Cenozoic Orogenic Growth of the North Andes: Shortening and Exhumation Histories of the Eastern Cordillera of Colombia*

Mauricio Parra[1], Andrés Mora[2], Edward R. Sobel[1], Manfred R. Strecker[1], Carlos Jaramillo[3], Paul B. O'Sullivan[4], and Román González[5]

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[1]Instutut für Geowissenschaften, Universität Potsdam, Potsdam, Germany (Mauricio@geo.uni-potsdam.de)
[2]Ecopetrol, Instituto Colombiano del Petróleo, Bucaramanga, Colombia
[3]Center for Tropical Paleoecology and Archeology, Smithsonian Tropical Research Institute, Panama, Panama
[4]Apatite to Zircon, Inc., Viola, ID
[5]Hocol S.A, Bogotá, Colombia

Abstract

Cenozoic to Recent oblique subduction and tectonic accretion of oceanic terranes in the NW corner of South America have resulted in orogenesis and foreland basin formation in the Colombian Andes. Basin analysis and apatite and zircon fission-track data from west of the modern volcanic arc of the Central Cordillera reveal a Cenozoic history of tectonic inversion and orogenic propagation. Late Cretaceous to Paleocene uplift of the Central Cordillera resulted in initial foreland basin development. Subsequent bivergent tectonic inversion of the Eastern Cordillera subdivided a formerly continuous basin into the present-day Magdalena Valley basin to the west and the Llanos basin to the east. Growth strata and episodes of rapid accumulation documented by the Cenozoic foreland record of these basins, as well as the present structural configuration of the mountain range, suggest eastward transferal of the tectonic load through an initial pop-up uplift of the Eastern Cordillera during the late Eocene-early Oligocene. Limited eastward migration of the leading edge of deformation since then seems to have resulted from contractional and transpressional deformation being accommodated along pre-existing anisotropies. Furthermore, variable thickness of the pre-orogenic stratigraphy may have prevented eastward orogenic migration by modifying critical taper angles. Denudation inferred from bedrock thermochronology and gravel petrography in palynologically dated foreland deposits at the eastern margin suggest moderate exhumation rates (~0.3 mm/yr) during the late Oligocene-Miocene, followed by rapid exhumation (1-2 mm/yr) in the Pliocene. We attribute this Pliocene acceleration in exhumation to focused denudation on the windward side of the orogen, where moisture-laden winds caused an effective erosional regime, resulting in a positive feedback with tectonic processes.

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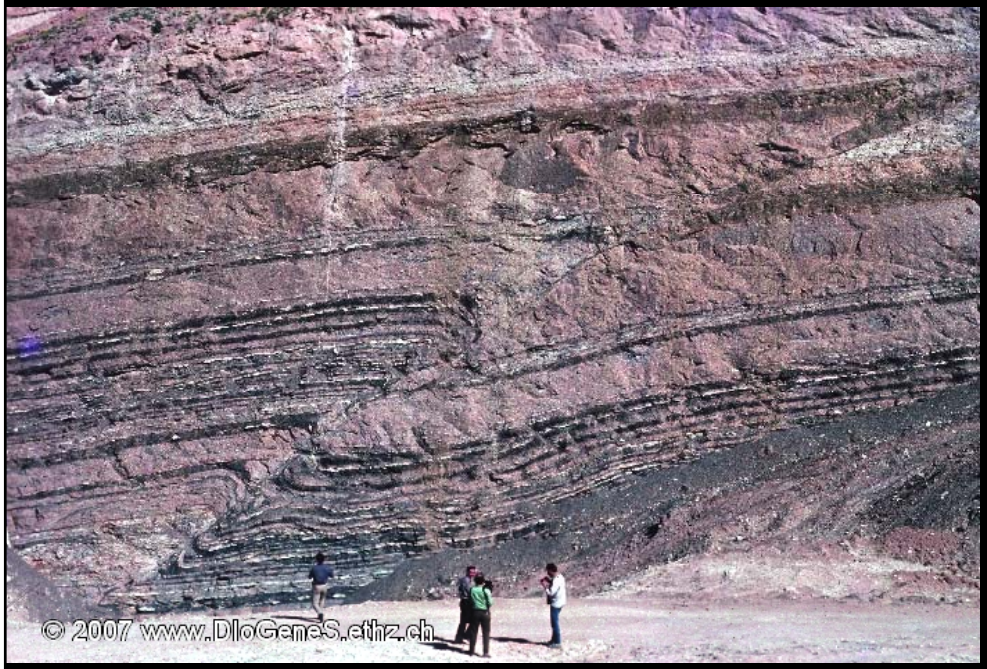
and R. González***

*Smithsonian Tropical Research Instuitute
**Apatite to Zircon, Inc
***Hocol S.A

Institute of Geosciences, University of Potsdam, Germany

Dating rock deformation vs Dating rock exhumation



- Assesment of oil prospectivity
- Processes and rates of orogenesis

Are deformation and exhumation synchronous across an orogen?

M. Parra et al, AAPG 2008

Dating rock deformation

Direct indicators

- Fault mineralization
- Cross-cutting relations
- Growth strata

Indirect indicators

- Subsidence analysis
- Provenance signal of newly uplifted sources
- Cooling related to erosional or tectonic exhumation

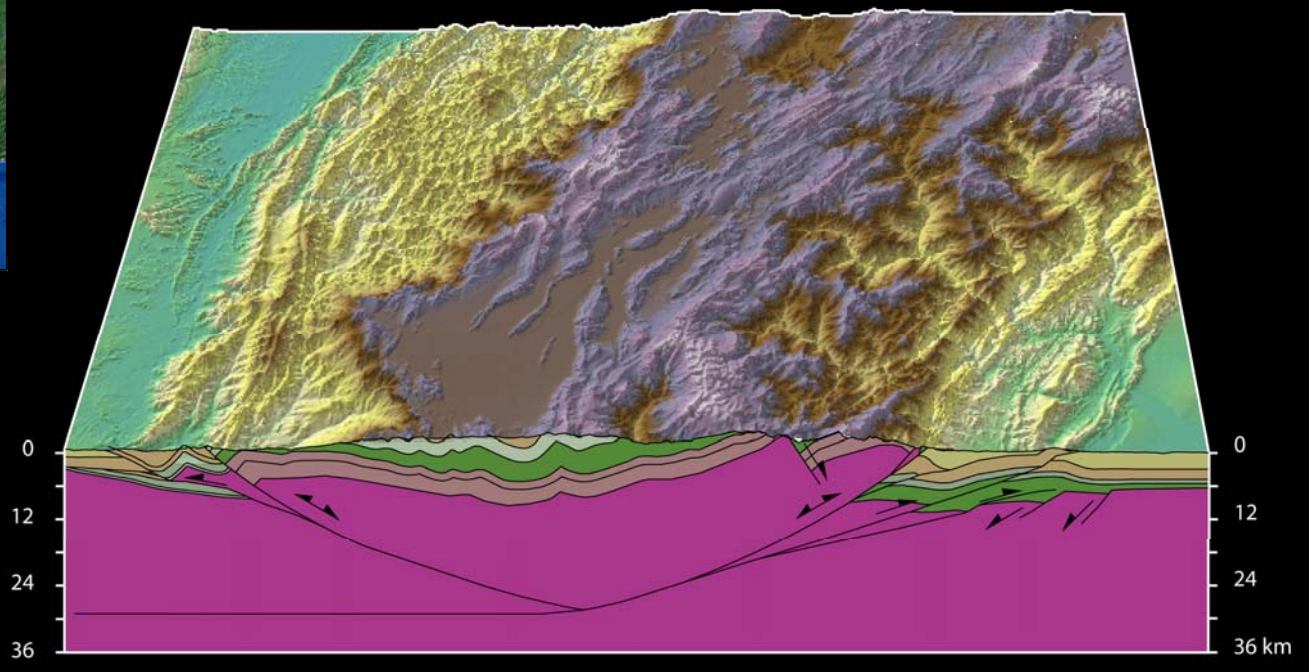
Courtesy B. Horton (UT)

Can we use thermochronology to date deformation?

M. Parra et al, AAPG 2008

The Eastern Cordillera

- Seismic reflection lines
- Borehole information
- Stratigraphy of Cenozoic basins
- Subsidence history



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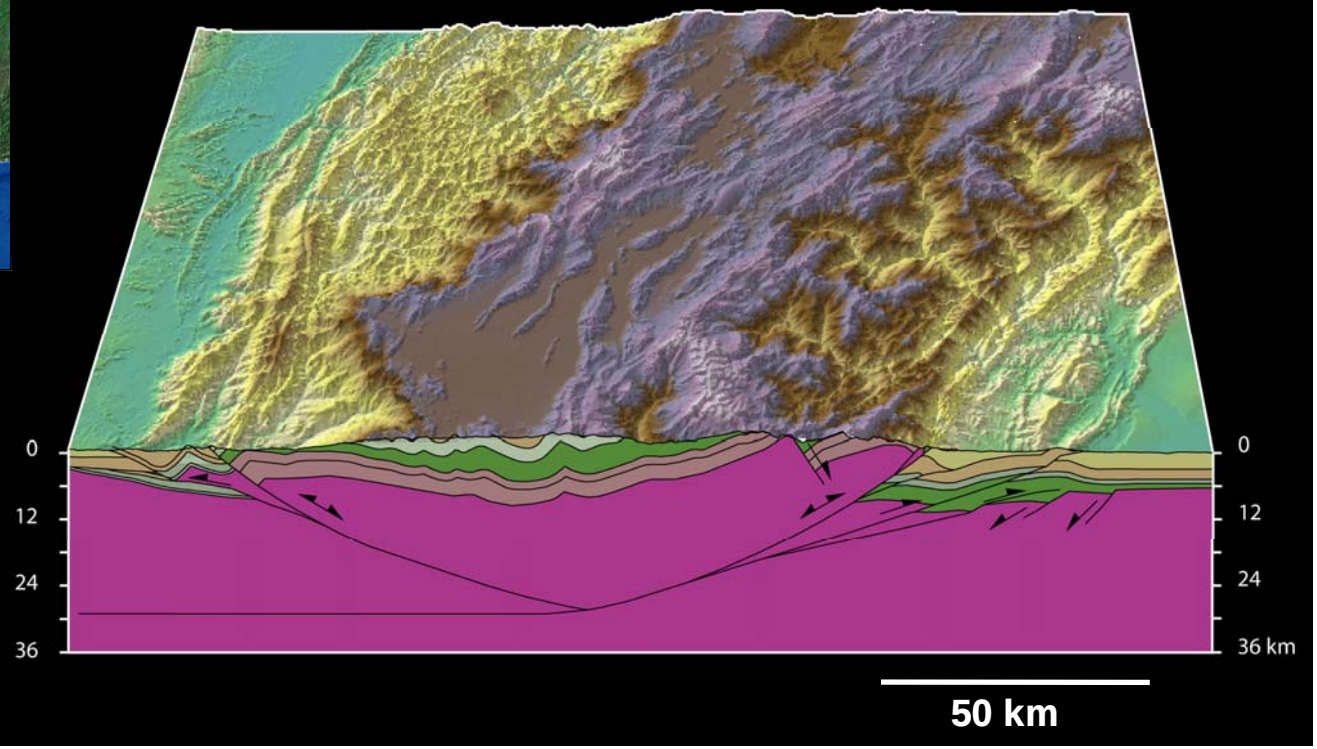
The Eastern Cordillera

- Deformation history
- Exhumation history
- Conceptual model that reconciles temporal discrepancies between both processes



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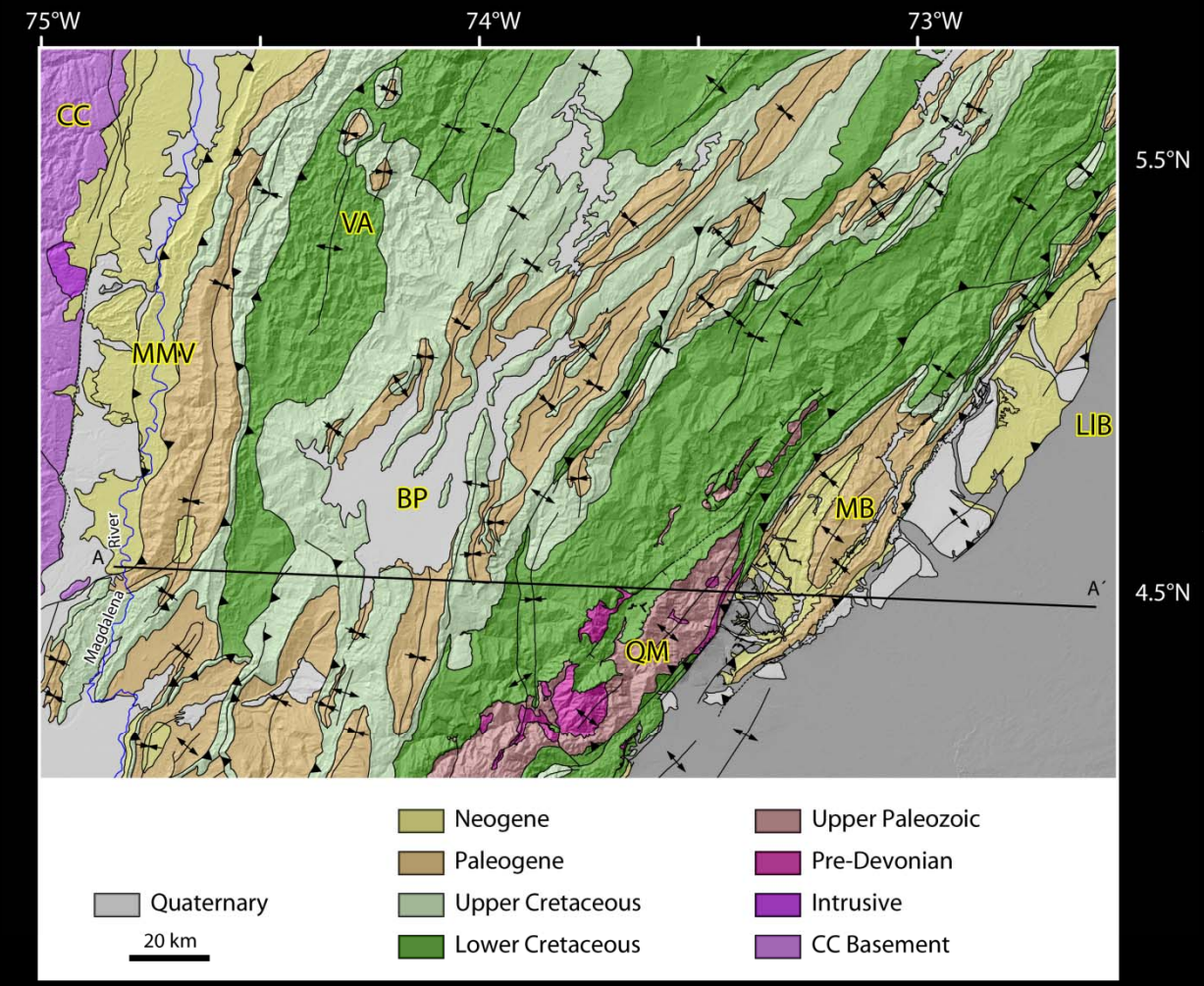
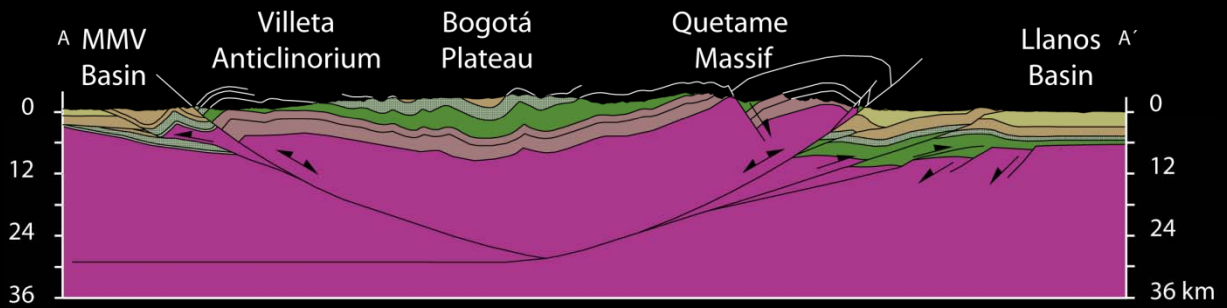
The Eastern Cordillera

- Double-verging orogen
- Inversion tectonics
- Mesozoic rift basin
- Cenozoic foreland basin system





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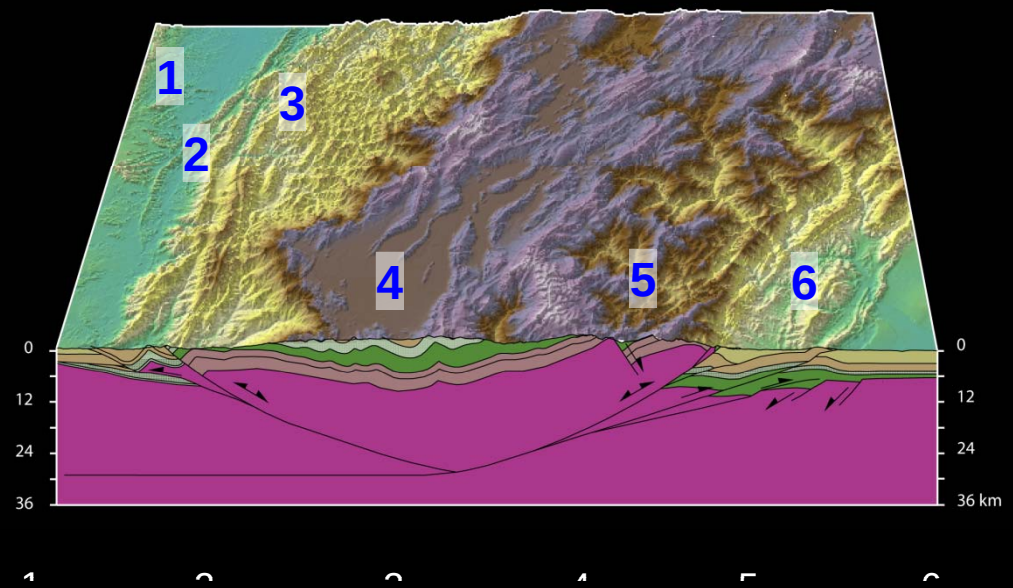
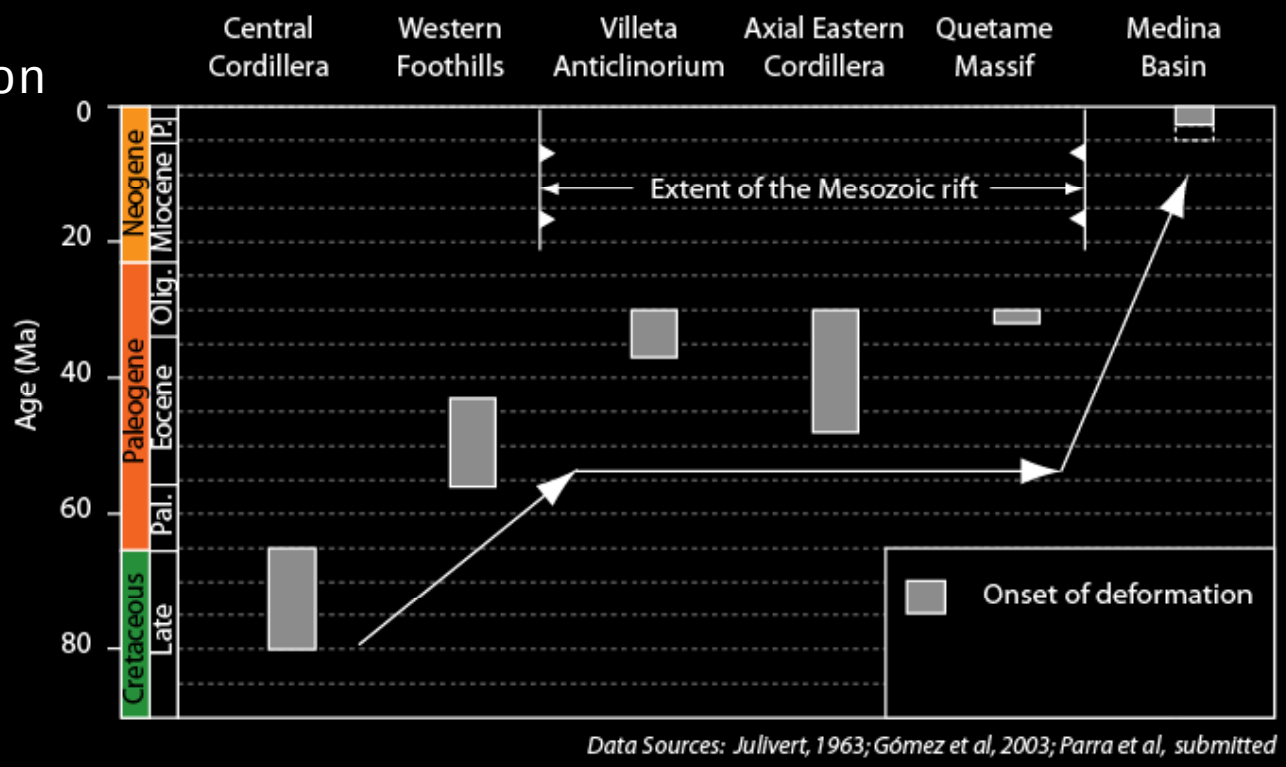
Deformation history

1. Provenance-basin analysis
2, 6. Cross-cutting relations
3, 4. Growth strata
5. Subsidence analysis



- Cratonward migration of orogenic front

Locus of Cenozoic deformation largely controlled by inherited anisotropies



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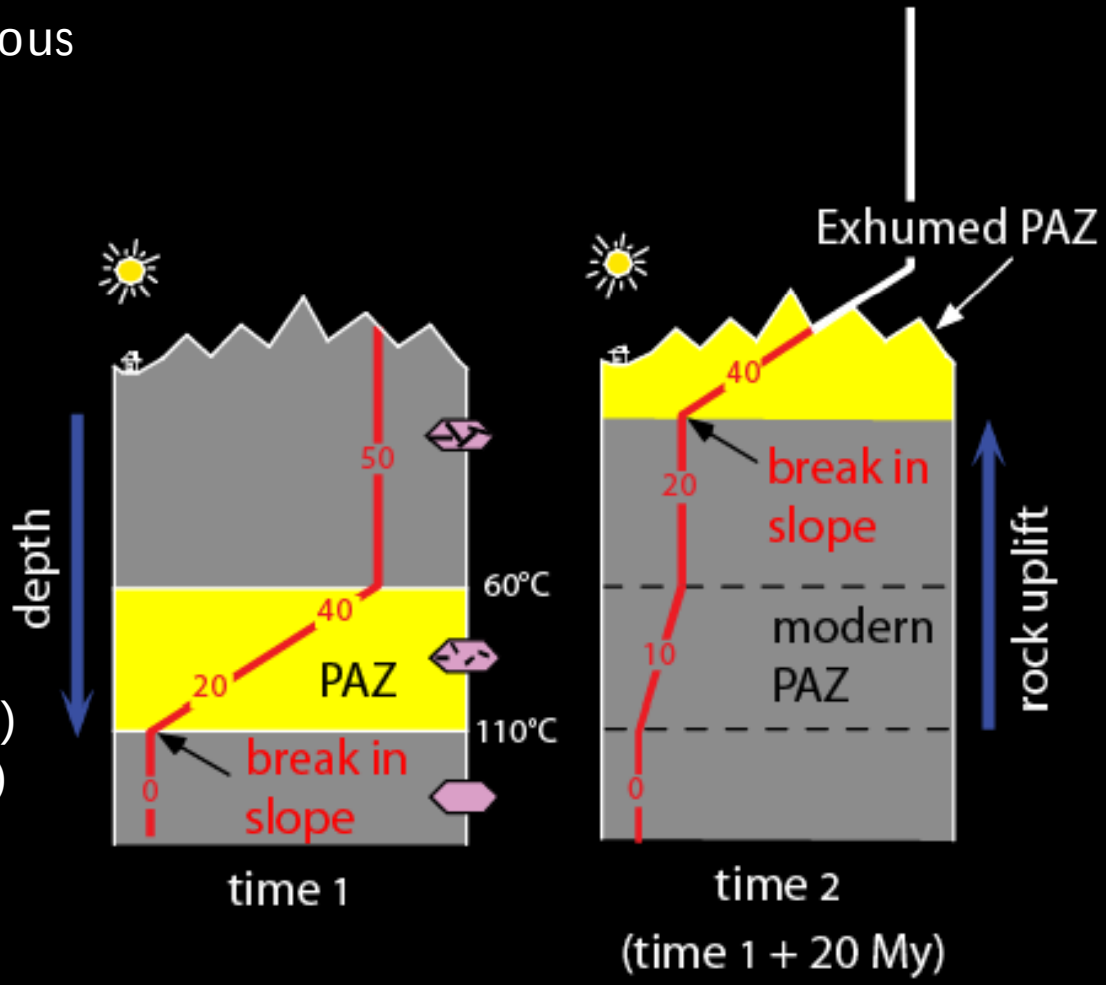
Fission-track dating

- Thermal stratigraphy for various thermochronometers

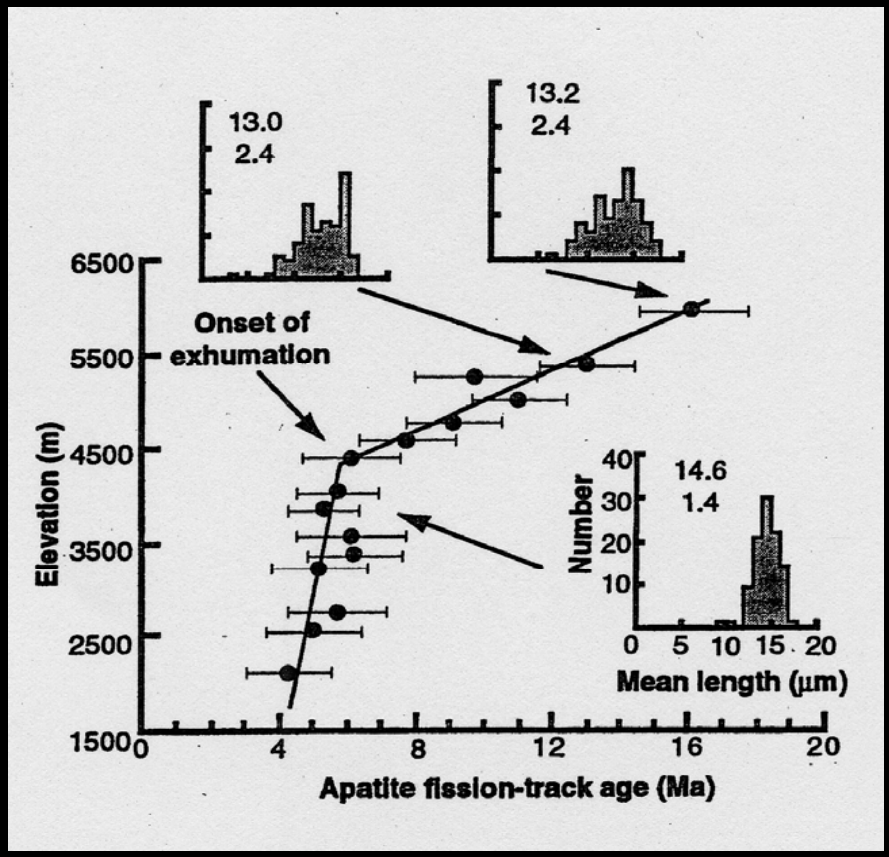


Apatite FT: ~110 °C (3-4 km)
Zircon FT: ~250 °C (8-10 km)

M. Parra et al, AAPG 2008

Fission-track dating

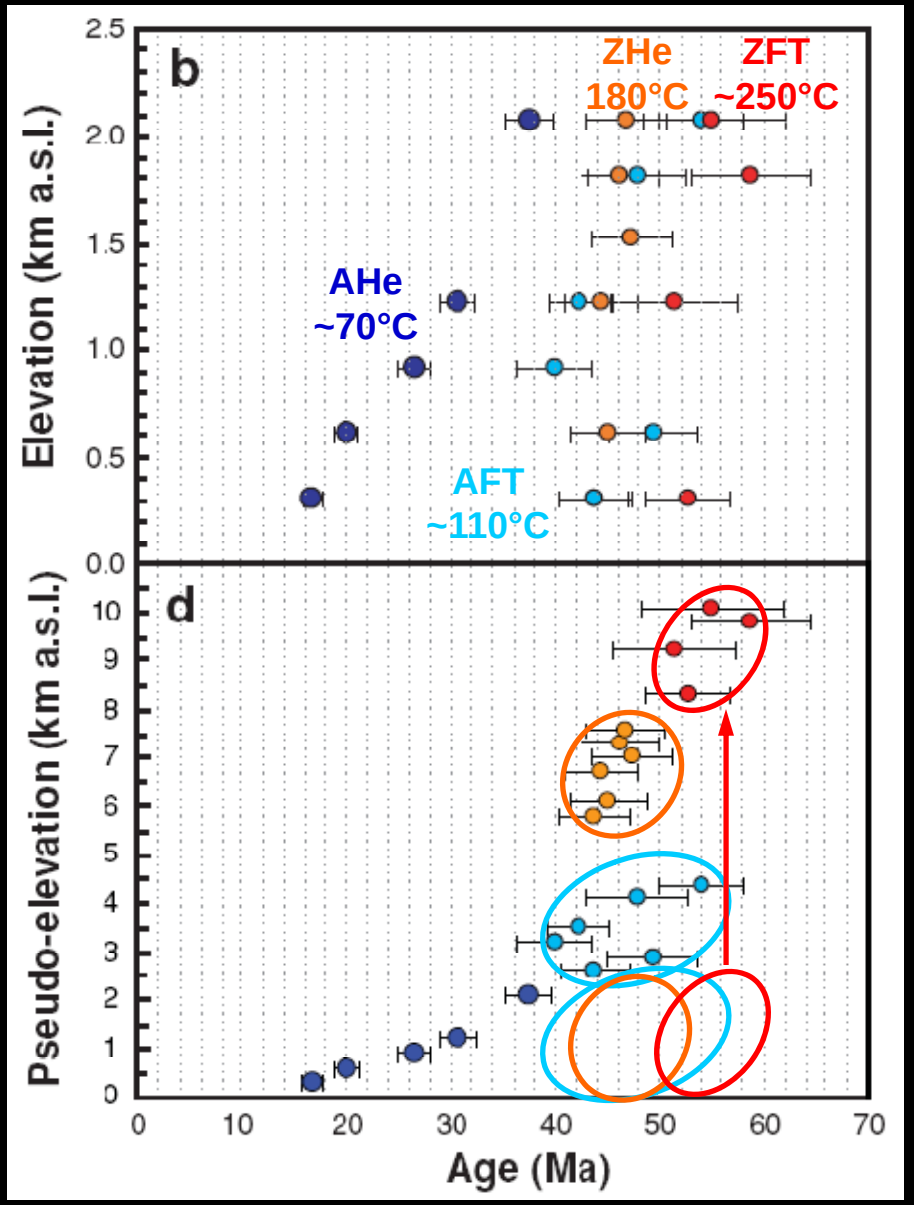
- Thermal stratigraphy for various thermochronometers
- Sub-vertical age-elevation profiles provide information on time, rate and amount of exhumation.
- Track-lengths reveal possible time-temperature paths of the rocks



Fitzgerald et al (1993)

Fission-track dating

- Thermal stratigraphy for various thermochronometers
- Sub-vertical age-elevation profiles provide information on time, rate and amount of exhumation.
- Track-lengths reveal possible time-temperature paths of the rocks
- Results from multiple thermo-chronometers from a single site are better analyzed by means of stacked pseudo-vertical profiles.



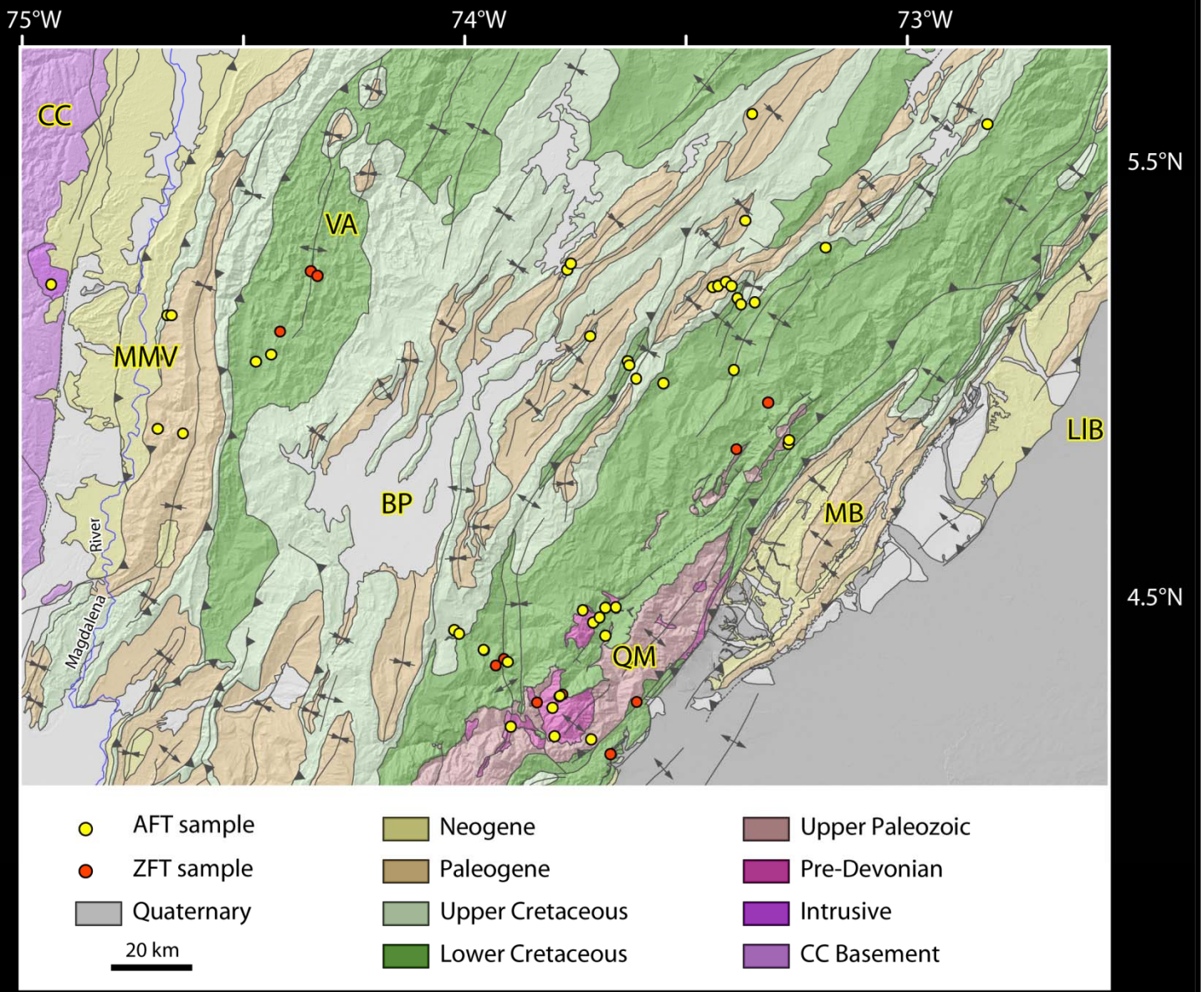
Reiners and Brandon (2006)

M. Parra et al, AAPG 2008

Exhumation history

Eastern flank:

- 38 AFT
- 19 ZFT



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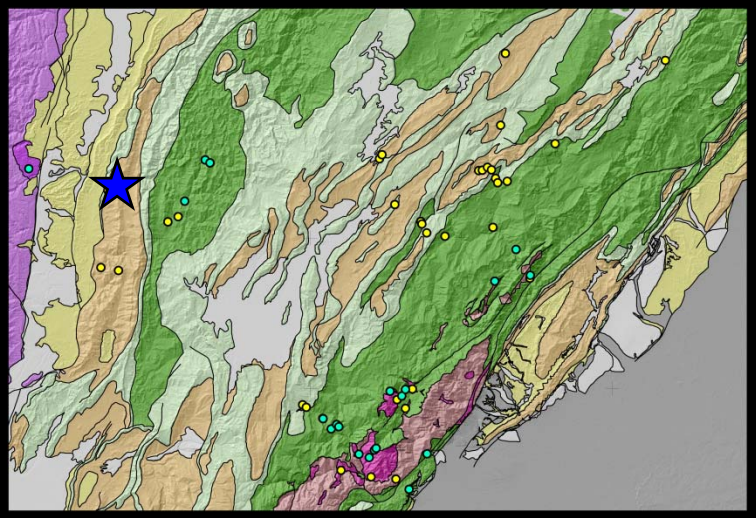
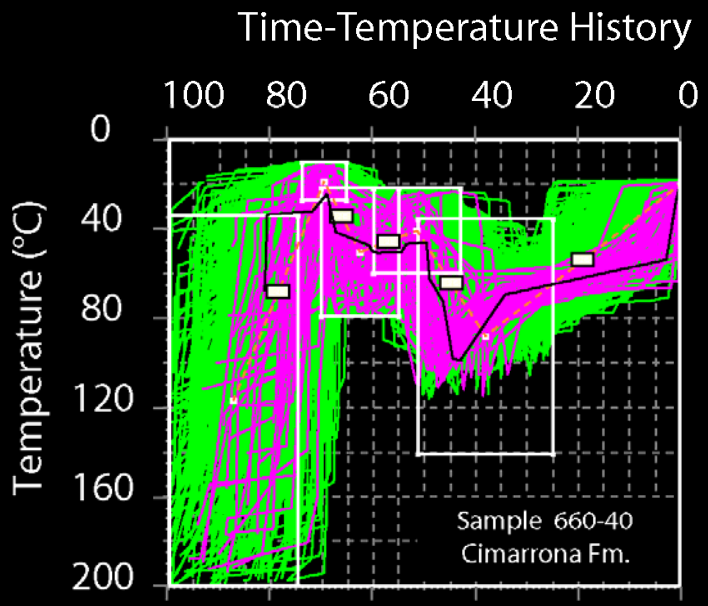
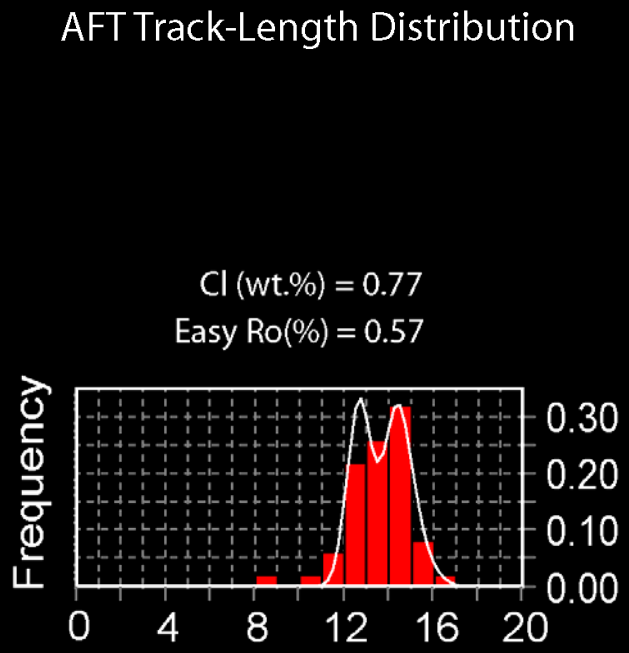
Exhumation history

1. Western foothills



- Thermal modeling of Upper Cretaceous samples orogenic front suggests initiation of cooling sometime between **55 and 35 Ma**

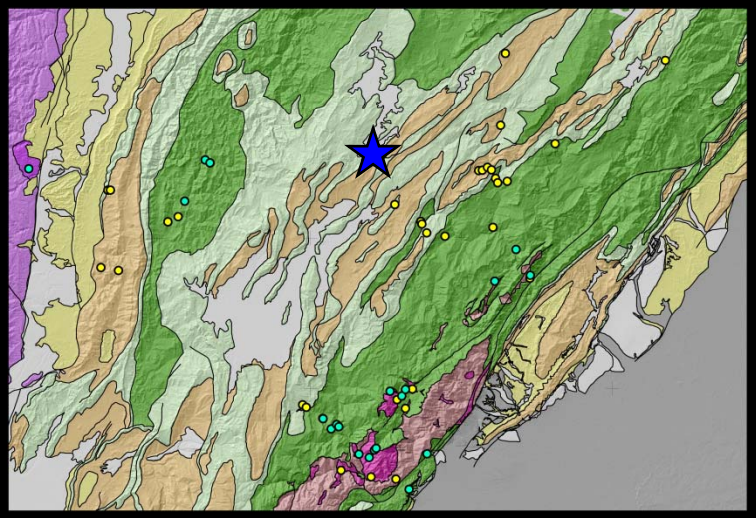




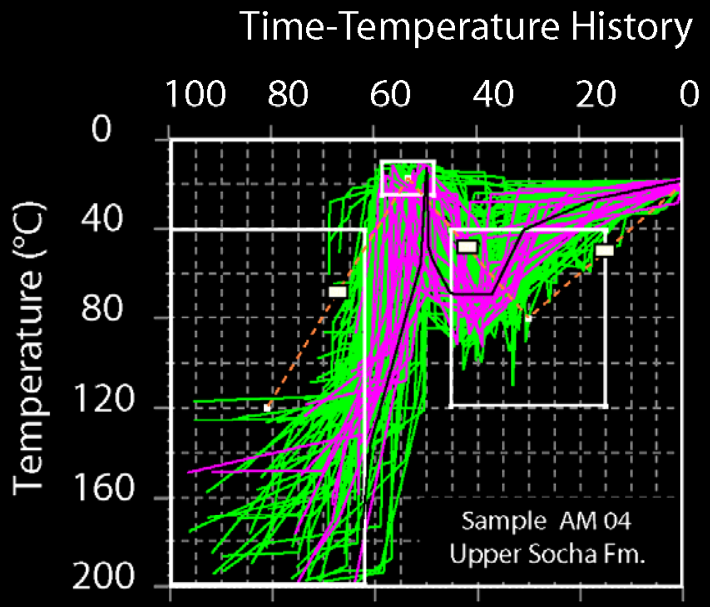
M. Parra et al, AAPG 2008

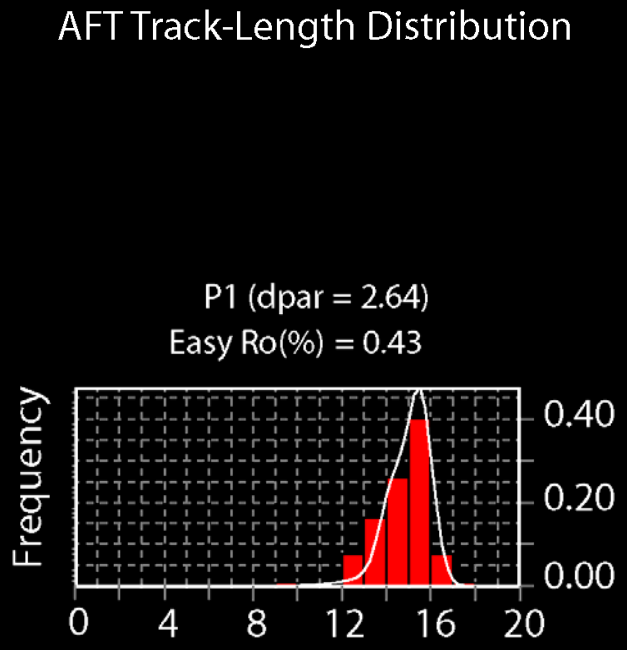
Exhumation history

2. Axial Eastern Cordillera



- Thermal modeling of Paleocene samples orogenic front suggests initiation of cooling sometime between **45 and 25 Ma**





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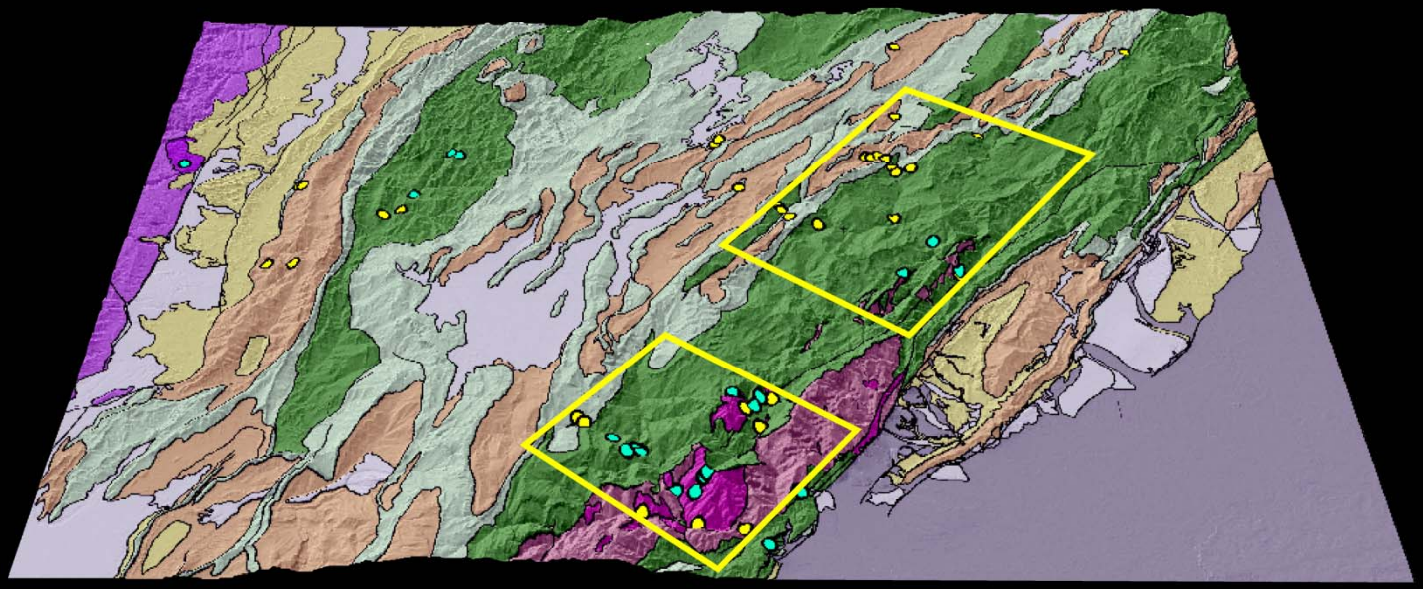
Exhumation history

3. Quetame Massif



Two transects comprising Paleozoic basement to Paleocene sedimentary rocks

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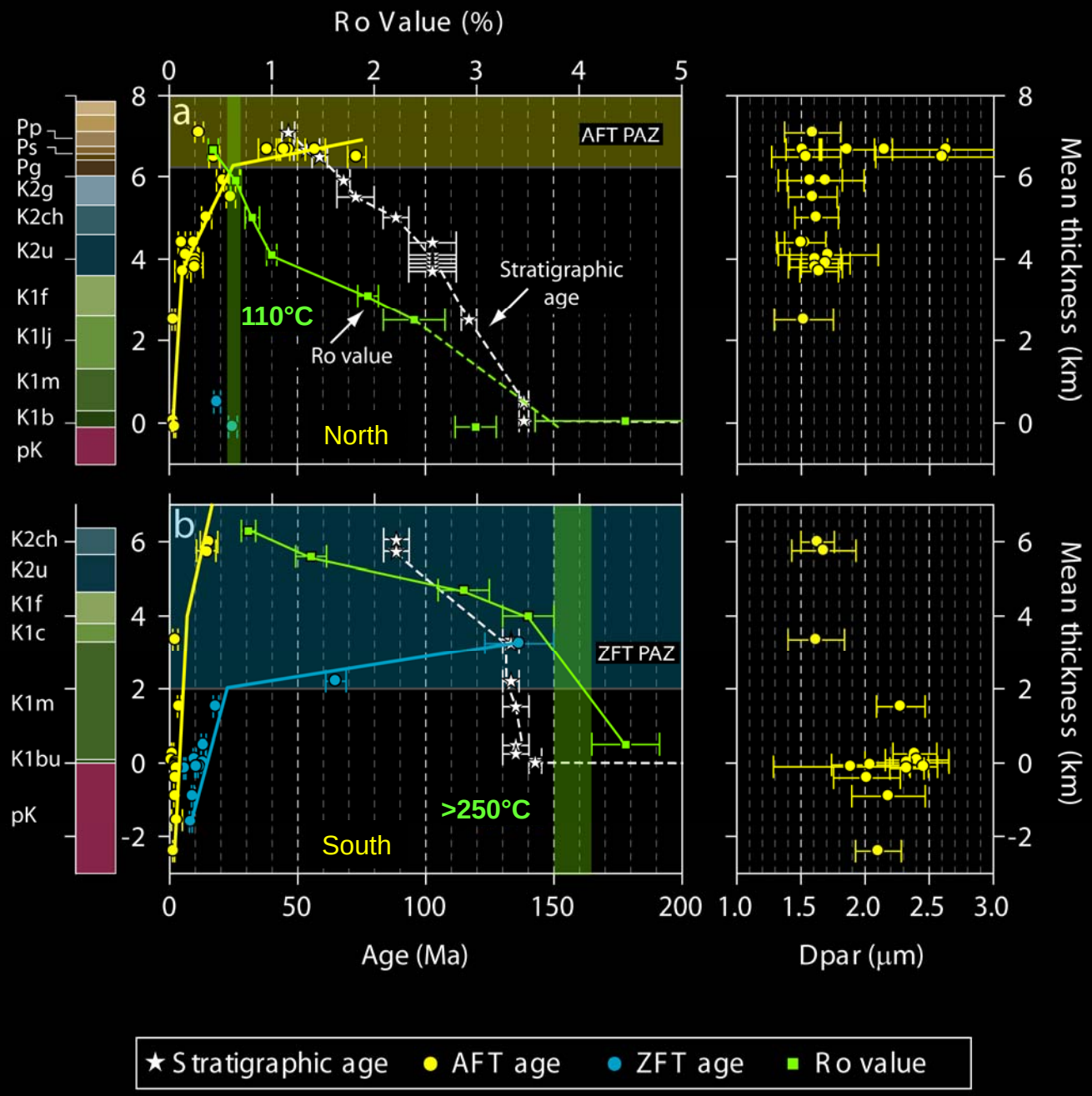
Exhumation history

3. Quetame Massif (FT ages vs Stratigraphic Position)

- Integration of Ro data with the distribution of FT ages with respect to their stratigra-phic position reveals the limits of the AFT and ZFT partial annealing zones (PAZ)



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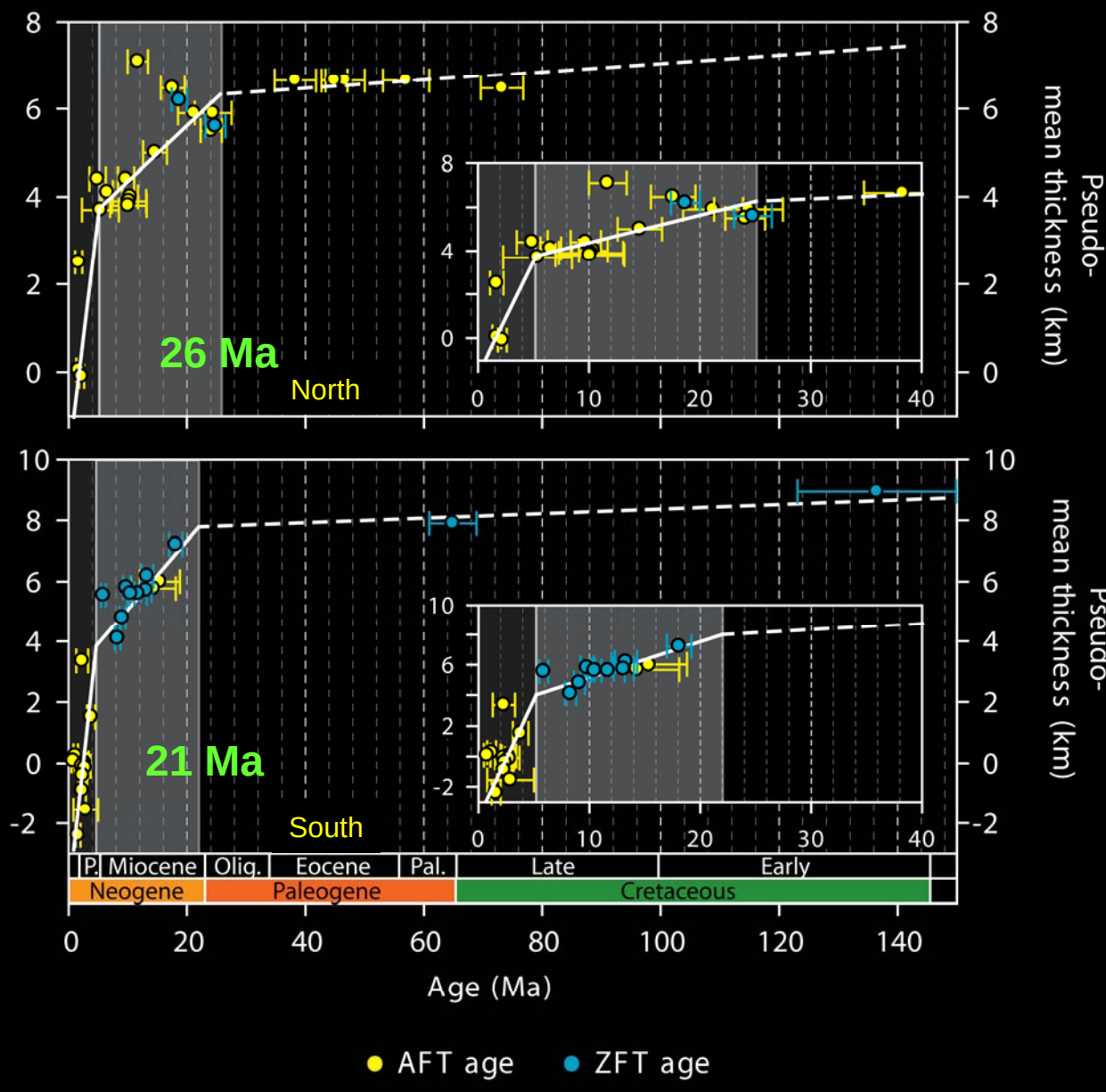
Parra et al, in review

Exhumation Patterns (Stacked pseudo-vertical profiles)

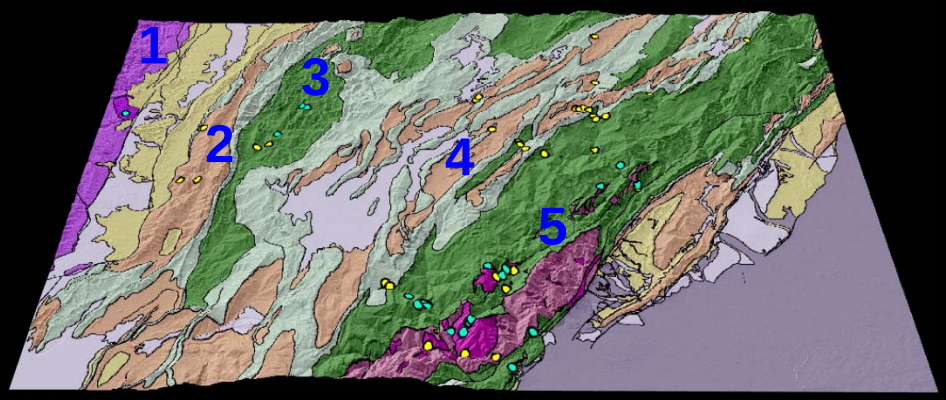
- Stacked pseudo-vertical profiles reveal initiation of erosional exhumation at **~26 Ma** for the northern transect and at **~21 Ma** for the southern transect
- Exhumation **accelerates** from ~0.3 to ~1.5 mm/yr at ~ **4 Ma**



M. Parra et al, AAPG 2008

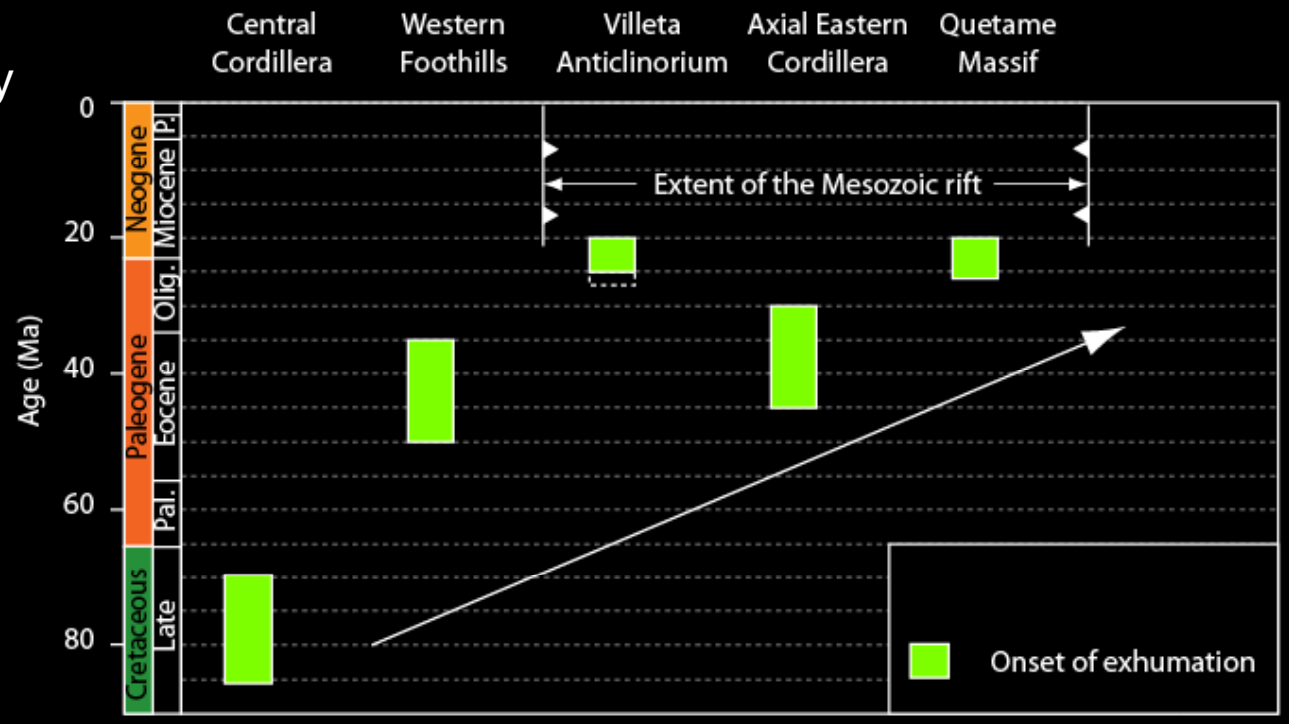
Parra et al, in review

Exhumation history



1 2 3 4 5

- Long-term eastward progradation of actively exhuming areas



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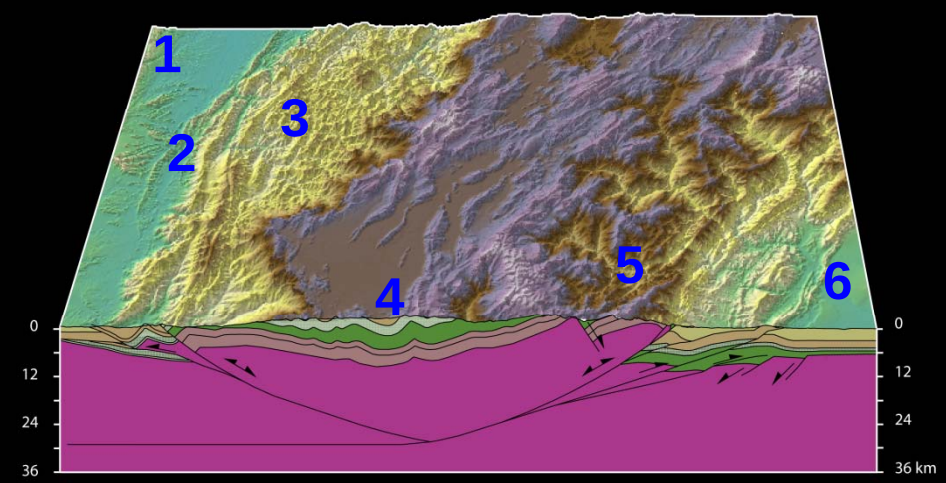
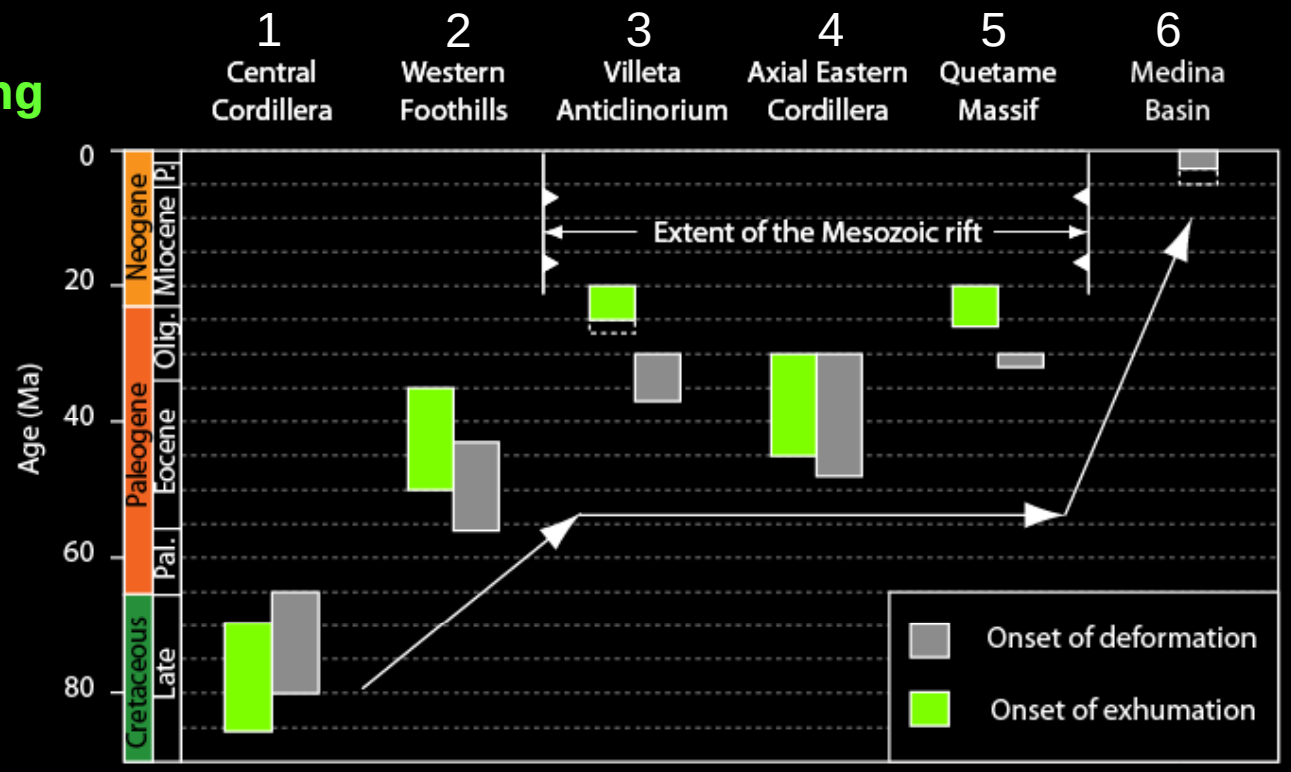
Exhumation vs. deformation histories

- Temporal decoupling of exhumation and deformation along the more deeply exhumed areas along the margins of the former rift

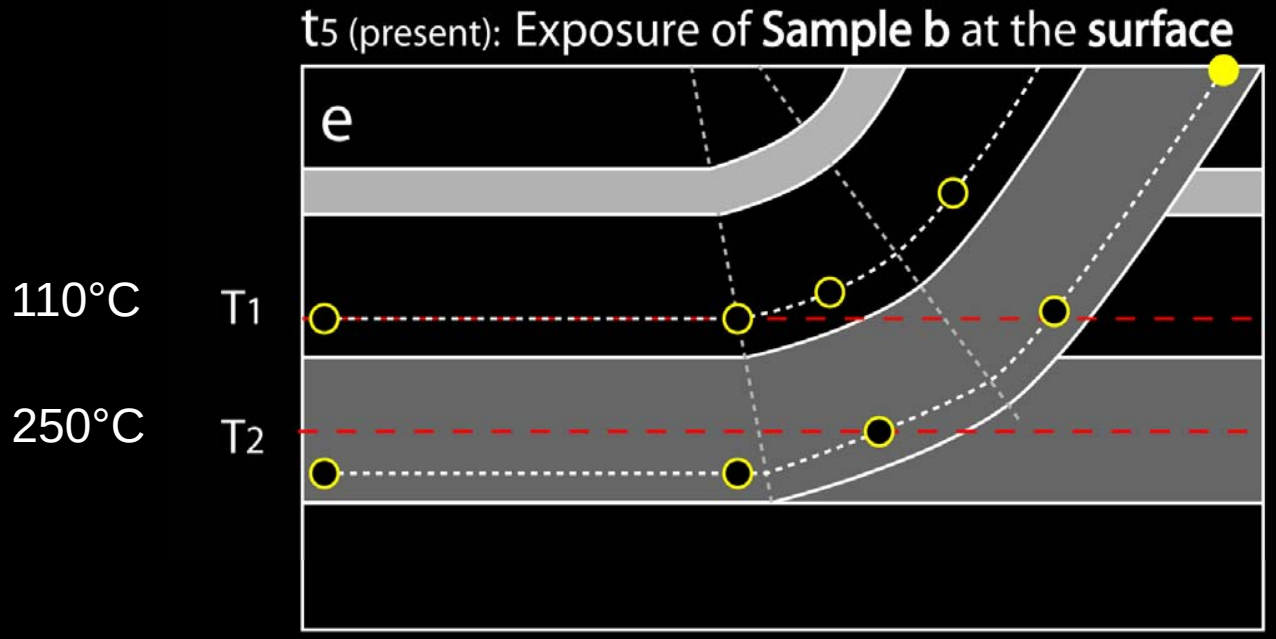




M. Parra et al, AAPG 2008

Data Sources: Julivert, 1963; Gómez, 2001; Gómez et al, 2003; Parra et al, submitted

Conceptual model of shortening and exhumation along a compressionally reactivated listric fault



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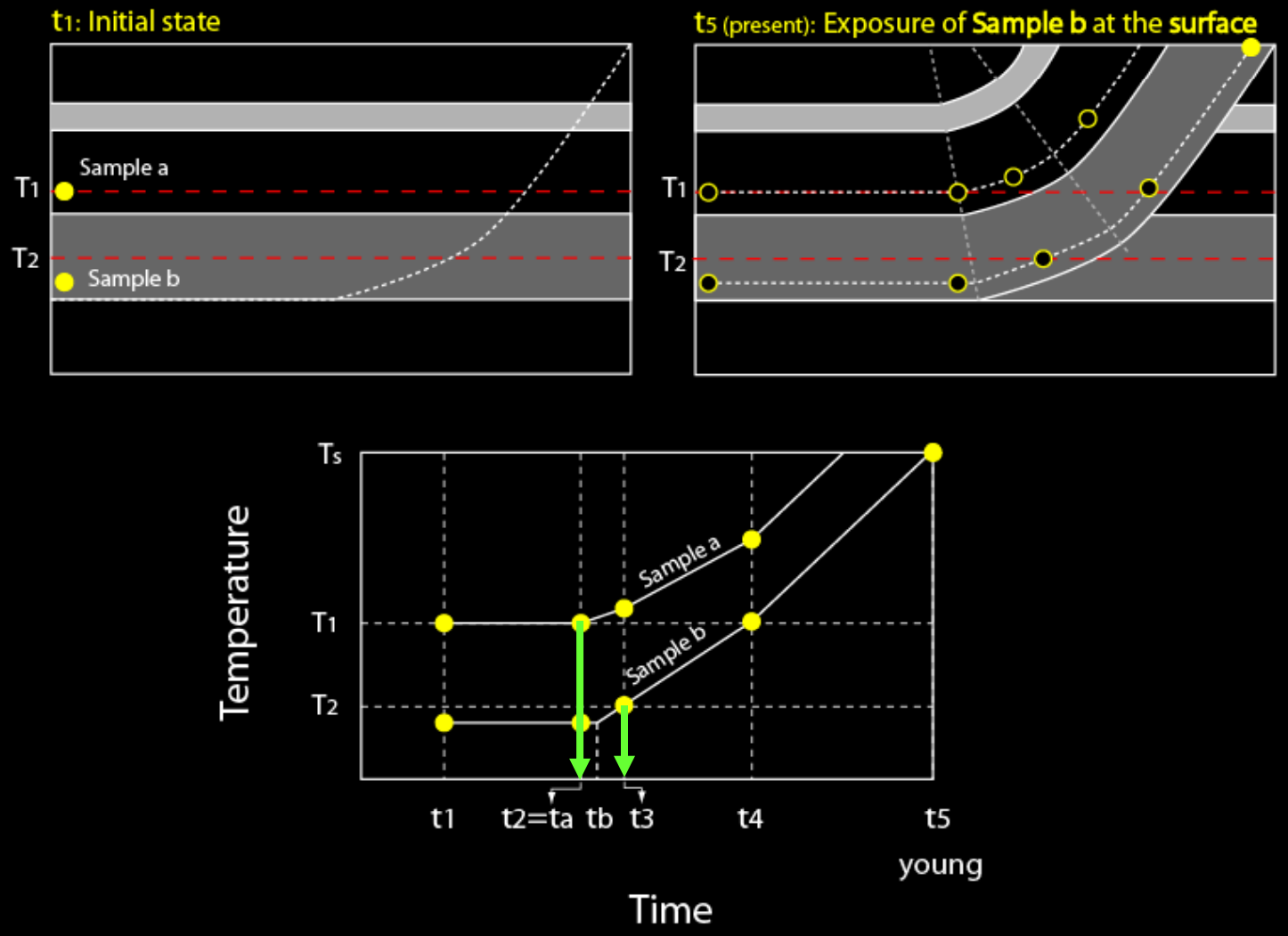

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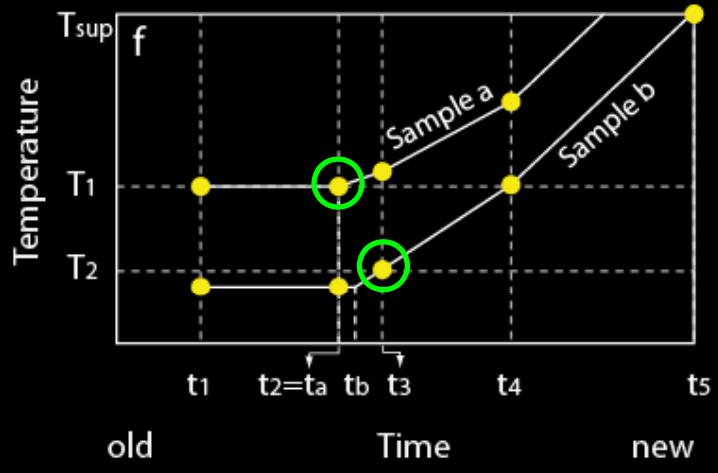
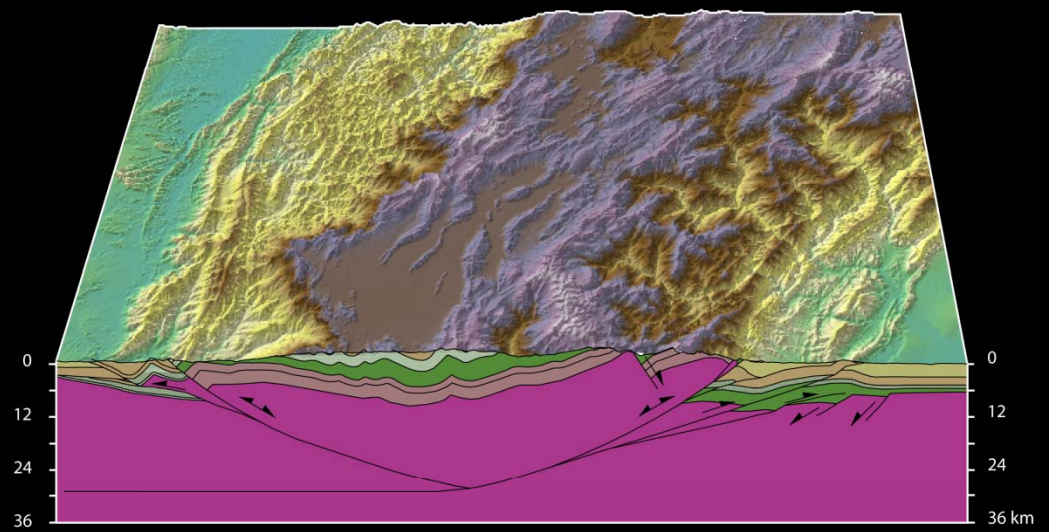
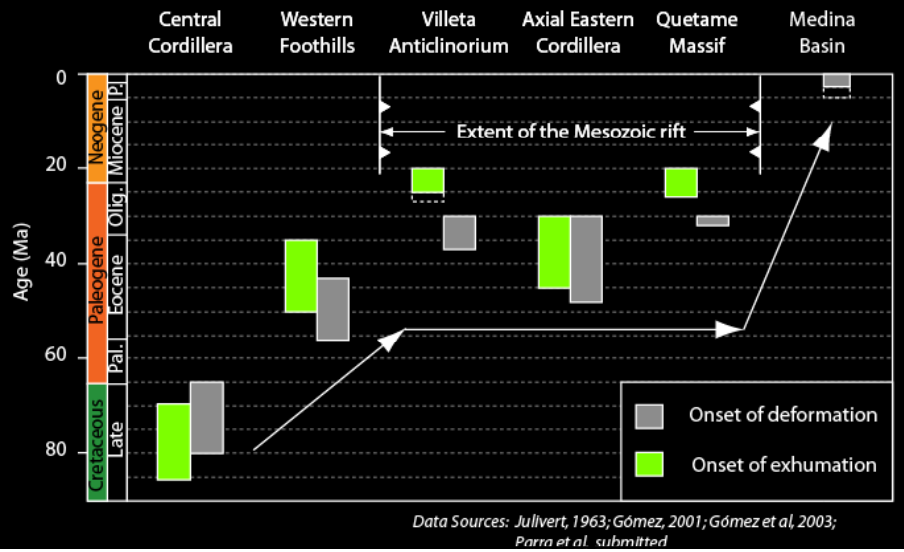
Conclusions (1)

- **Thrust-induced cooling postdates initial shortening due to fault geometry**







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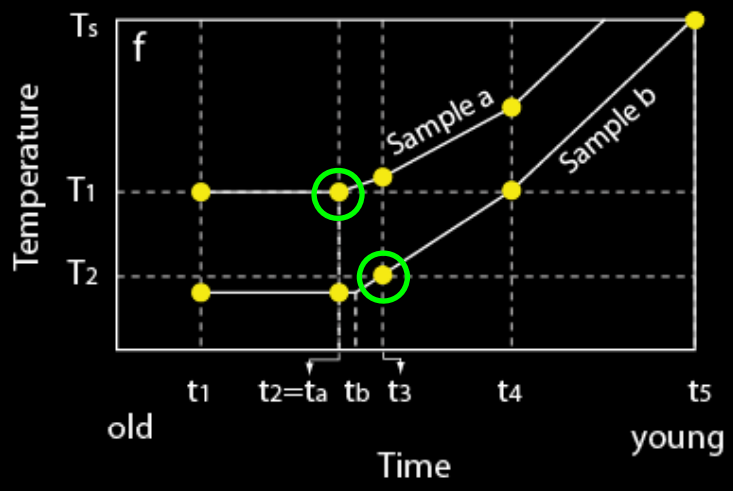
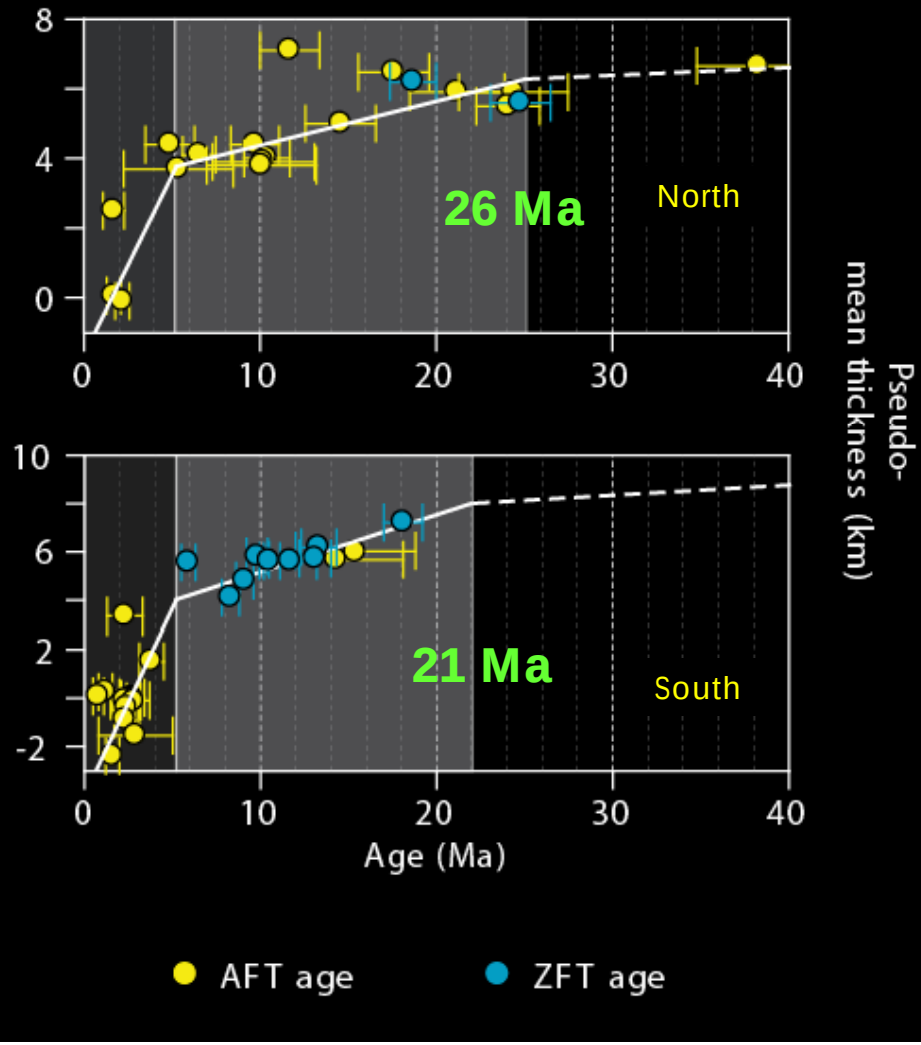
Conclusions (2)

Predicted thermal history



Observed FT-age distribution



- **Deeper thermo-chronometers show a longer lag time between shortening and exhumation**

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Acknowledgements

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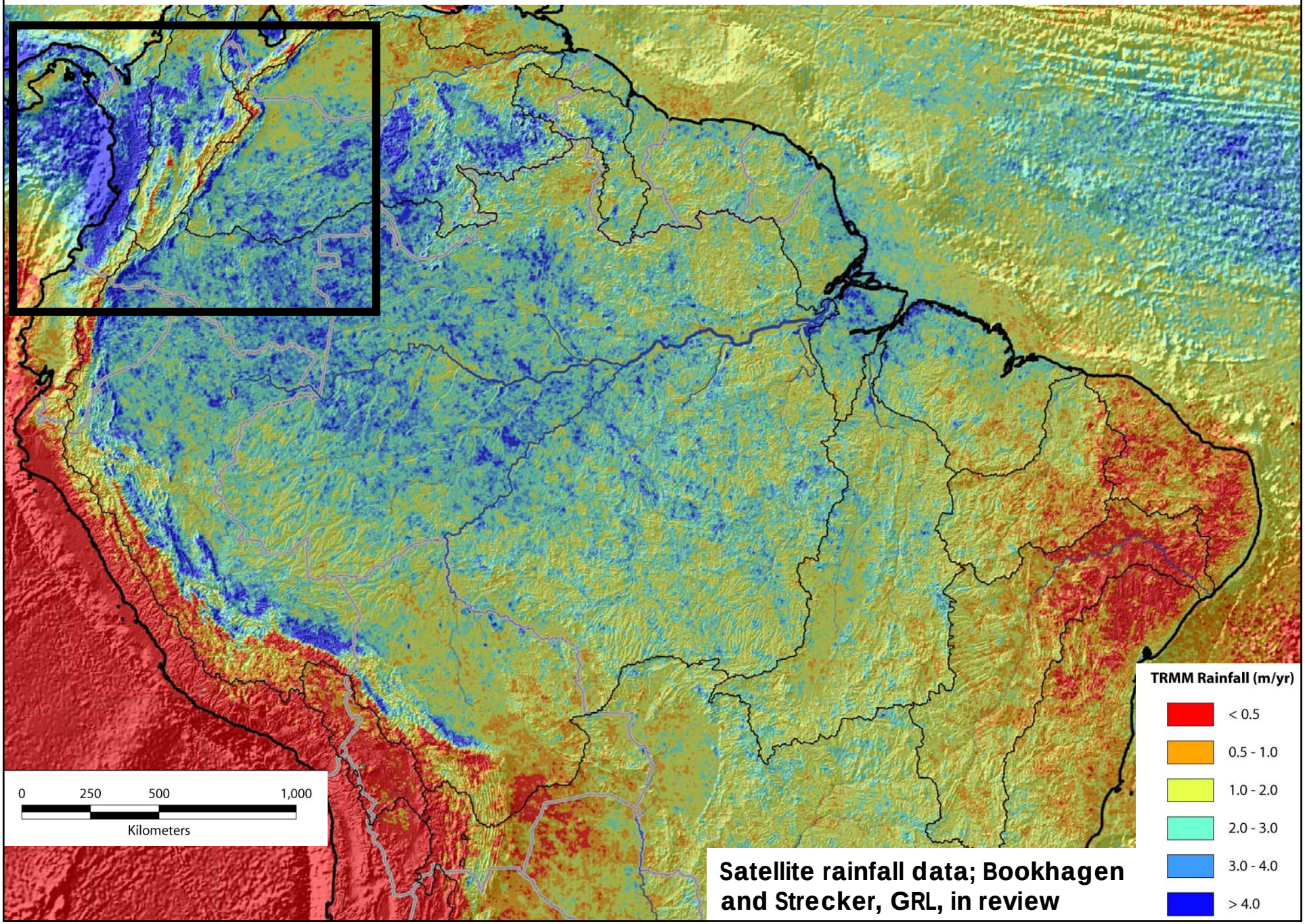
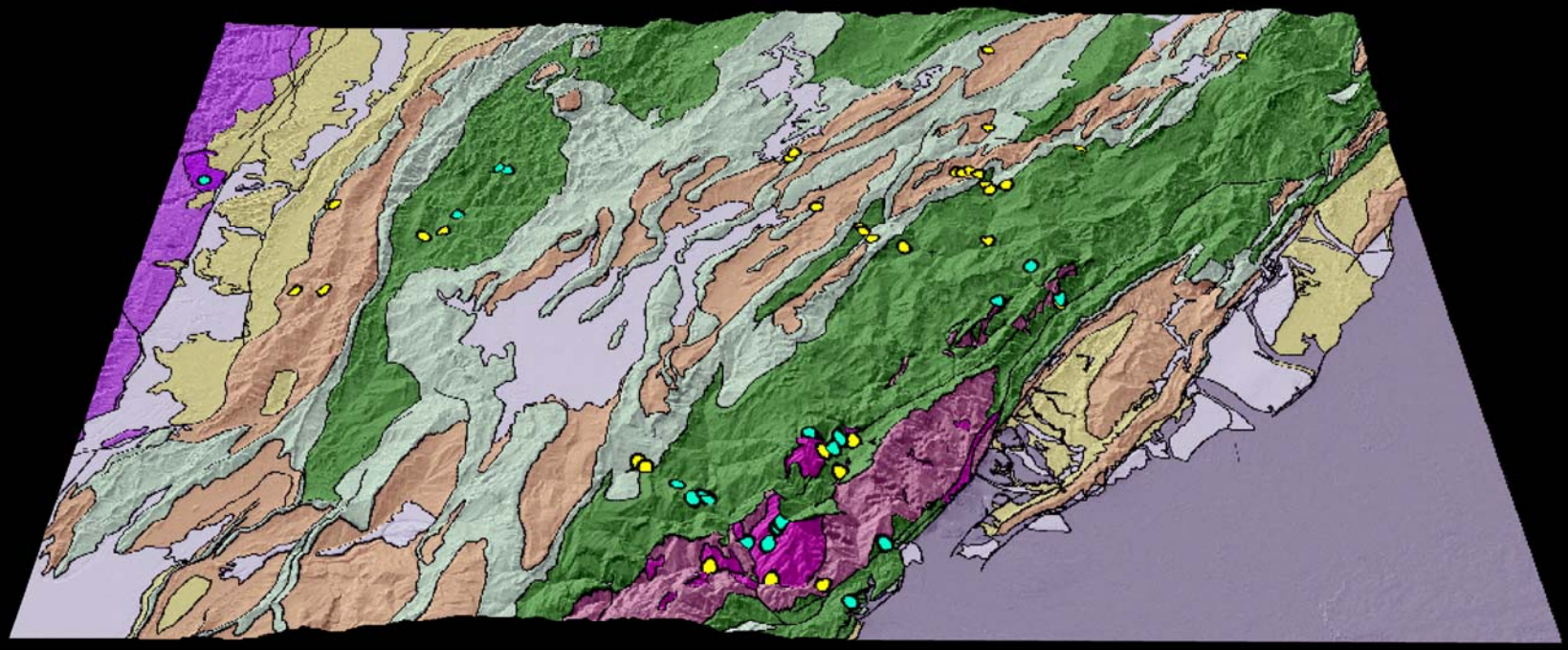
THE ANDES AS AN OROGRAPHIC BARRIER





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