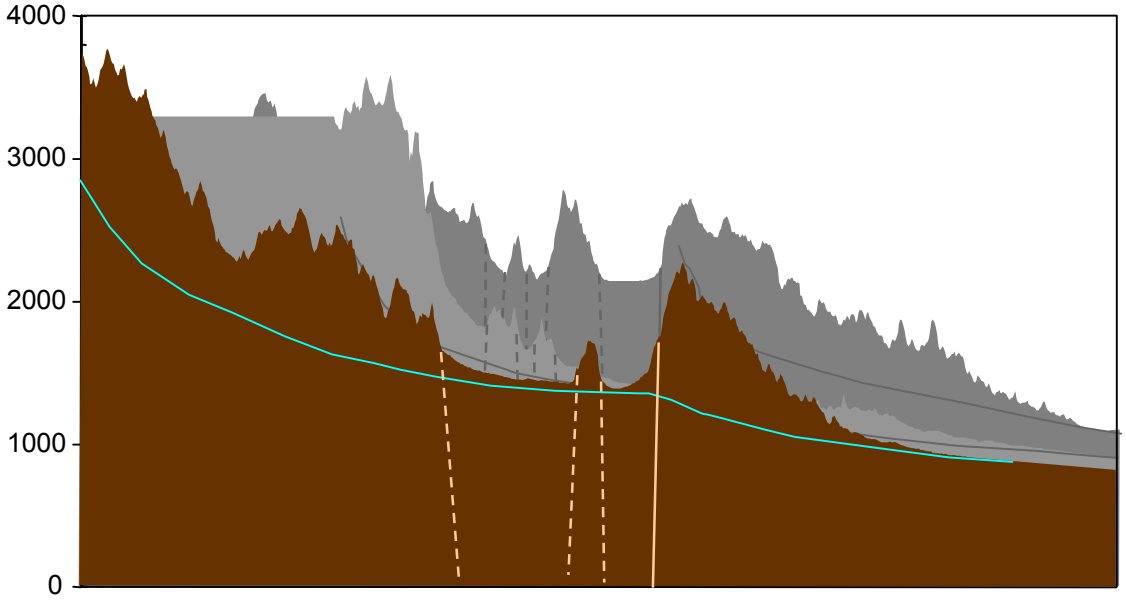
=> degradation of the rifting structures
by propagation of an erosion wave



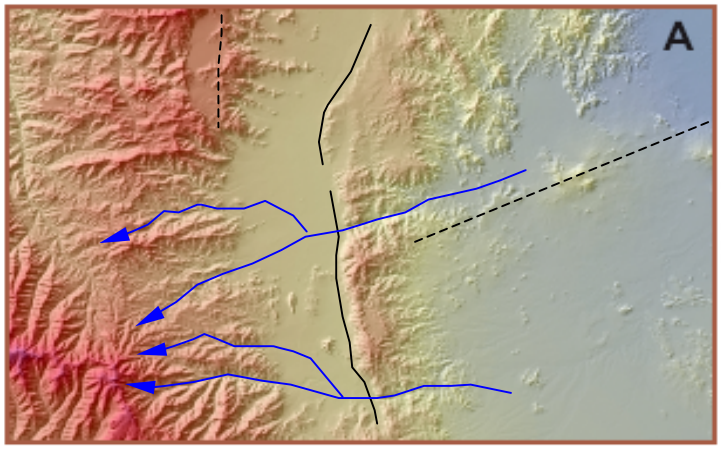


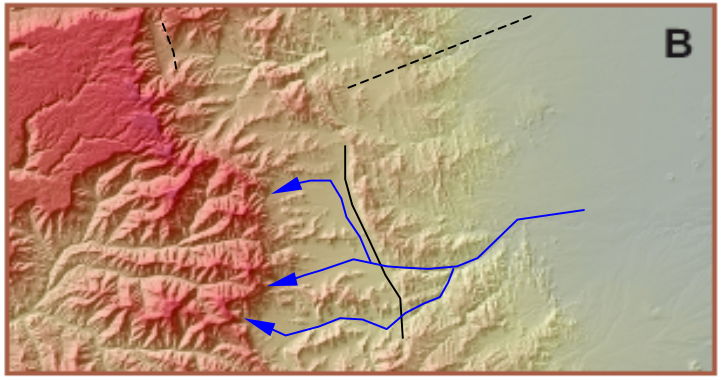


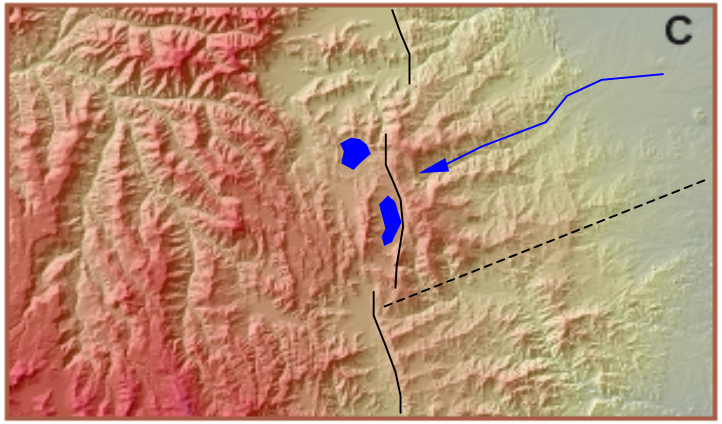
Propagation of the Erosion wave



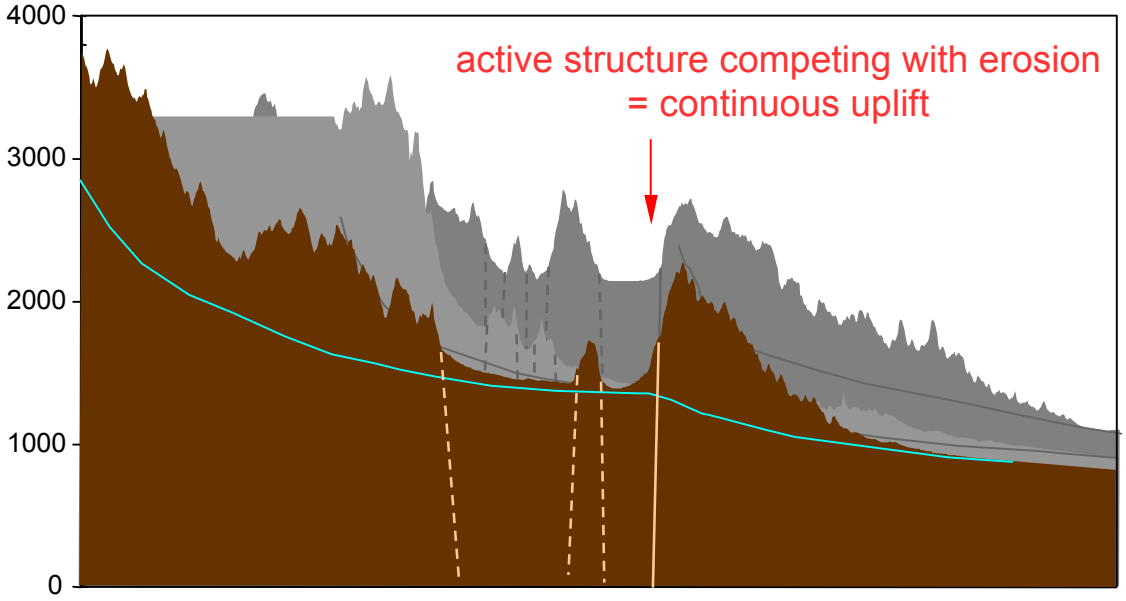
=> degradation of the pre-rift plateau
by propagation of an erosion wave

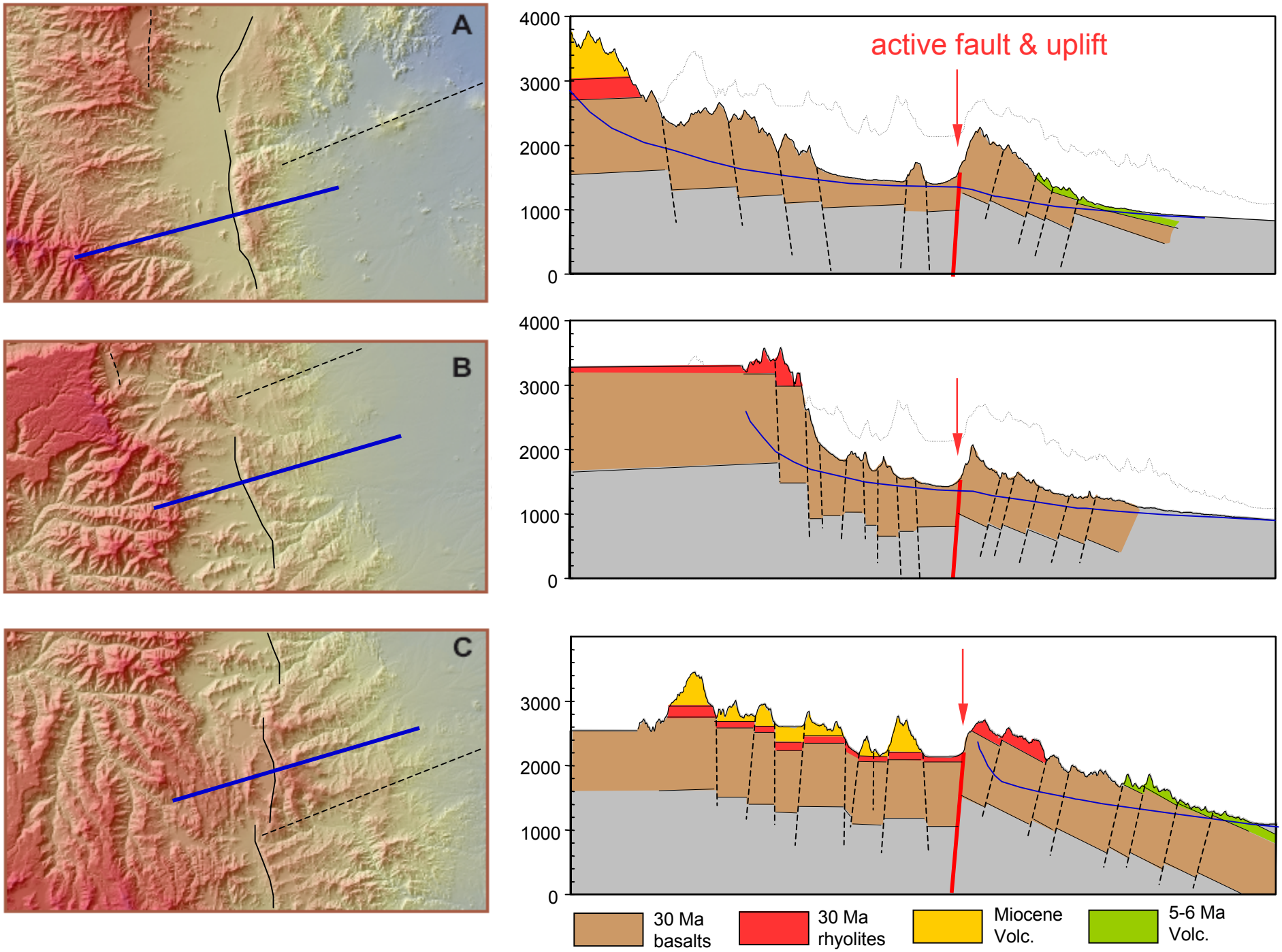


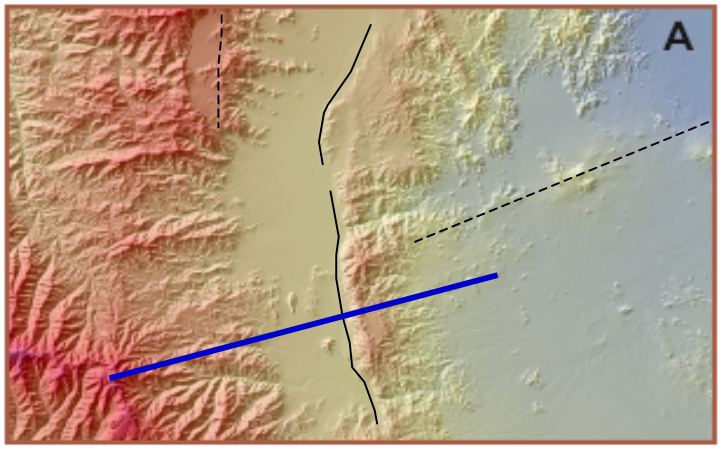


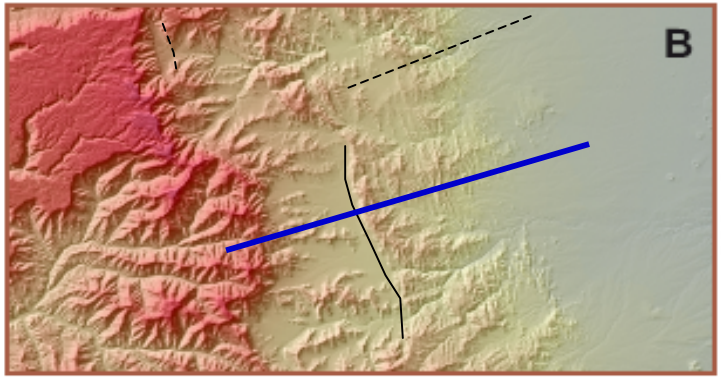


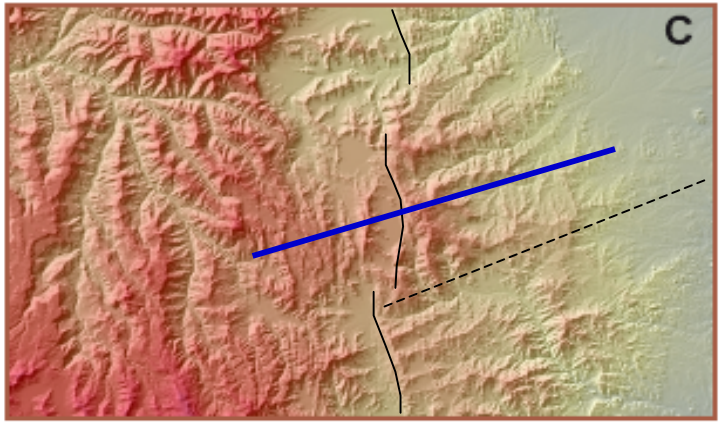
Tectonic implication :

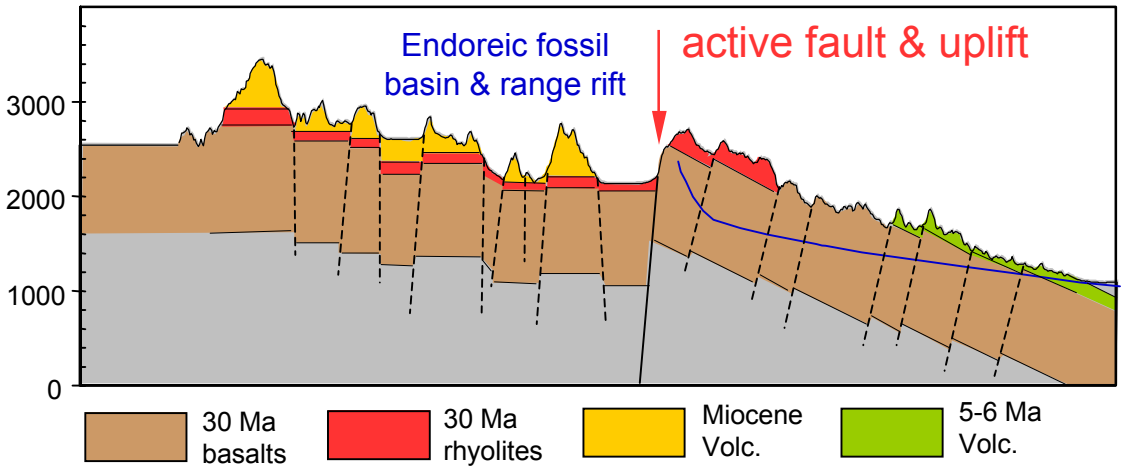


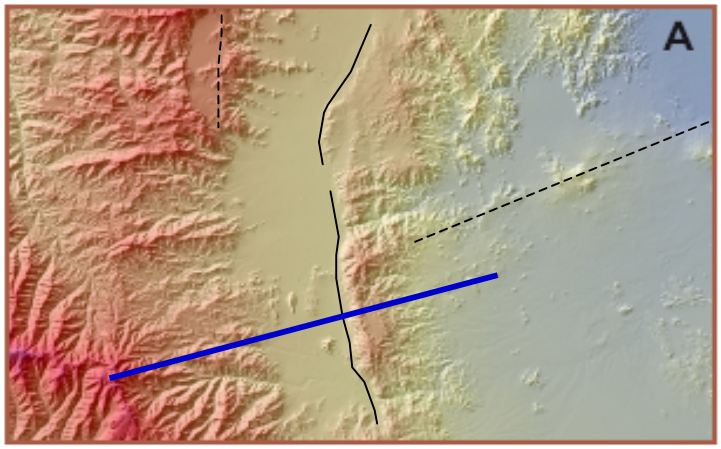

A
B
C
4000
3000
2000
1000
0
active fault & uplift
30 Ma basalts
30 Ma rhyolites
Miocene Volc.
5-6 Ma Volc.

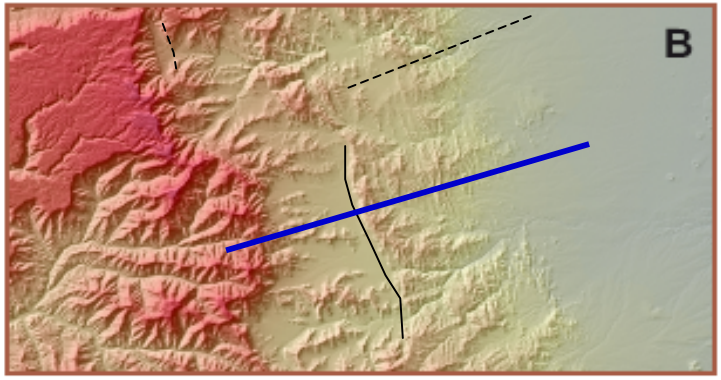

A

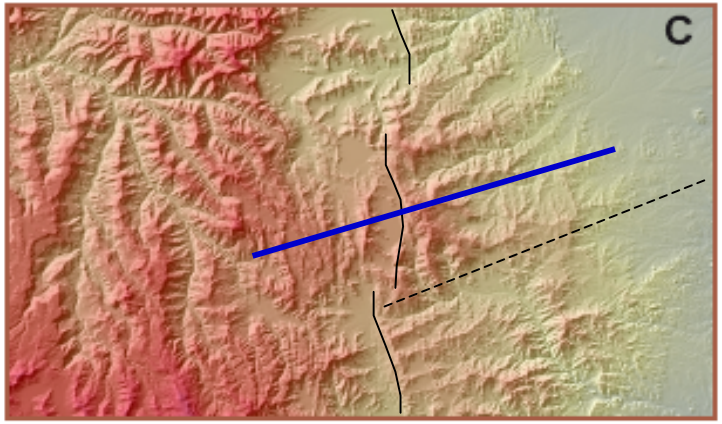

B

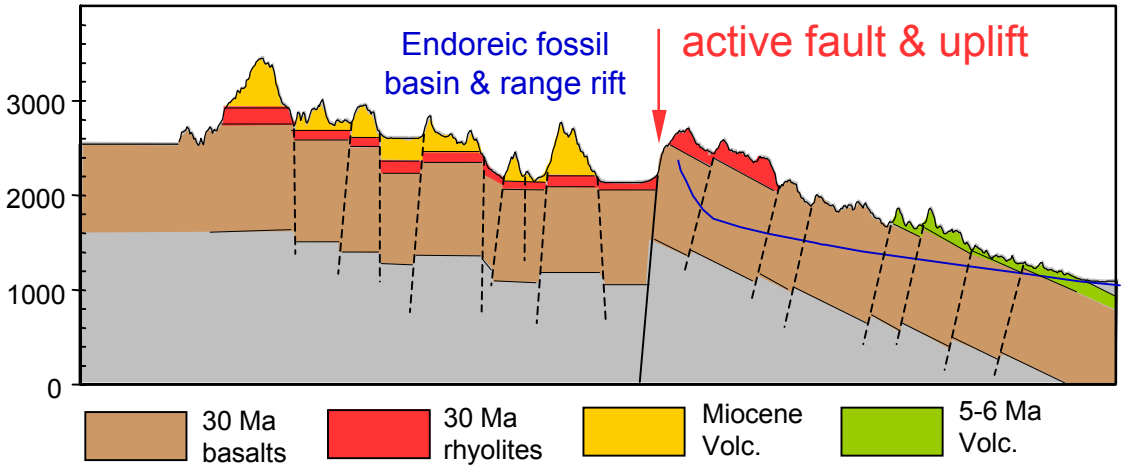

C

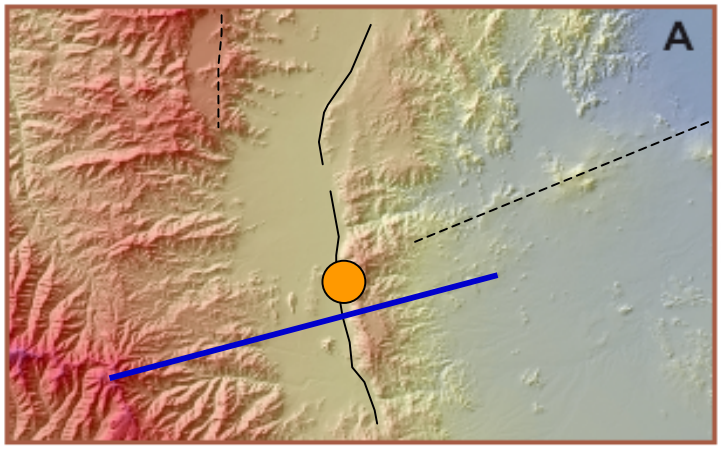

Endoreic fossil
basin & range rift
active fault & uplift
3000
2000
1000
0
30 Ma
basalts
30 Ma
rhyolites
Miocene
Volc.
5-6 Ma
Volc.

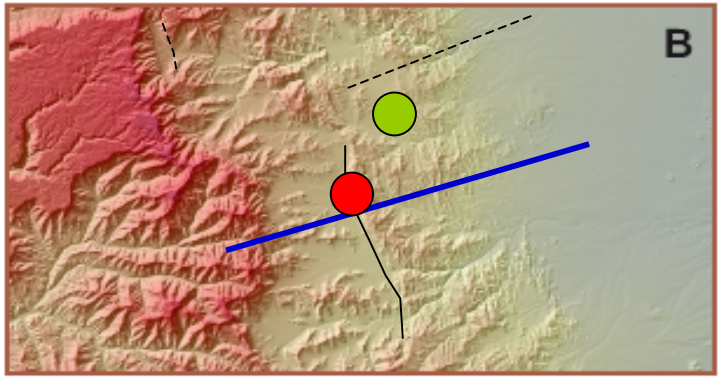

A

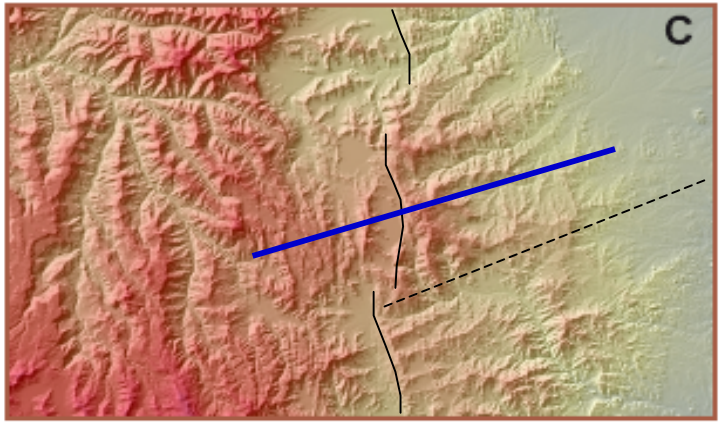

B


C


Endoreic fossil
basin & range rift
active fault & uplift
3000
2000
1000
0
30 Ma
basalts
30 Ma
rhyolites
Miocene
Volc.
5-6 Ma
Volc.







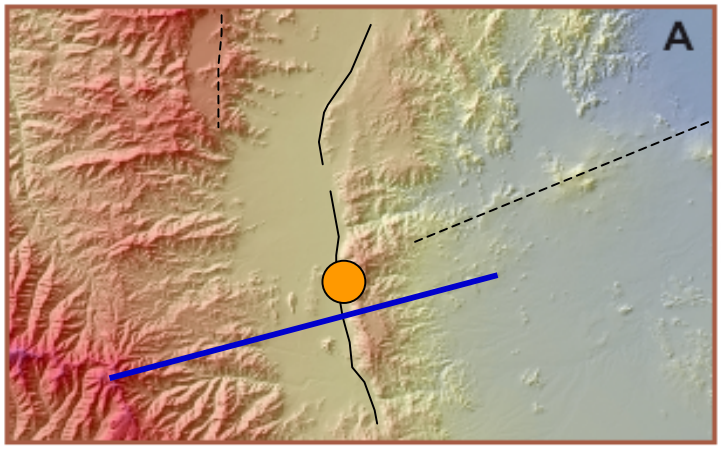
Age constraints for development of this system

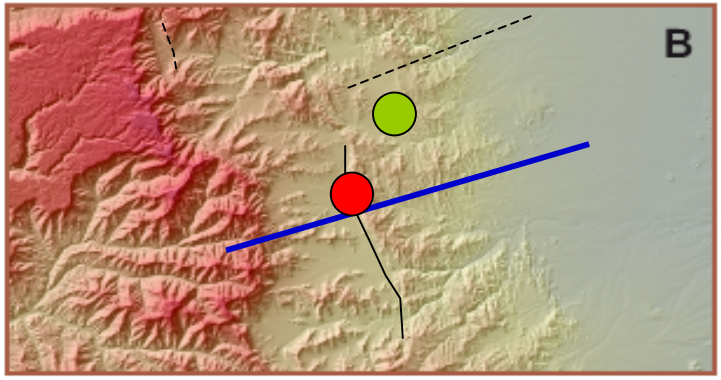
- flexure and drop of base level :
  - younger than the tilted 5-6 Ma marginal volc.
  - older than 3.8 Ma volc. in Afar (?)

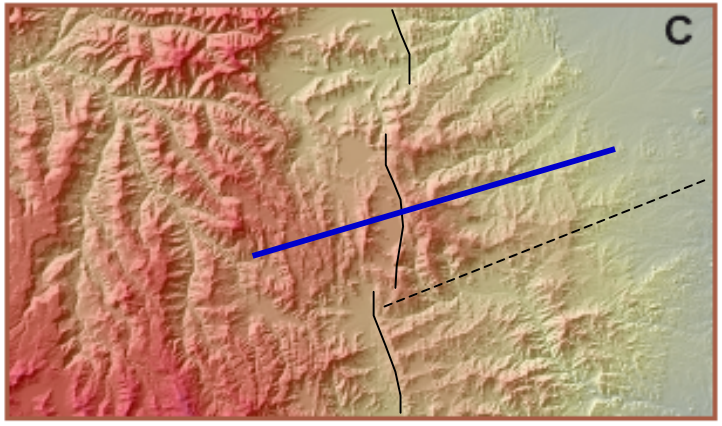
- unroofing & dissection of the marginal grabens :

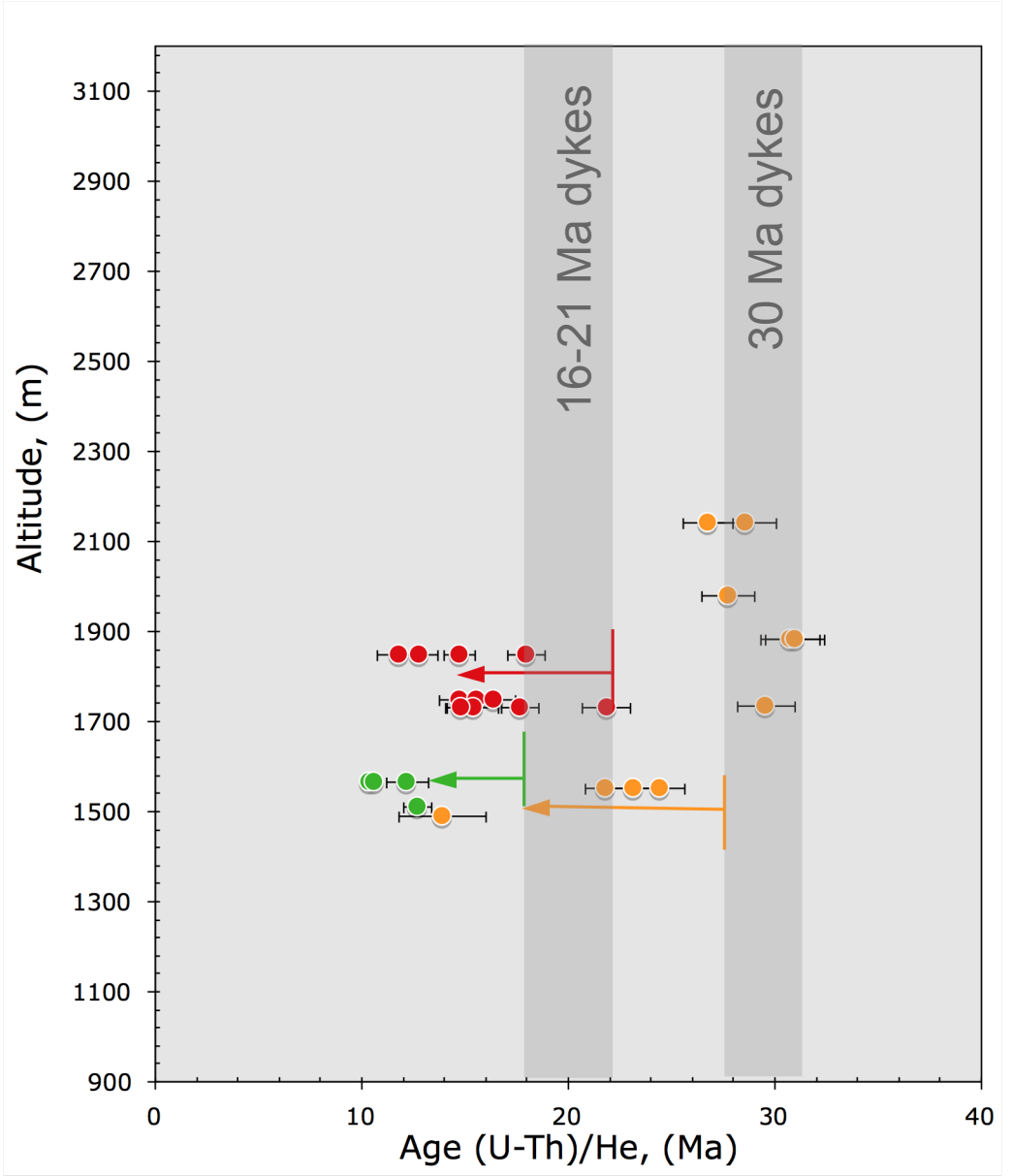
=> low-T (U-Th)/He thermochronology

apatites, Tc ~ 70 °C : cooling history

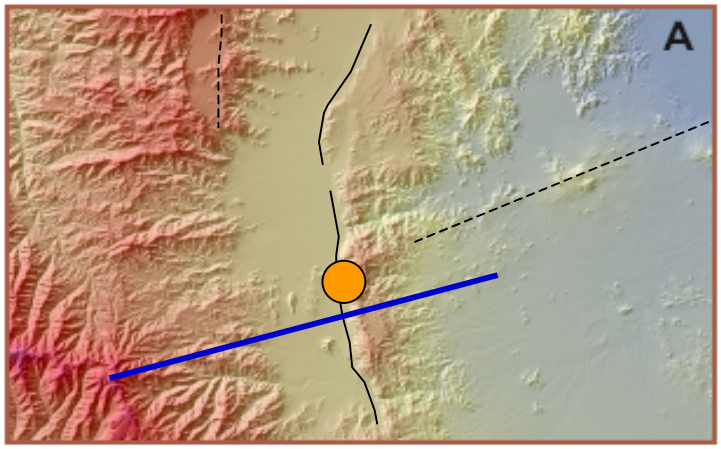


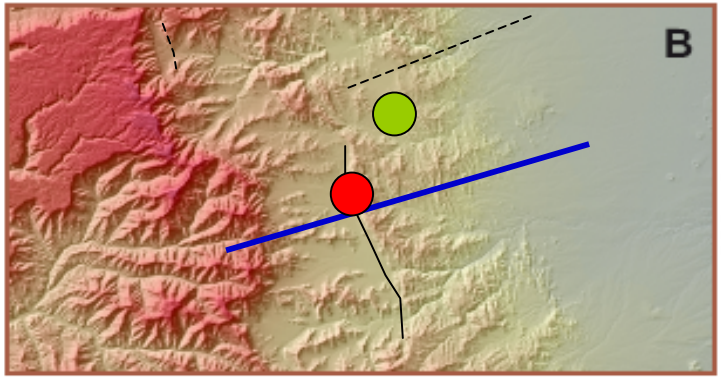


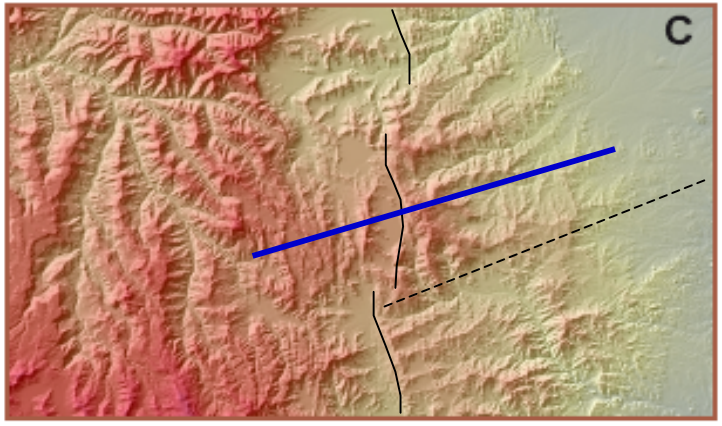


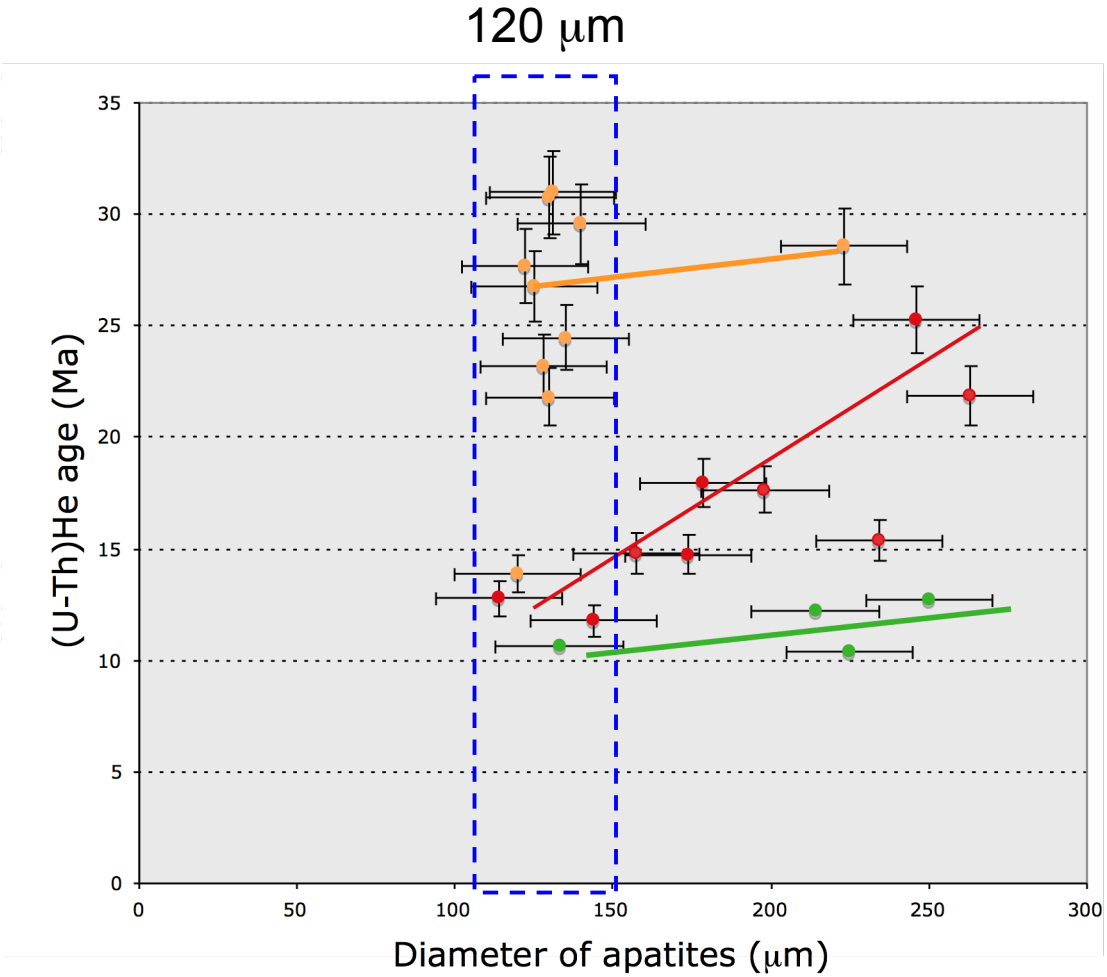


⇒ *since emplacement of dykes apatites at depth have lost their $^{4}He^{*}$*



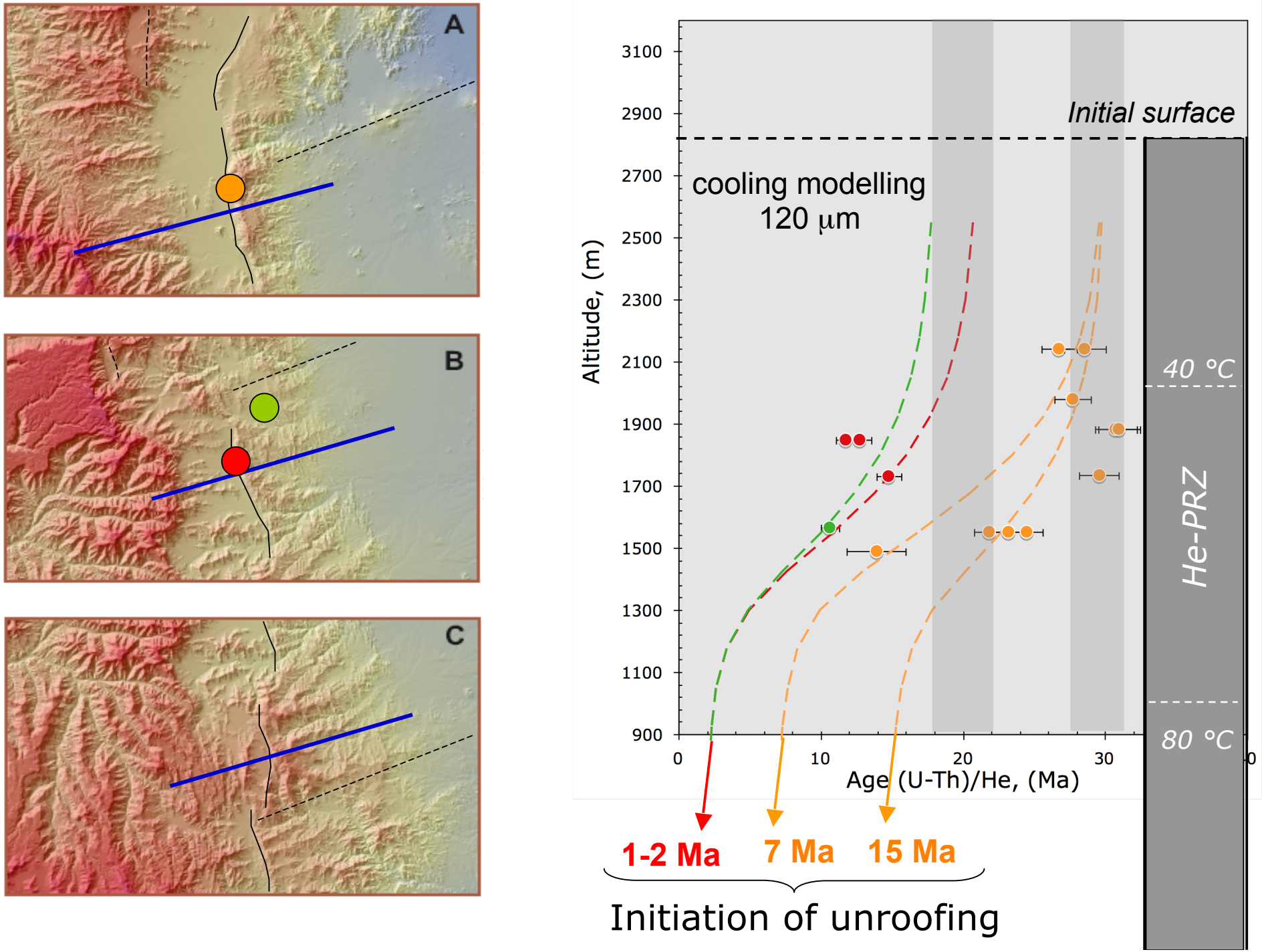


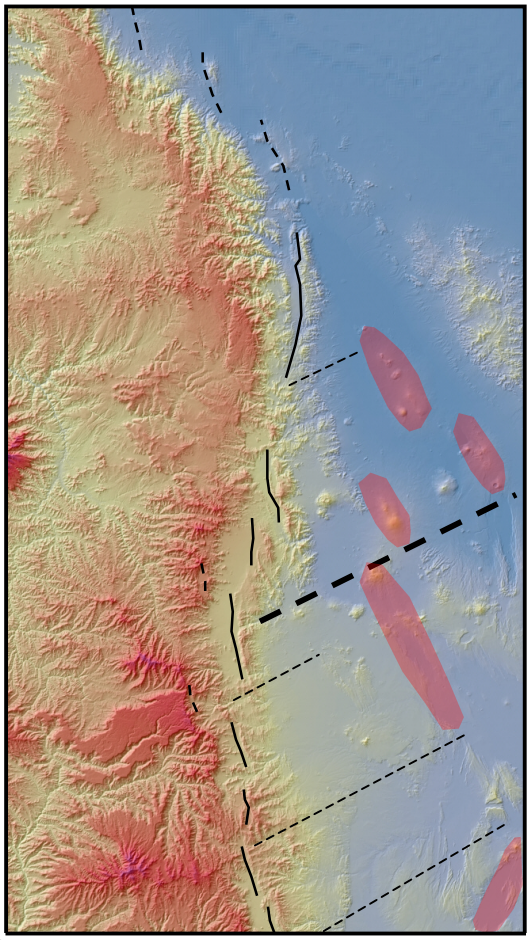


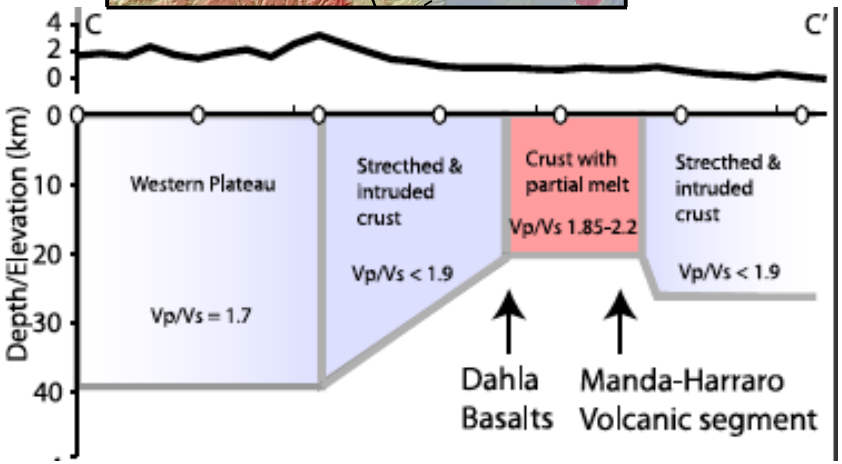


⇒ *diffusion of $^4He^*$ in apatites*

is function of grain size


A
B
C
Initial surface
cooling modelling
120 μm
Altitude, (m)
3100
2900
2700
2500
2300
2100
1900
1700
1500
1300
1100
900
0
10
20
30
Age (U-Th)/He, (Ma)
40 °C
He-PRZ
80 °C
1-2 Ma
7 Ma
15 Ma
Initiation of unroofing





Conclusion & implications

- marginal graben system morphology :

  => *2 scarps : erosion + tectonic*

- segmentation of the margin seems very old :

  => *21 Ma (rifting stage)*

- northern part of Afar :

  => *older unroofing = older low-lands*

  = earlier structures

- tectonics is still active in the structures which are bounding the flexure :

  => *strain ?*

  => *which structures to accommodate the max of crust attenuation ?*