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## **Lithospheric strength: a potential controlling factor over differential subsidence in the Early Triassic Sonoma Foreland Basin (western USA)?**

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# Lithospheric strength: a potential controlling factor over differential subsidence in the Early Triassic Sonoma Foreland Basin (western USA)?

Gwénaél Caravaca\*, Arnaud Brayard, Emmanuelle Vennin, Michel Guiraud, Nicolas Olivier, Anne-Sabine Grosjean, Christophe Thomazo, Emmanuel Fara, Gilles Escarguel

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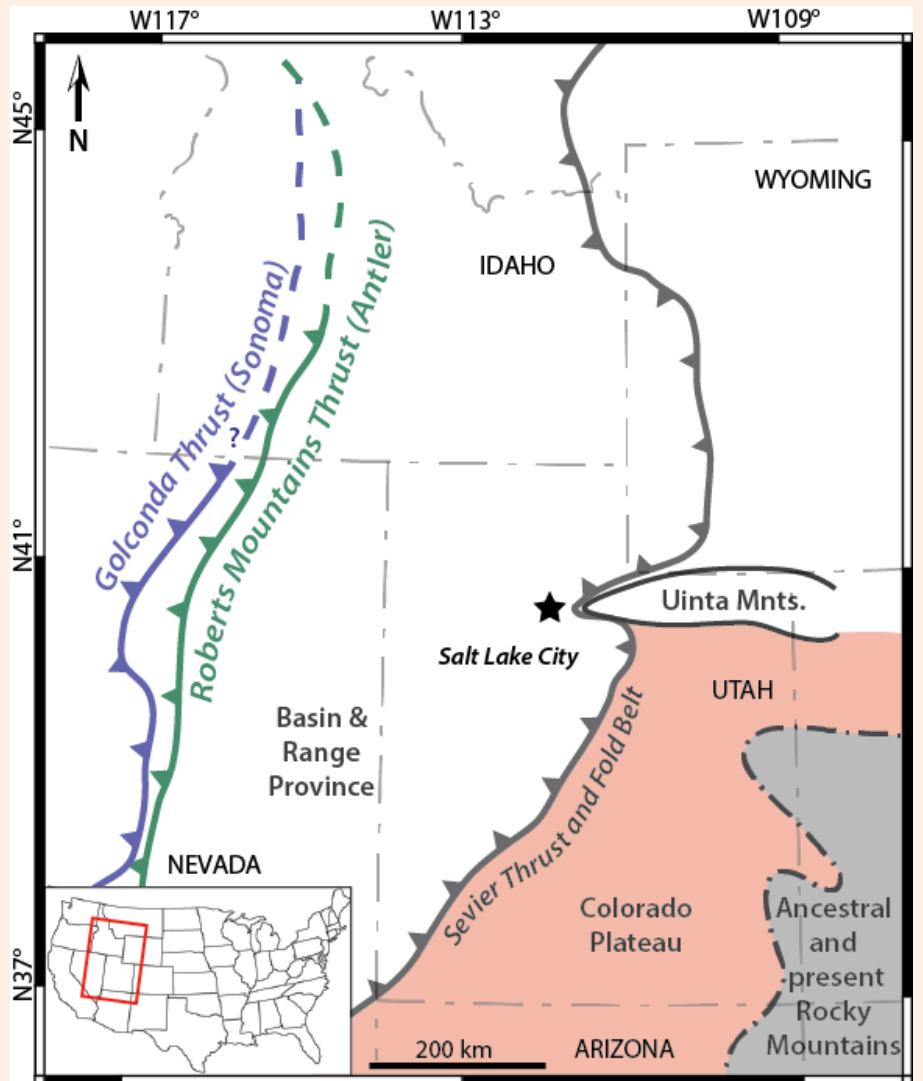
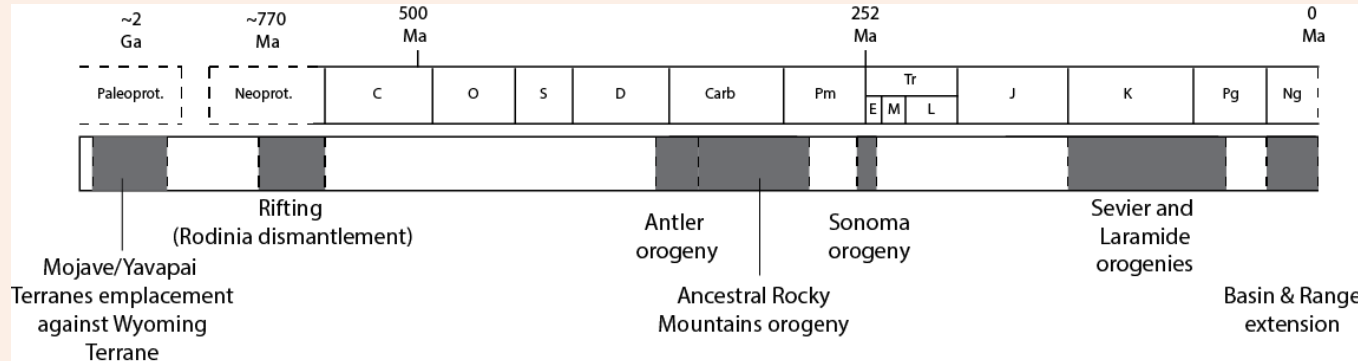
Université de Bourgogne Franche-Comté, France

# Introduction and localization



Long and complex tectonic history of the Eastern Great Basin

Many **now obliterated** orogenic features



After Caravaca et al., subm.



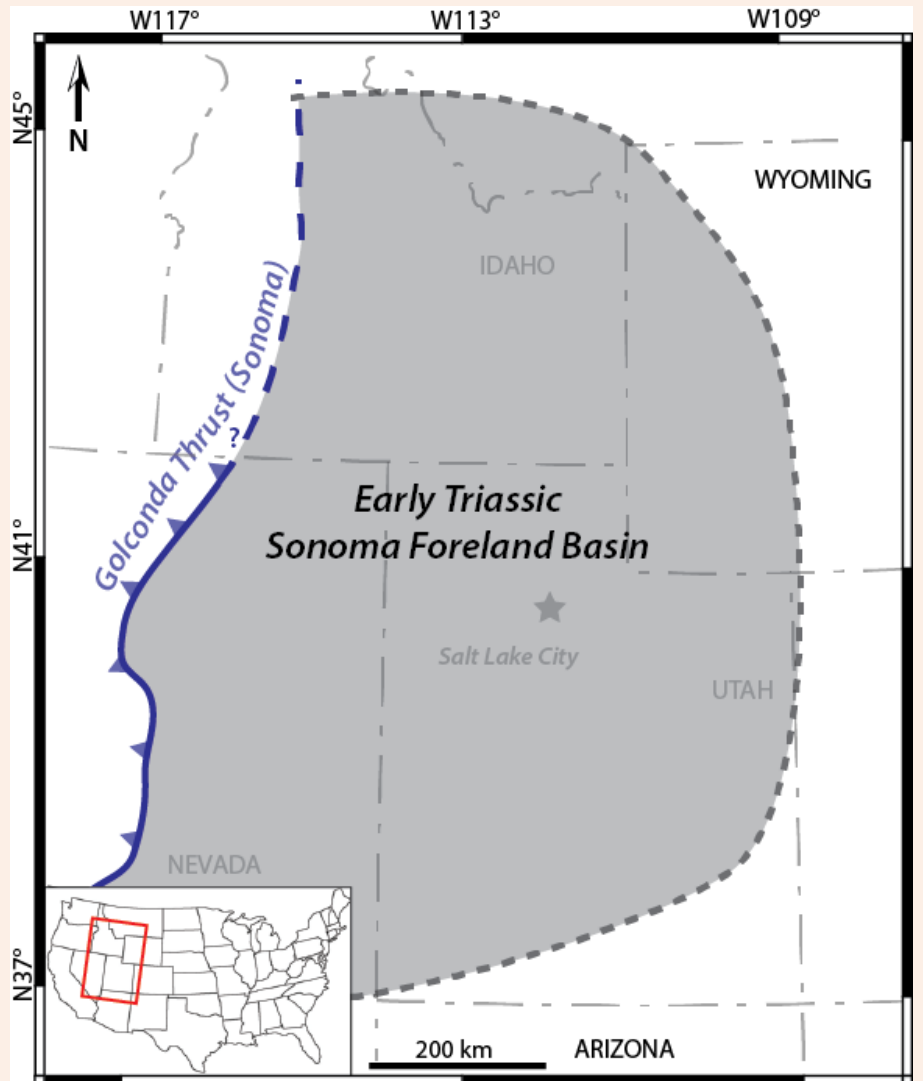
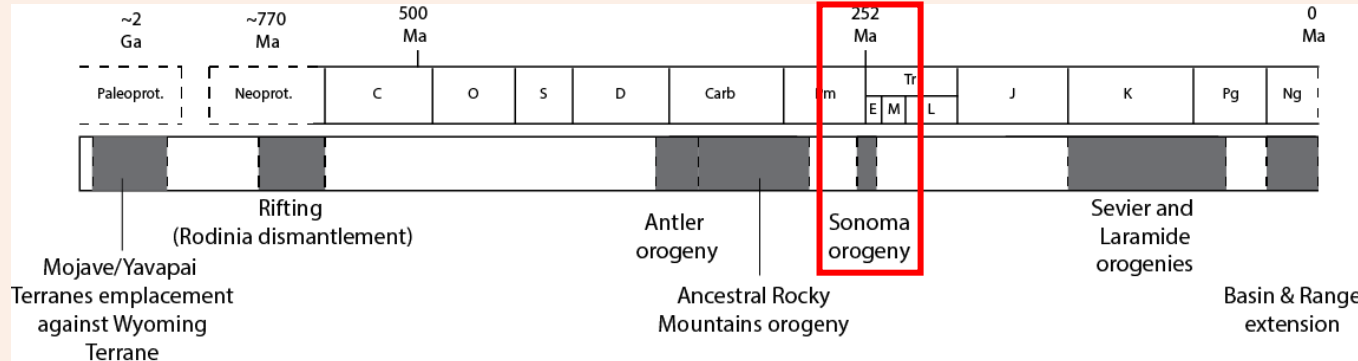
# Introduction and localization

Long and complex tectonic history of the Eastern Great Basin

Many now obliterated orogenic features

⇒ Focus on the **Sonoma orogeny**  
(~252 Ma at the **Permian-Triassic Boundary**)

⇒ **Sonoma Foreland Basin**  
formed by emplacement of **Golconda Allochthon**

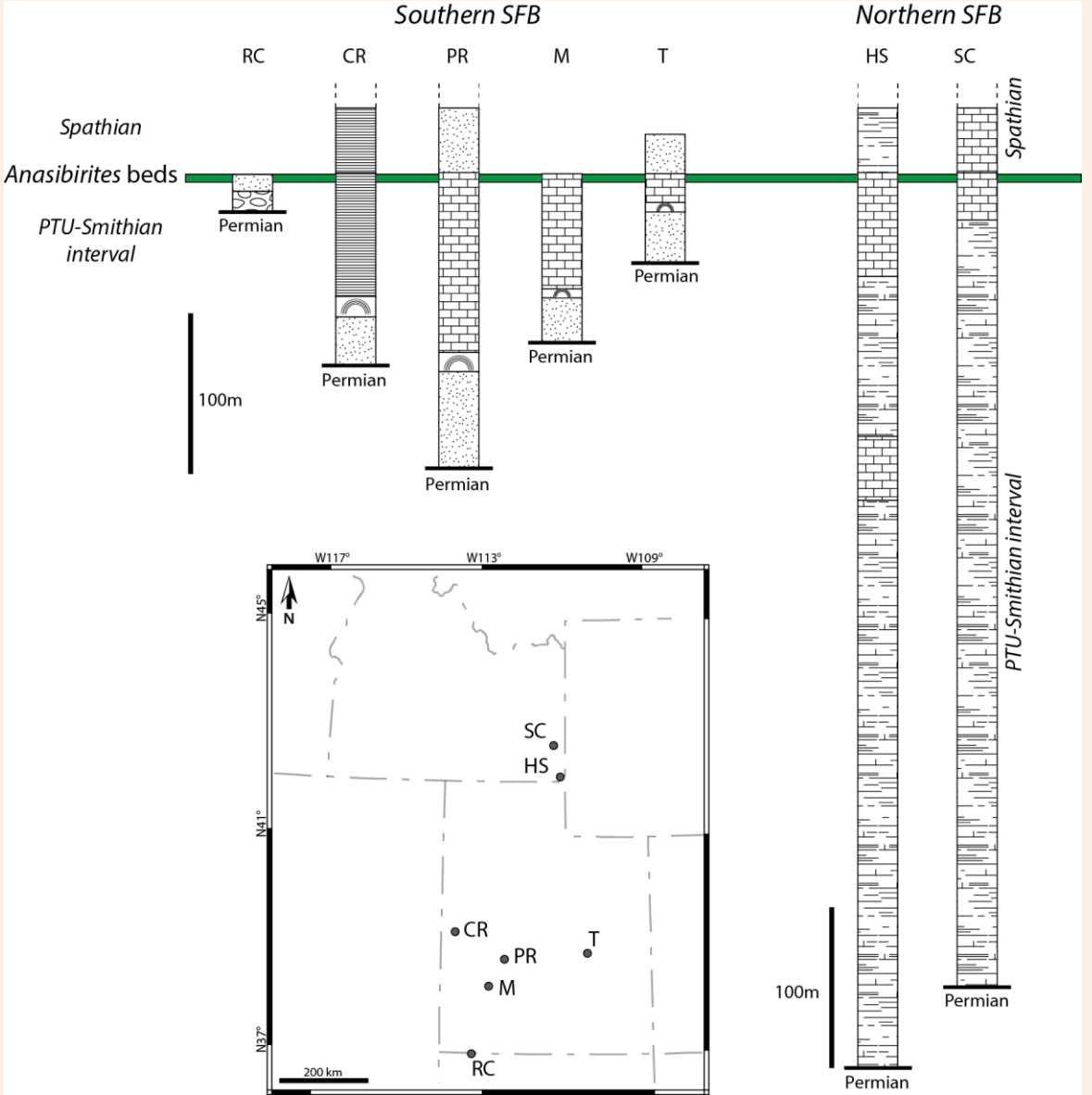
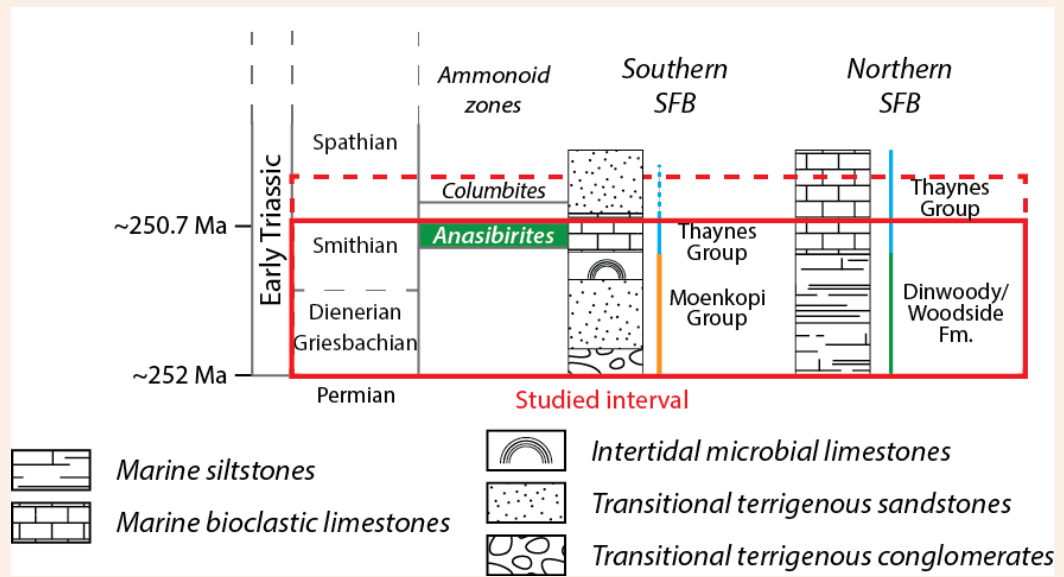


After Caravaca et al., subm.

# Introduction and localization

## Sonoma Foreland Basin (SFB)

- ⇒ **Excellent fossil and sedimentary record** of the aftermath of the end-Permian mass-extinction
- ⇒ **PT unconformity-Smithian interval** (PTU; ~1,3 Myr-long)
- ⇒ **Marked discrepancies** in term of facies and thicknesses between **northern and southern parts**



# Methods

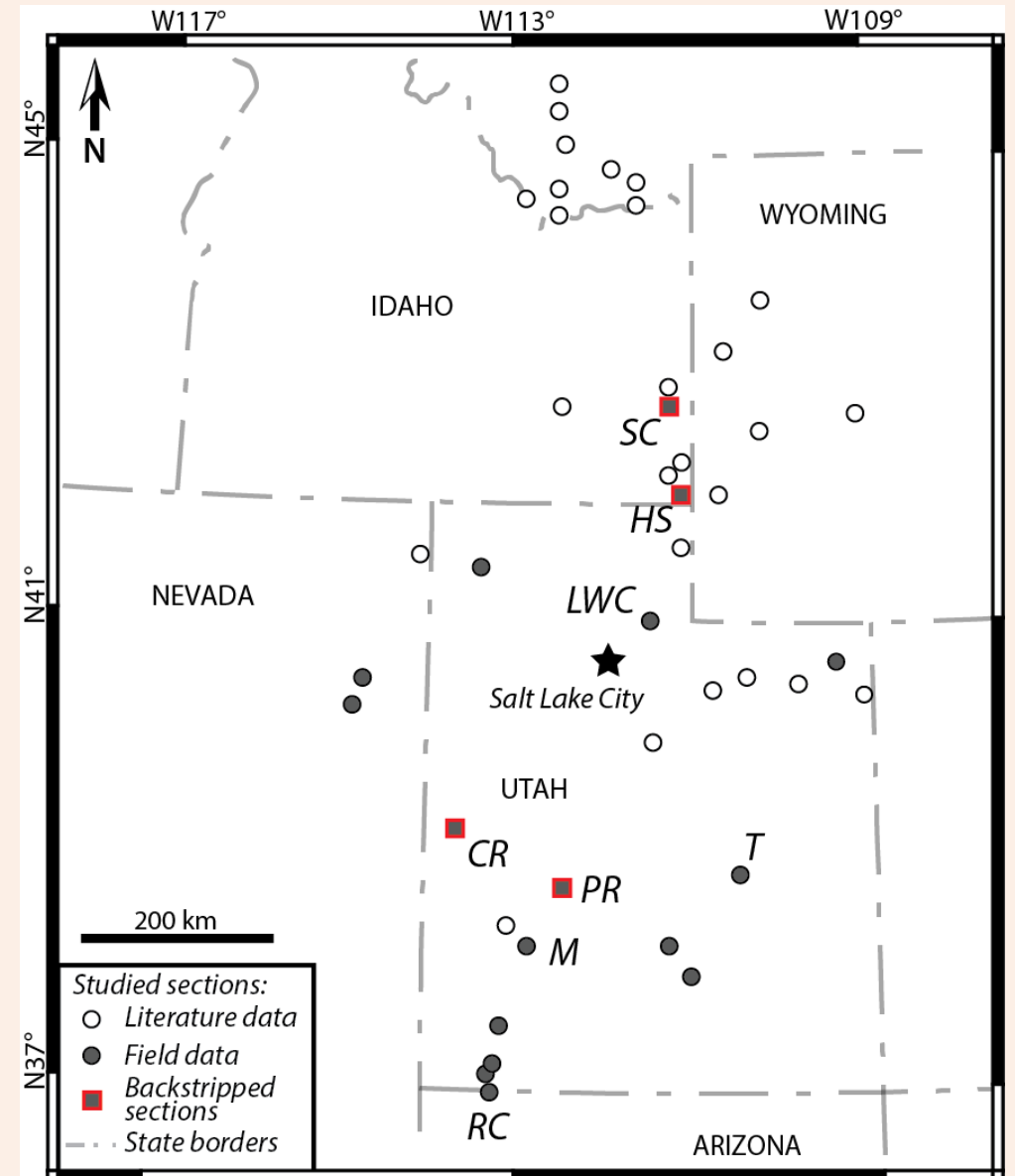
Focus on these record discrepancies and their origin

⇒ **Integrated basin-scale study**

Using sedimentology, paleontology, cartography, GIS spatialization

**Dataset:**

- **43 selected sections** after literature and field work
- **High time-resolution biostratigraphic framework** based on ammonoids biozonation (after Brayard *et al.*, 2013)



After Caravaca *et al.*, *subm.*

# Methods

Focus on these record discrepancies and their origin

## ⇒ Integrated basin-scale study

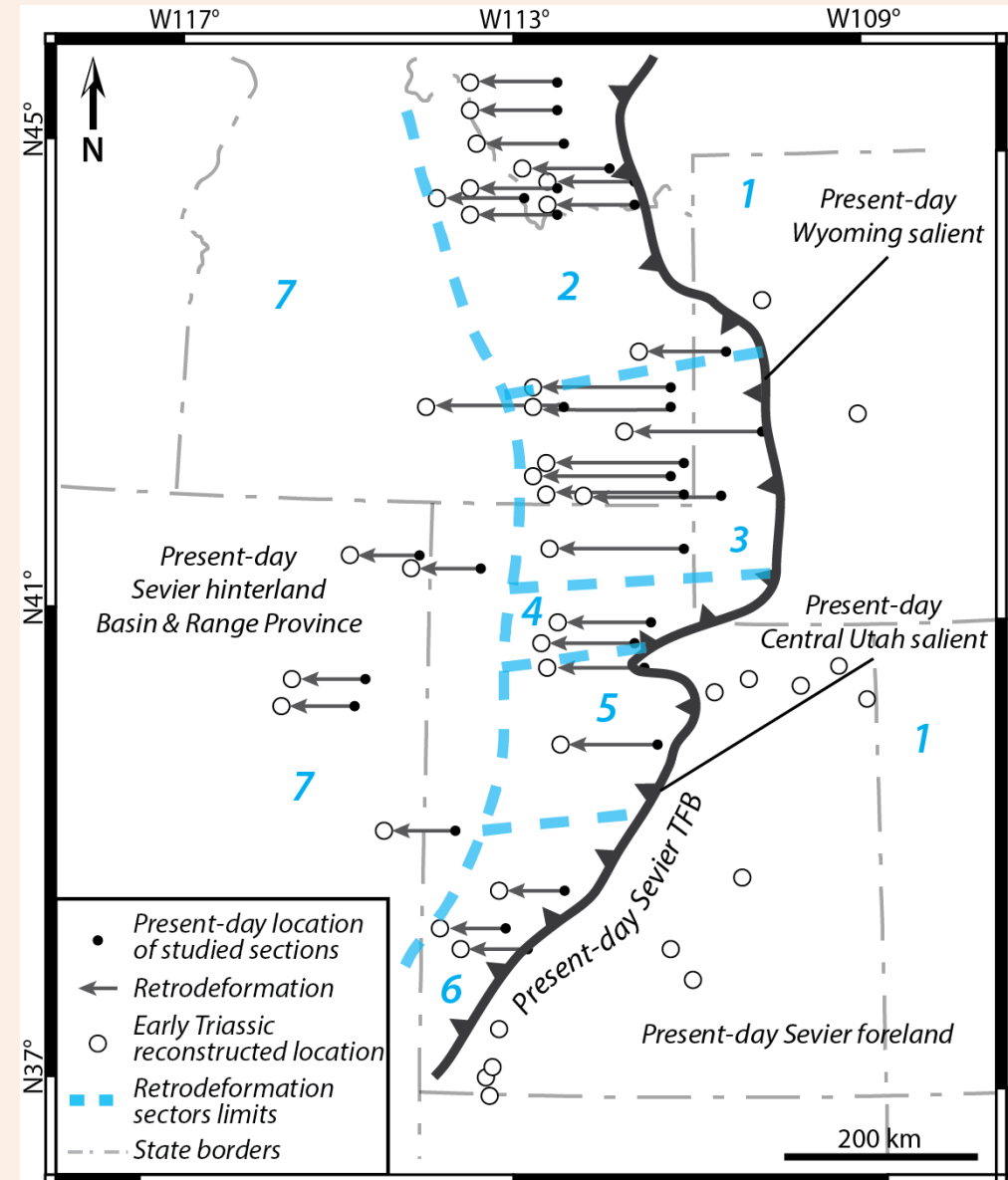
Using sedimentology, paleontology, cartography, GIS spatialization

Dataset:

- 43 selected sections after literature and field work
- High time-resolution biostratigraphic framework (after Brayard *et al.*, 2013)

## Palinspastic reconstructions:

- **Necessary to obtain an unbiased view** of the area during the Early Triassic
- **Original location** of the sections within the basin



After Caravaca *et al.*, *subm.*

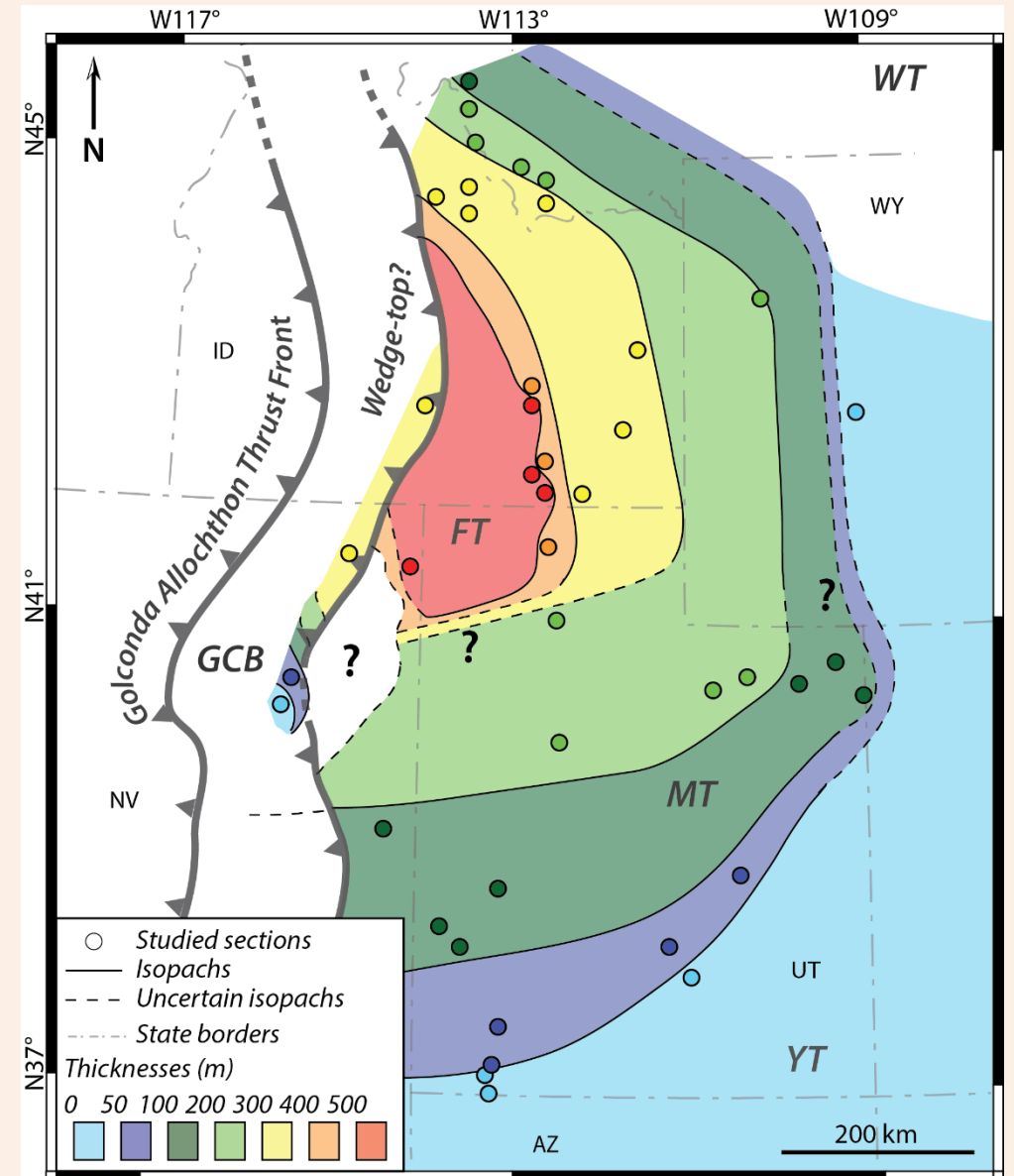
## Results: thickness variations in the basin

Isopach map of the PTU-Smithian interval

⇒ Spatial distribution of sedimentary thickness

2 different areas in the basin:

- **Northern high thickness zone** (>300 up to ~550m thick)
- **Southern low thickness zone** (~10 up to 250m thick)





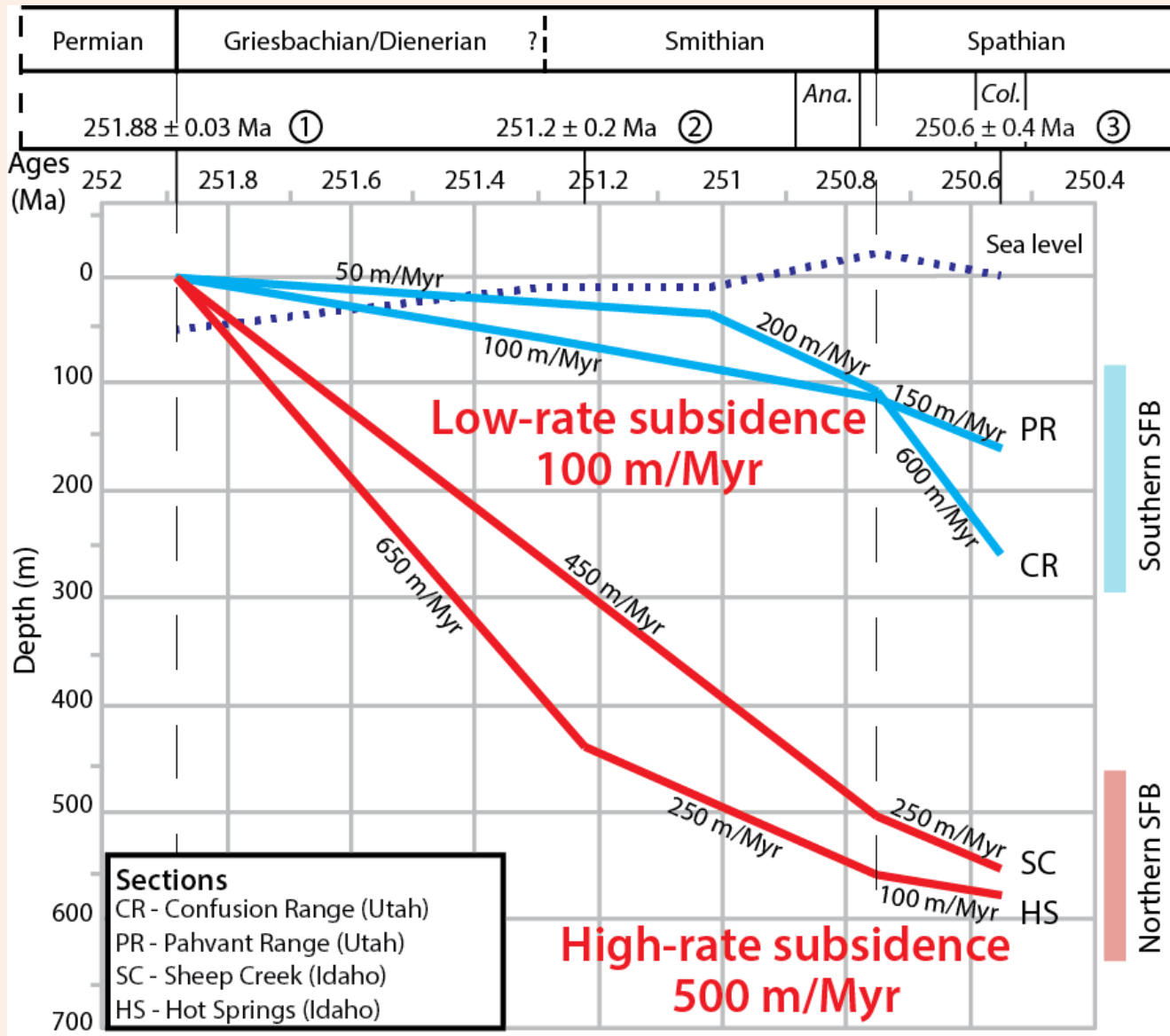
# Results: subsidence variations in the basin

## Backstripping analysis of the PTU-Smithian interval

- ⇒ Tectonic subsidence is preponderant
- ⇒ Shape: characteristic of a foreland basin

### Differential subsidence in the basin:

- Northern high-rate subsidence
- Southern low-rate subsidence



After Caravaca et al., subm.



***What are the mechanisms controlling this differential subsidence observed in the Early Triassic Sonoma Foreland Basin?***

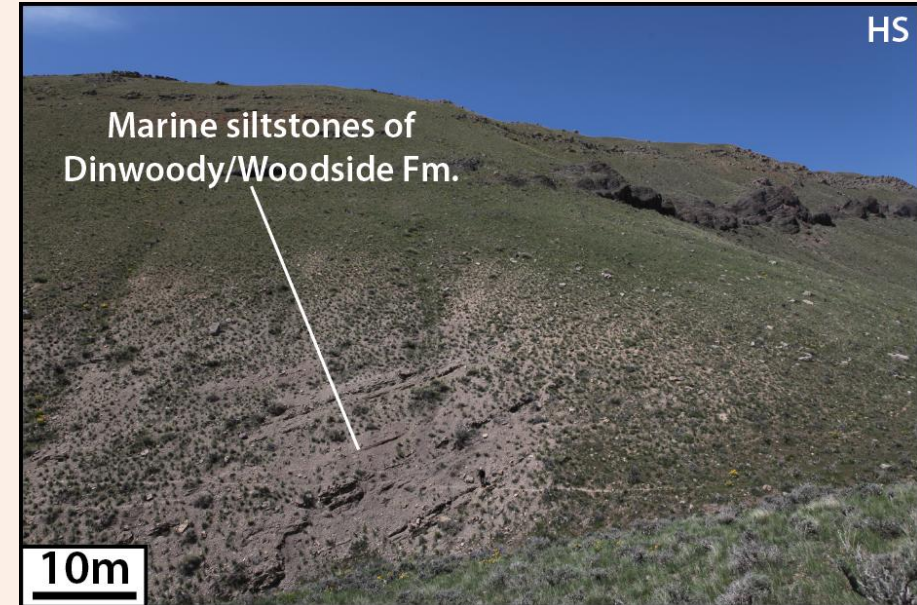
# Hypotheses

- *Sedimentary overload?*

**Sedimentary loading should be in southern SFB**  
⇒ **at variance with our results**

*Southern SFB*

*Northern SFB*



**Coarse terrigenous** of the Moenkopi Group  
(conglomerates and sandstones)  
( $d \sim 2.5$  to  $2.8 \text{ kg/cm}^3$ )  
Topped by metric beds of **microbial limestones**  
( $d \sim 2.6$  to  $2.8 \text{ kg/cm}^3$ )

Dominated by **fine marine siltstones** of the  
Woodside and Dinwoody Fm.  
( $d \sim 2.3$  to  $2.7 \text{ kg/cm}^3$ )



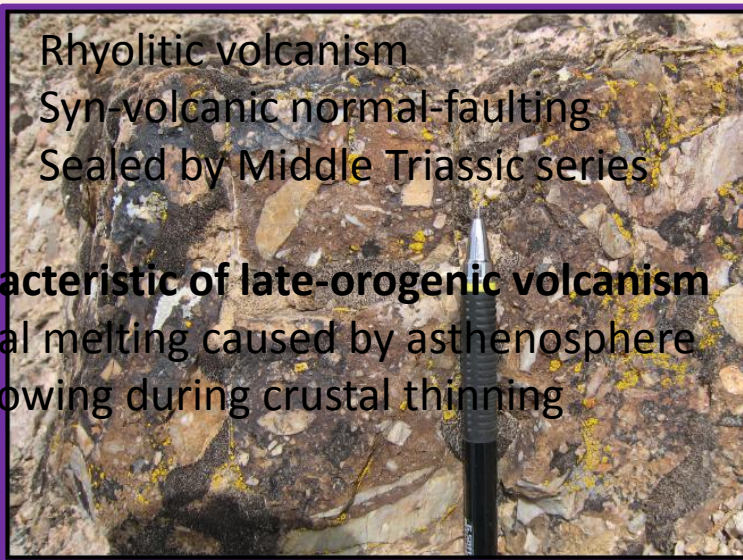
# Hypotheses

- Differential topographic loading?

Golconda Allochthon remains in central Nevada:

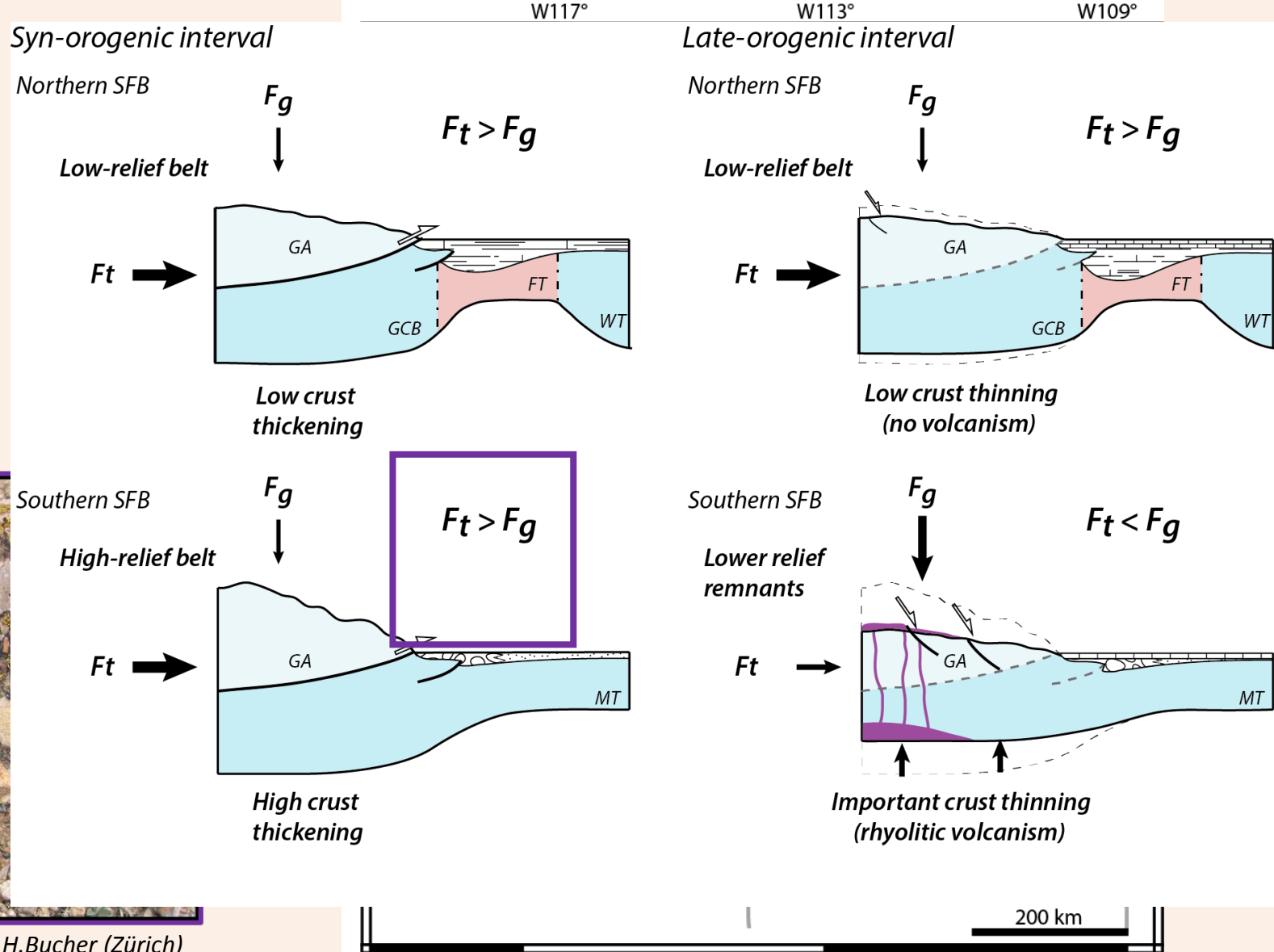
⇒ Presence of coarse conglomerates in West-central SFB

⇒ Presence of Koipato volcanics in Southwest SFB



⇒ **Characteristic of late-orogenic volcanism**  
Partial melting caused by asthenosphere shallowing during crustal thinning

Photo courtesy of H. Bucher (Zürich)



Caravaca et al., subm.



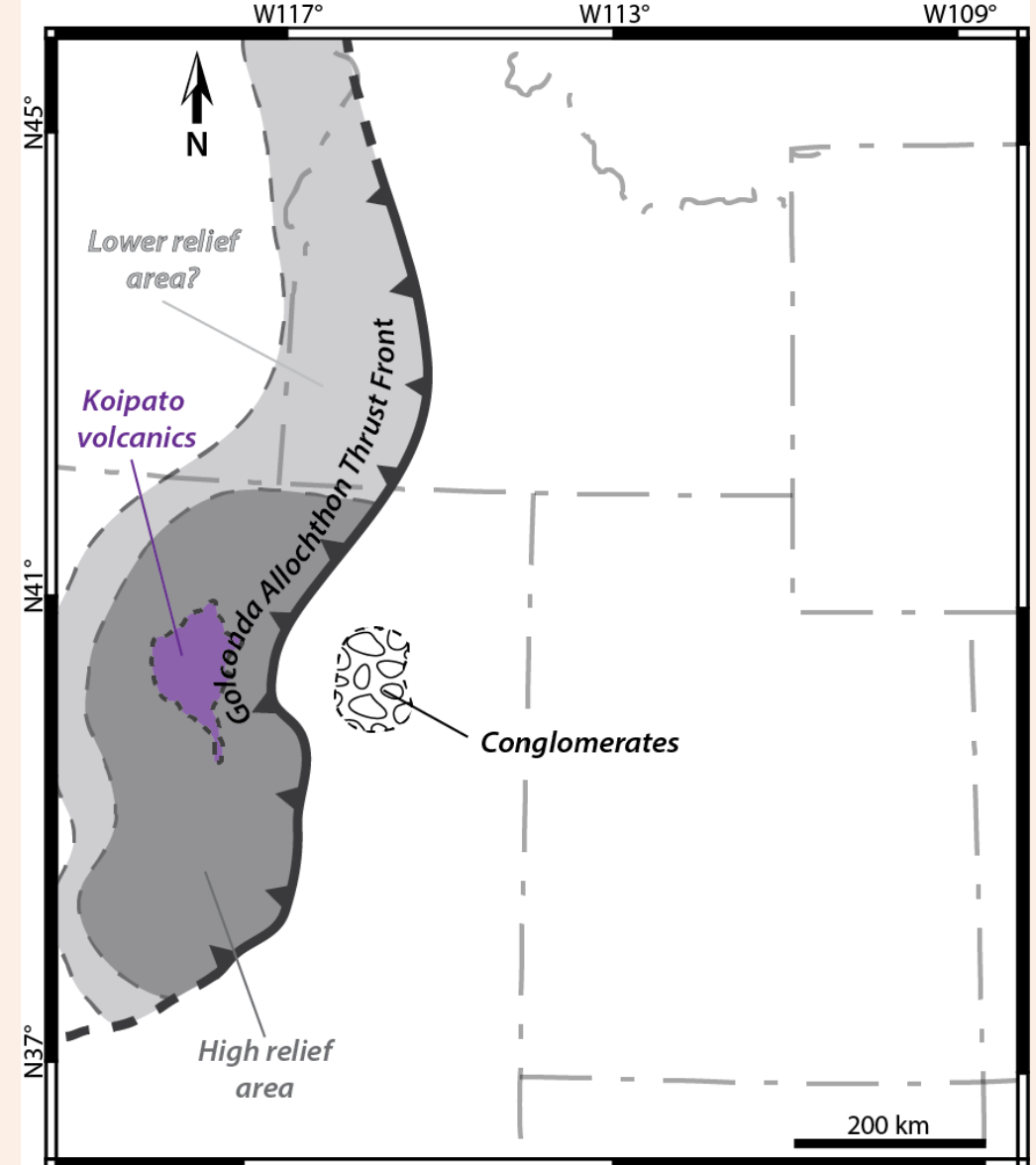
# Hypotheses

- *Differential topographic loading?*

Highest relief in South-central Golconda front

⇒ **Cannot rule out impact of the topographic load**

⇒ **Not the main controlling factor**



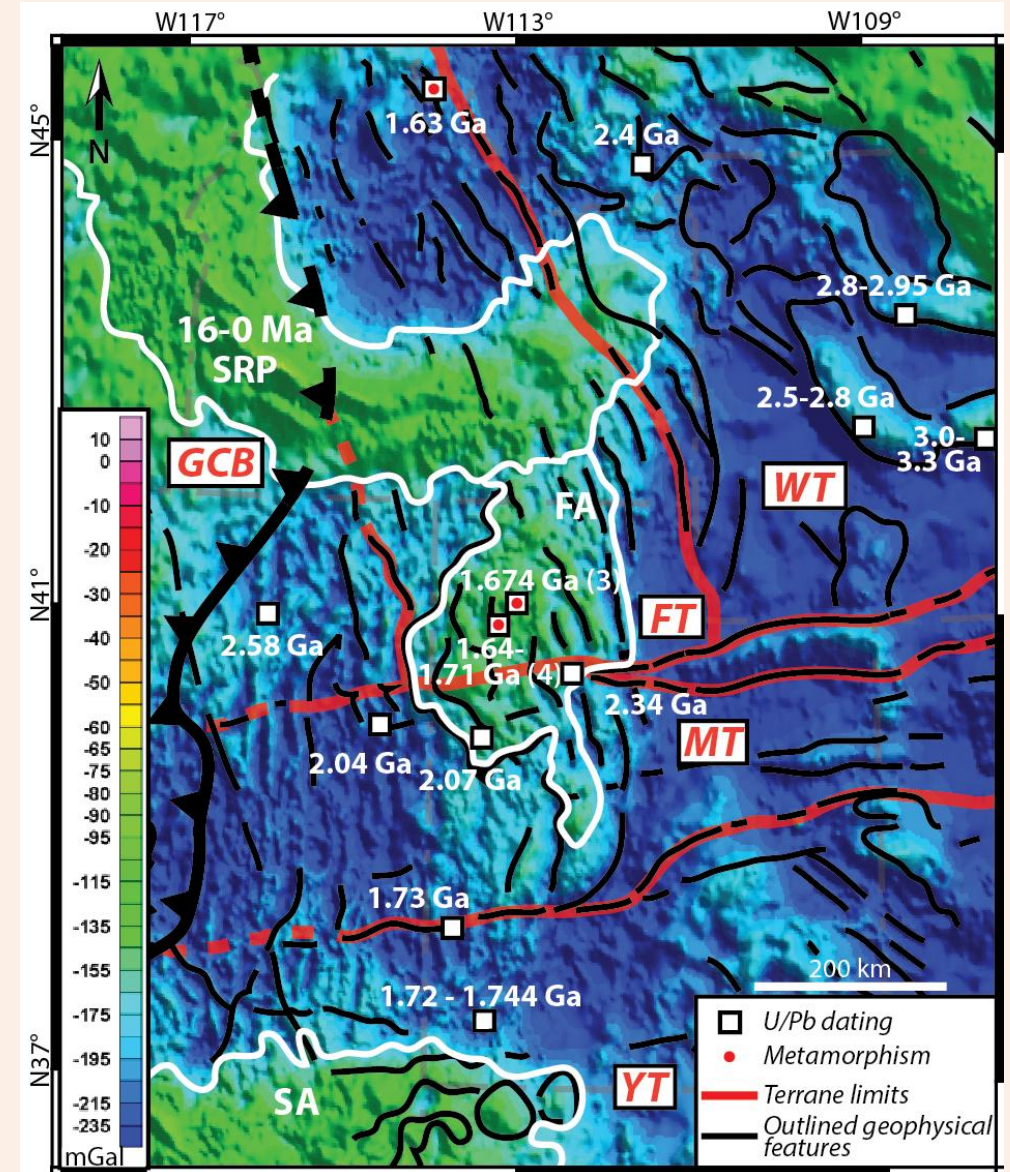
# Hypotheses

- *Differential rheological resistance?*

⇒ **New local terrane maps from literature and geophysical data**

- **Five terranes identified, with different ages:**

- Archean Wyoming Terrane (WT)
- Archean Grouse Creek Block (GCB)
- Paleoproterozoic Mojave Terrane (MT)
- Mesoproterozoic Yavapai Terrane (YT)
- Mesoproterozoic Farmington Terrane (FT)



# Hypotheses

- *Differential rheological resistance?*

## ⇒ Strong lithospheres

Oldest (>1.7 Ga), coldest and more rigid, **resistant to flexuration**

- WT, GCB, MT

## ⇒ Weak lithosphere

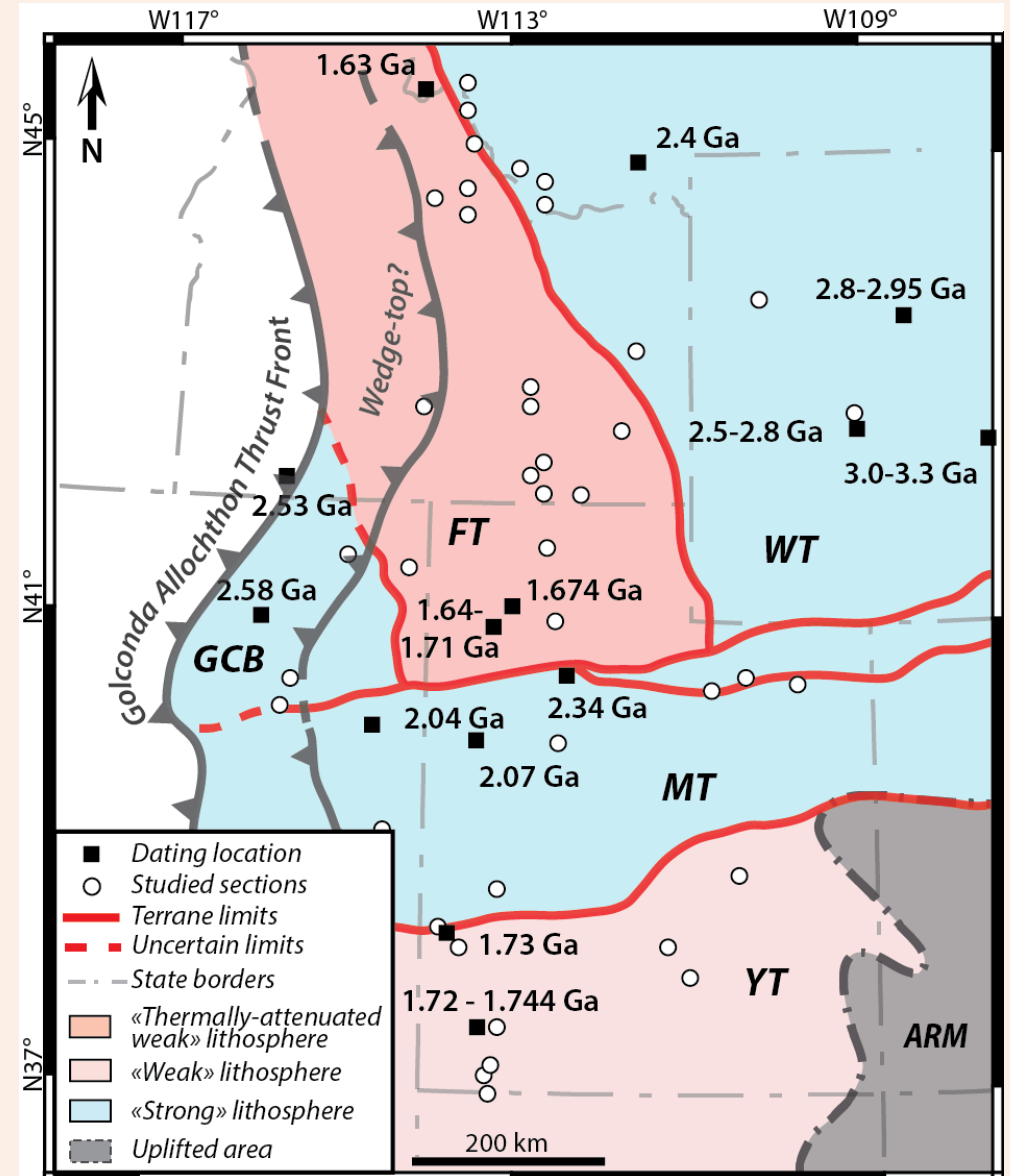
Juvenile (<1.6 Ga), warmer and **less rigid**, more prone to deformation and flexuration

- YT

## ⇒ Thermally-attenuated weak lithosphere

Underwent at least one **intense thermal metamorphism event** (~1,6 Ga)

- FT (Mobile belt)

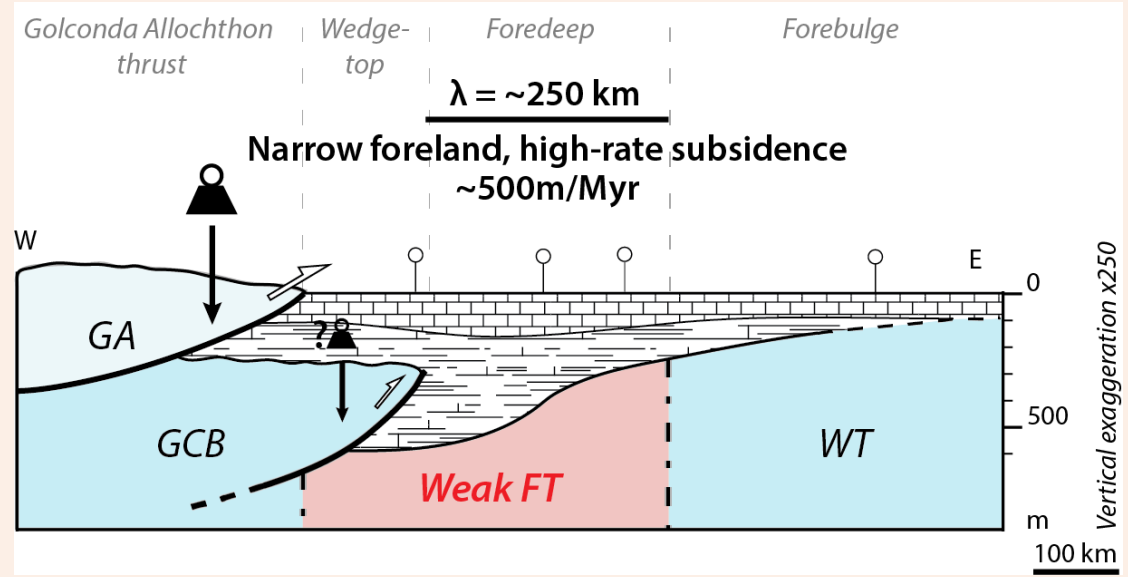




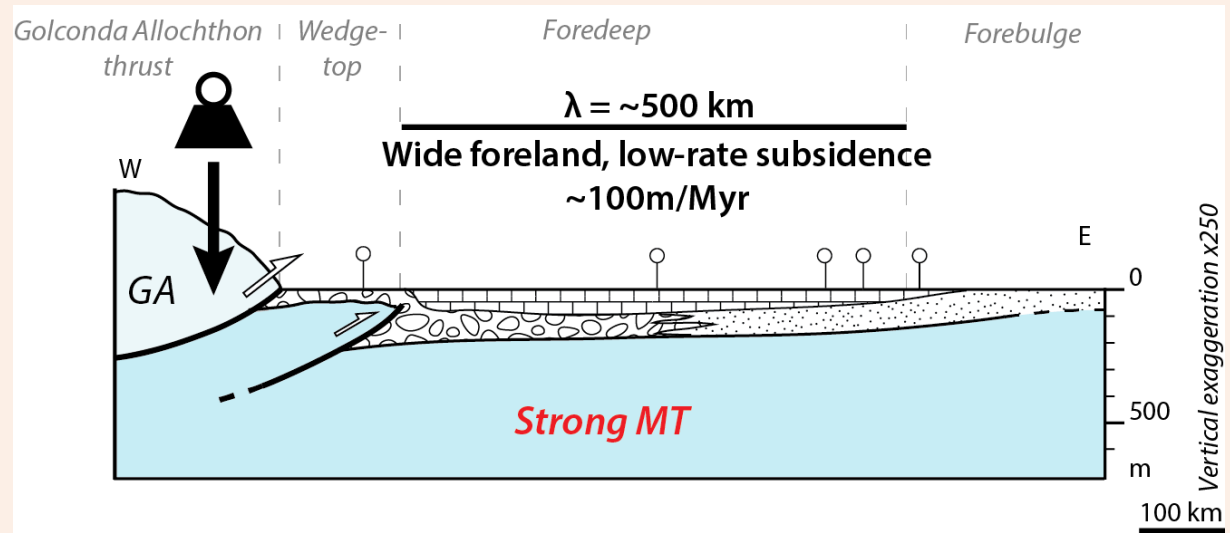
*Proposed model*



⇒ **Highest thicknesses and accommodation rates** in northern SFB above **Weak-attenuated** terrane



⇒ **Lowest thicknesses and accommodation rates** in southern and eastern SFB above **Strong** terranes

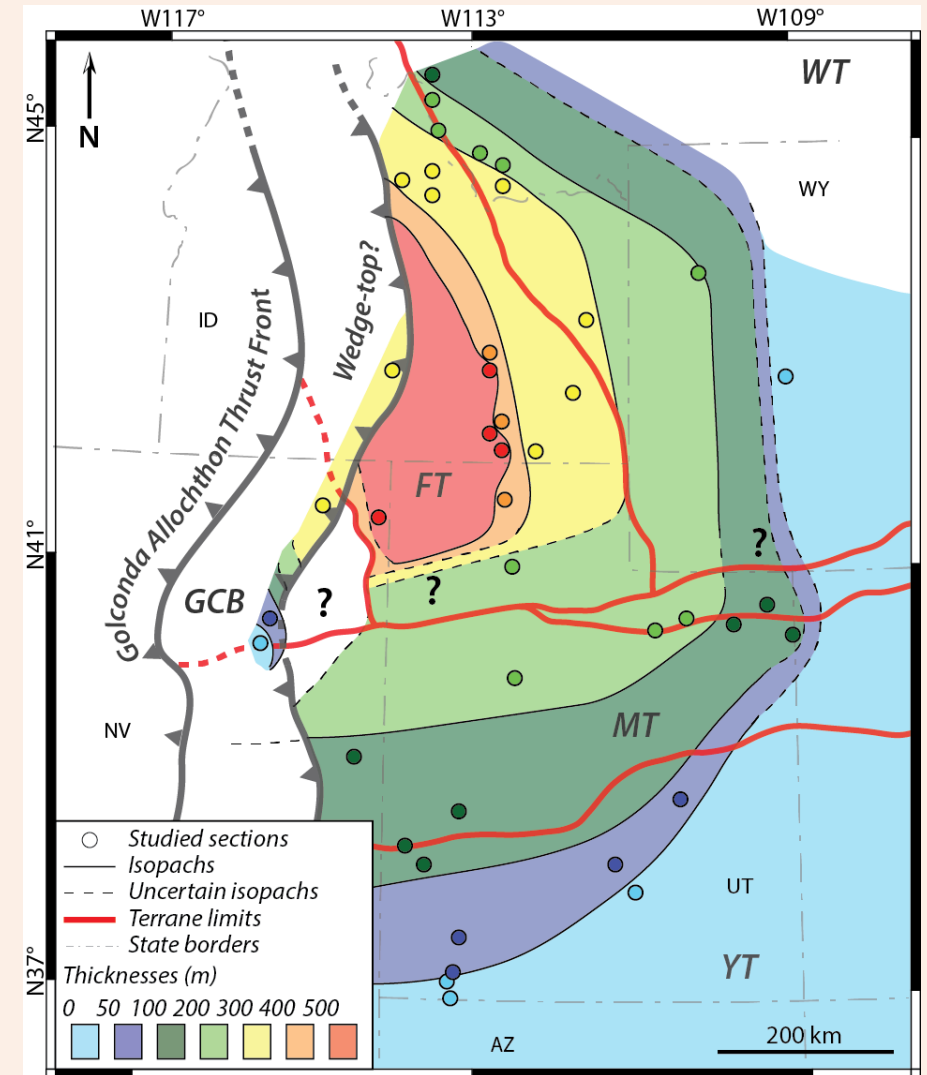


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## Conclusion

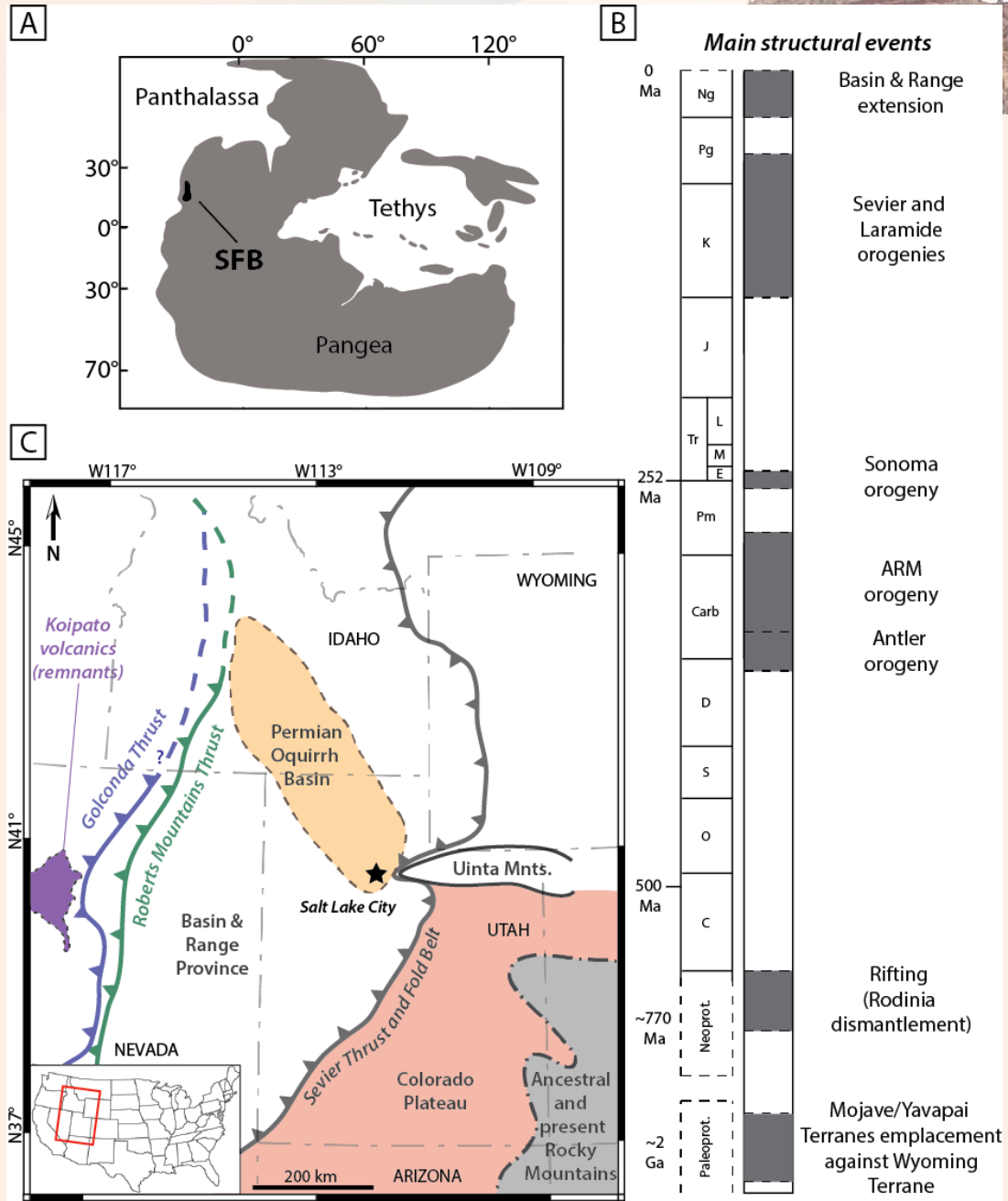
- Early Triassic **Sonoma Foreland Basin: two parts with differential tectonic subsidence**
- Controlling mechanisms?
  - **Negligible** sedimentary overloading
  - **Weak impact of the topographic loading**
  - **Rheological behaviour** of the basement is likely the main controlling factor
- **Lithospheric strength: a major controlling factor on flexuration**, and consequently on the **differential tectonic subsidence in the basin**



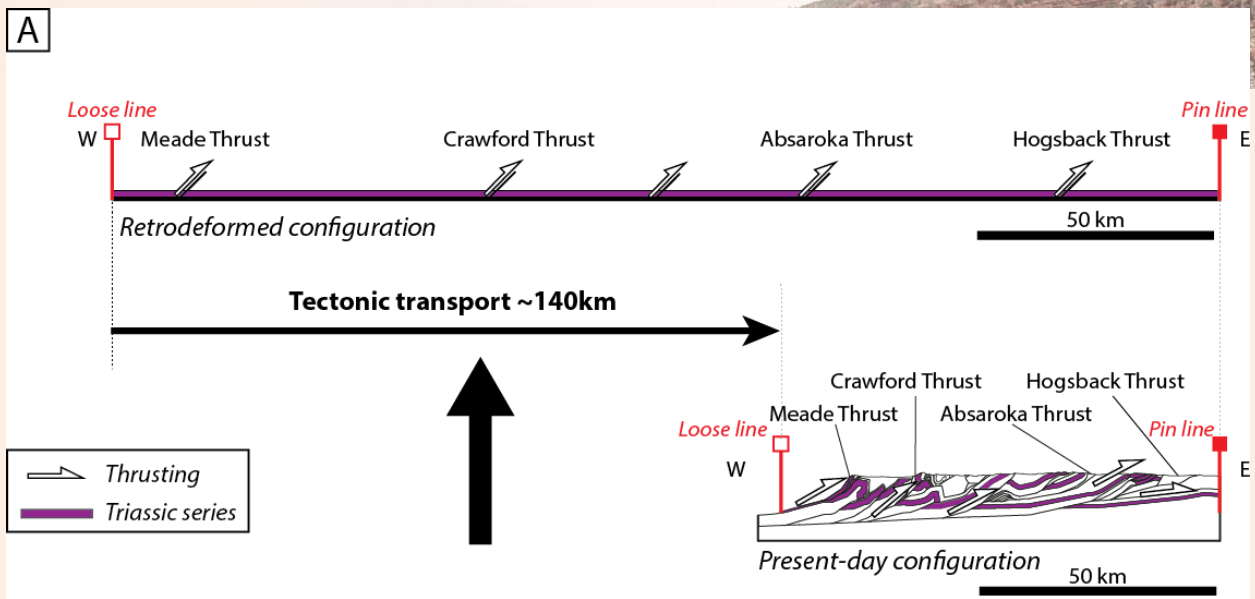
*Thank you for paying attention!*



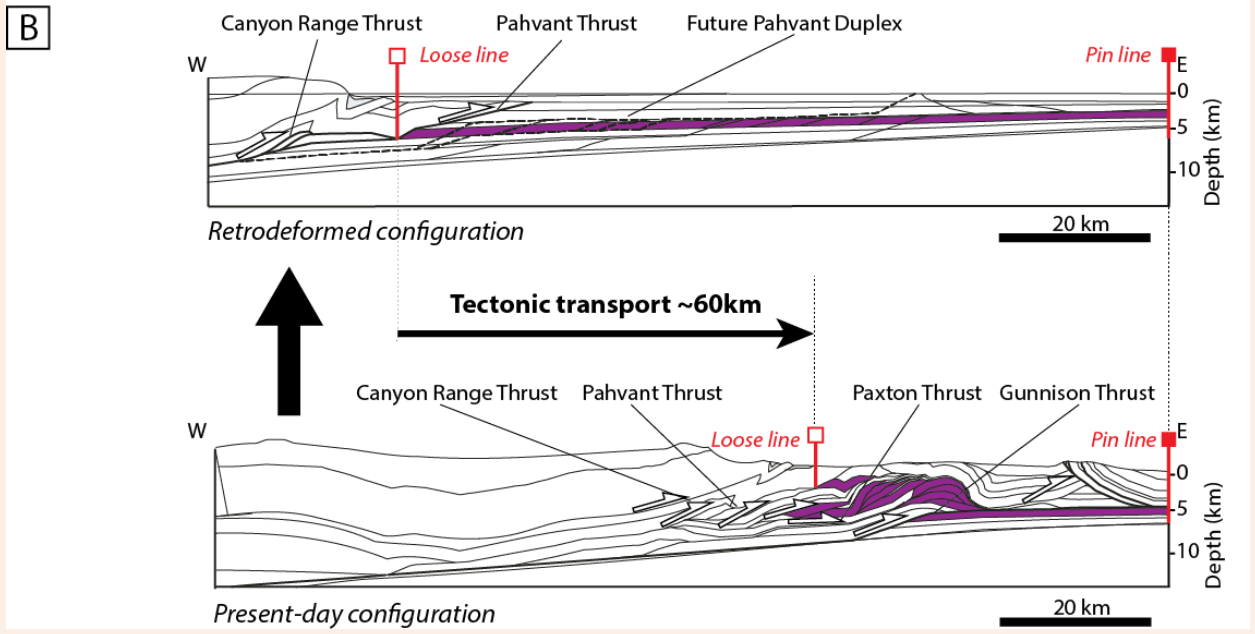
Supplements



Caravaca\_et\_al\_figure\_1

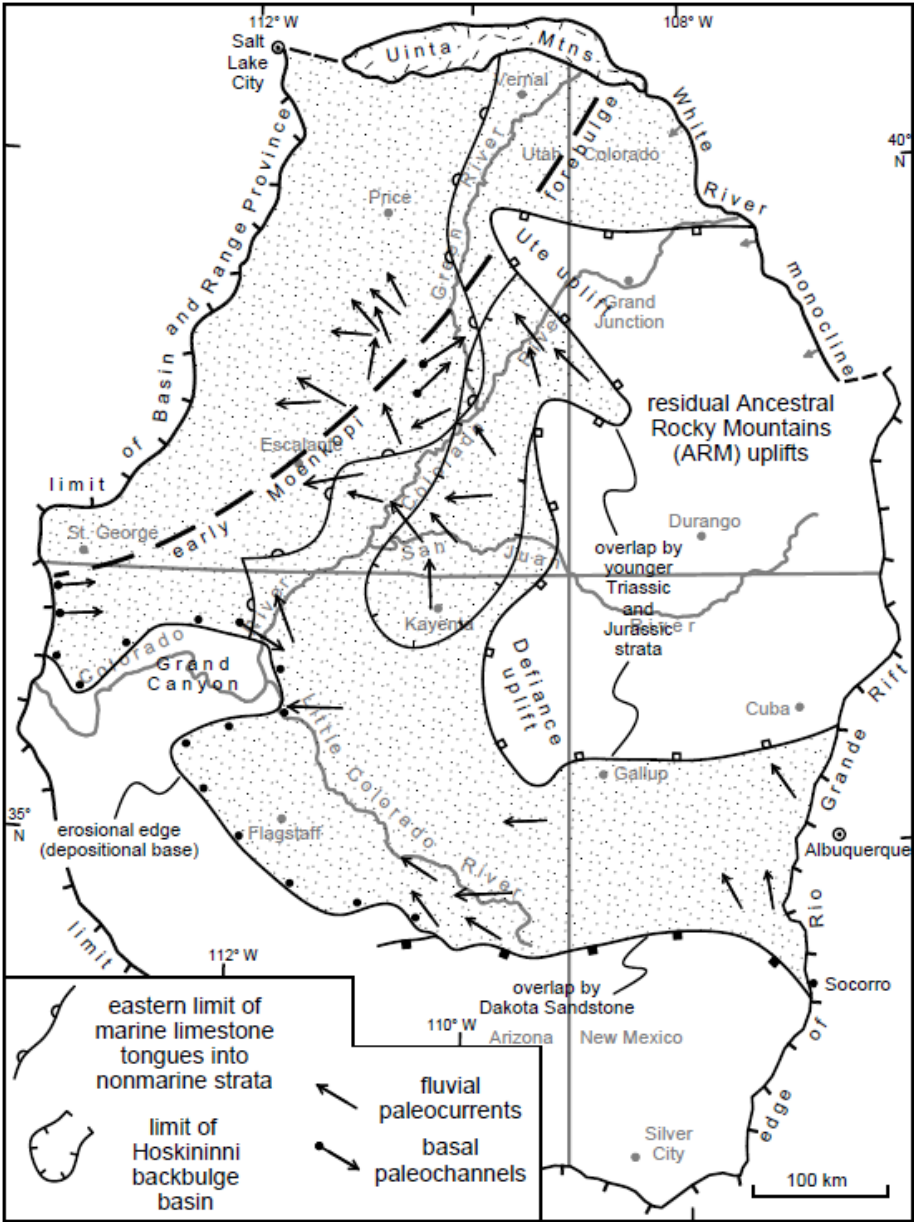


Retrodeformation method





Perspectives: depositional settings



W.R. Dickinson, Pers. comm.

Oldest lithospheres are:

- Thicker and colder than juvenile counterparts (due to R\* elements depletion)
  - More buoyant ( $d^{\circ} < d^{\circ}$  juvenile lithosphere)
- ⇒ More rigid and resistant to flexuration

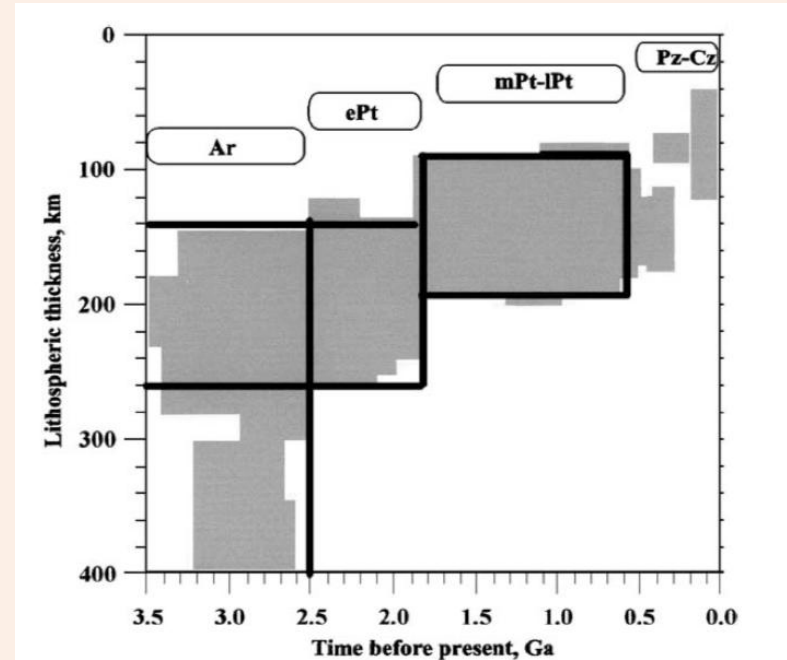
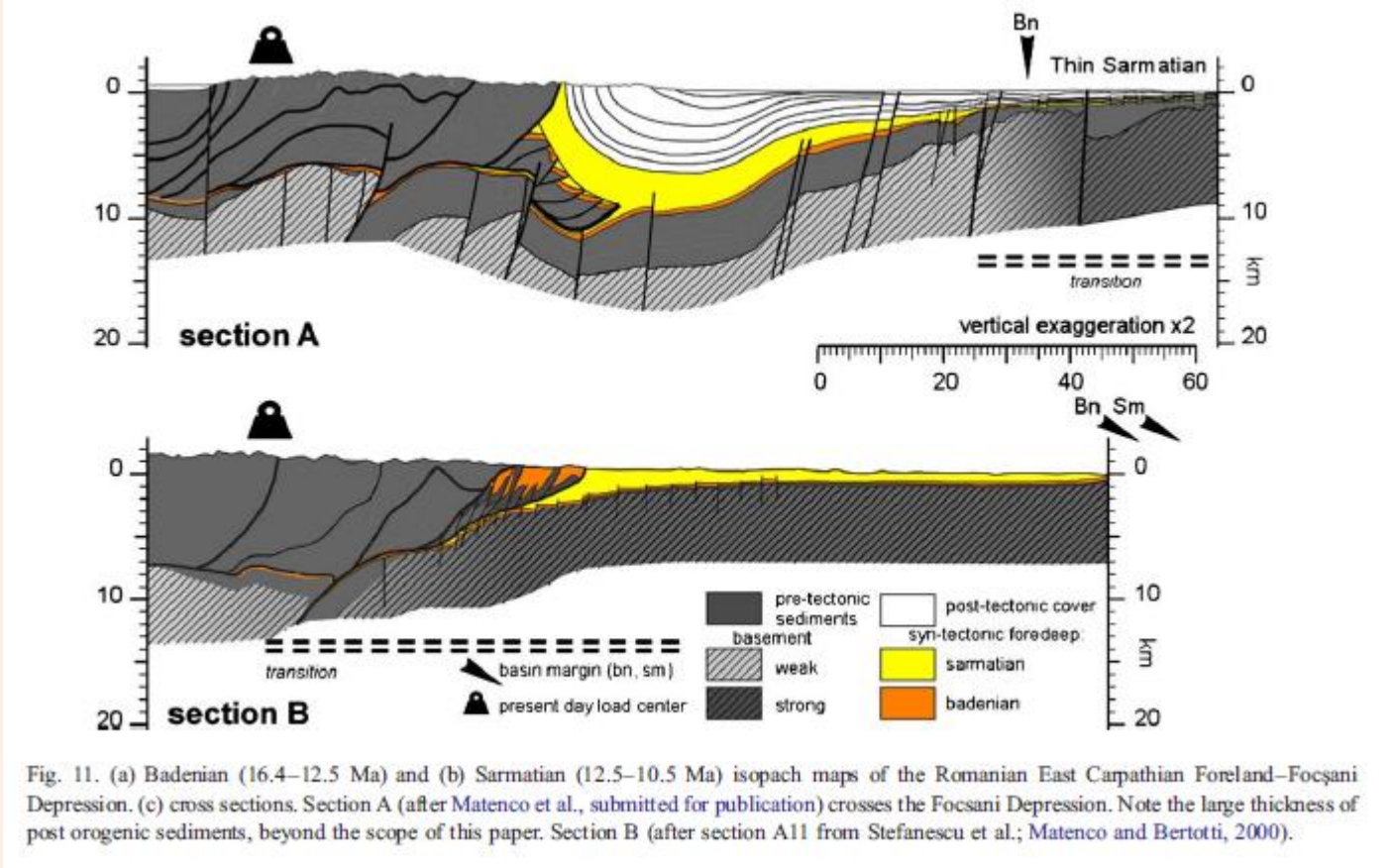
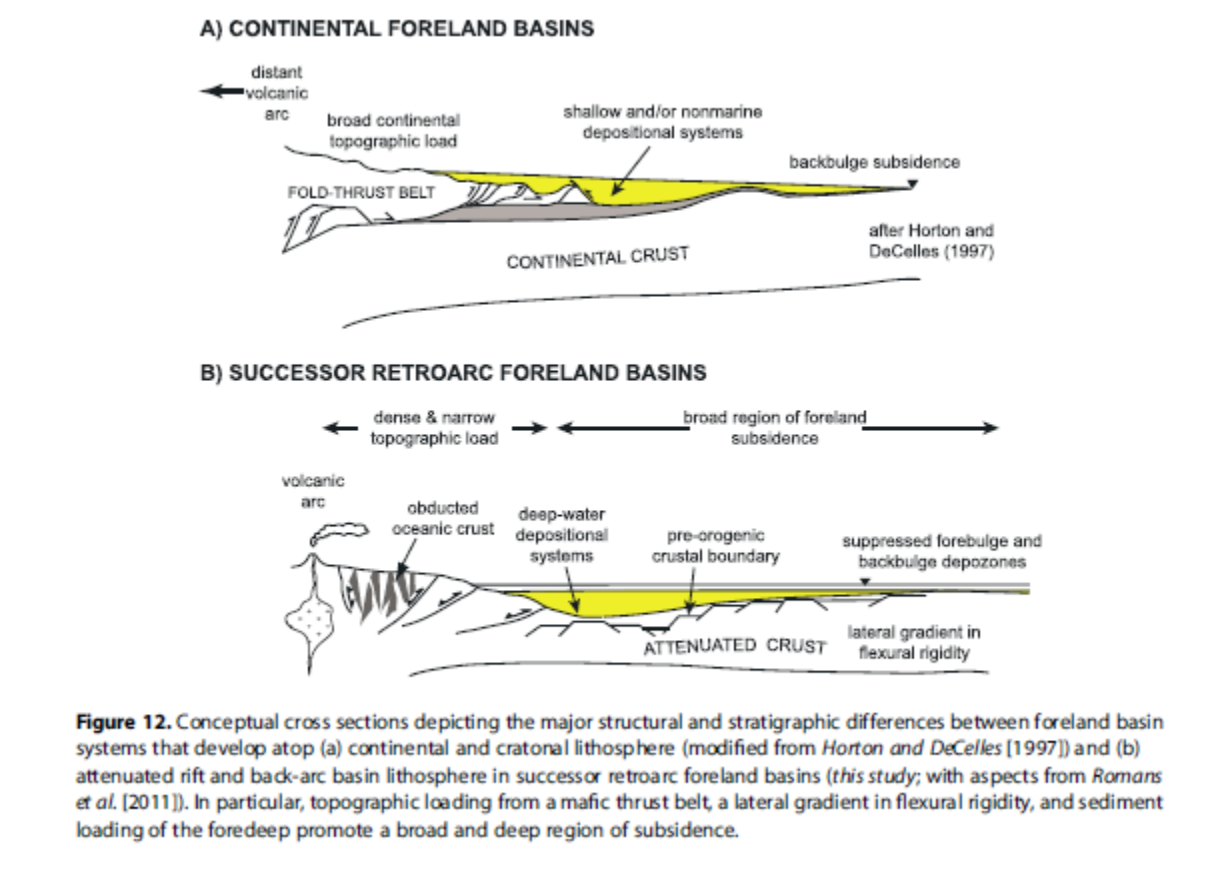


Fig. 2. Lithospheric thermal thickness versus geologic age of the continental lithosphere. The Archean lithosphere has bimodal thickness distribution centered at  $\sim 350$  and  $\sim 220$  km. Gray area shows the lithospheric thickness estimates derived from thermal data (Artemieva and Mooney, 2001). Key: Ar—Archean; ePt, mPt, lPt—early, middle and late Proterozoic, respectively; Pz—Paleozoic; Cz—Cenozoic.

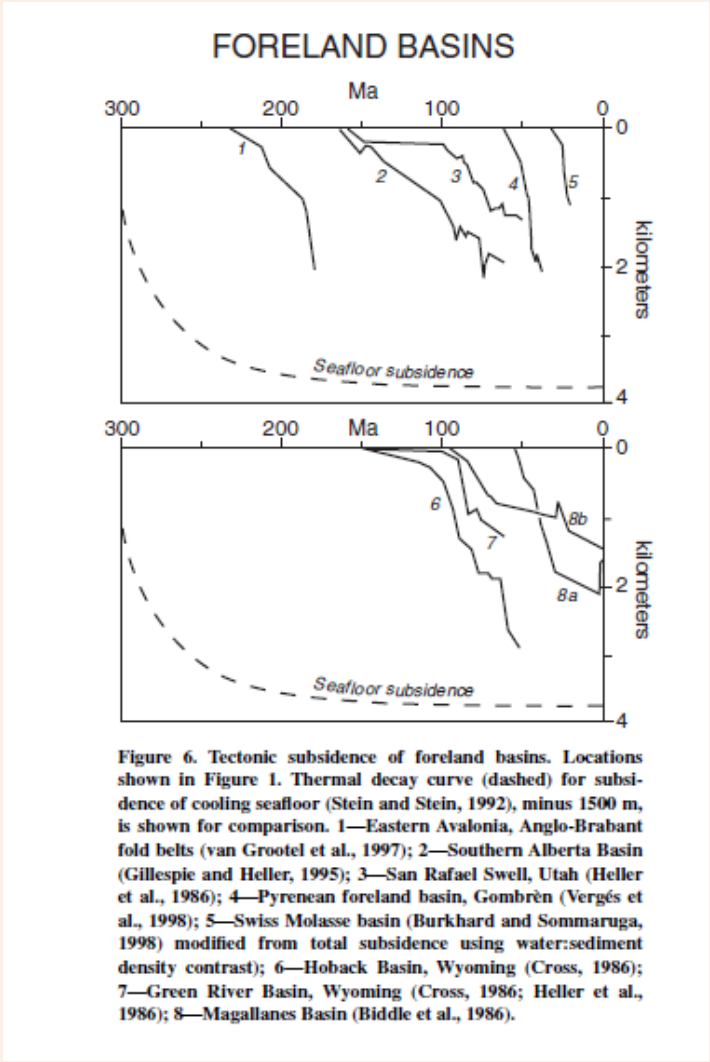
Carpathians, differential subsidence after rheology



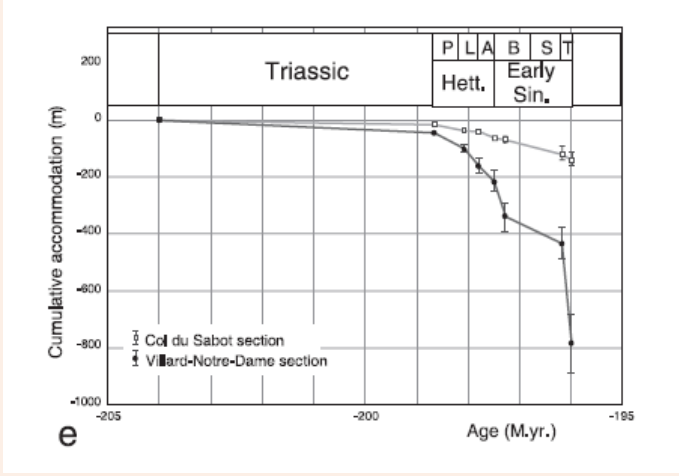
Magallanes basin, differential subsidence after rheology (attenuated lithosphere)



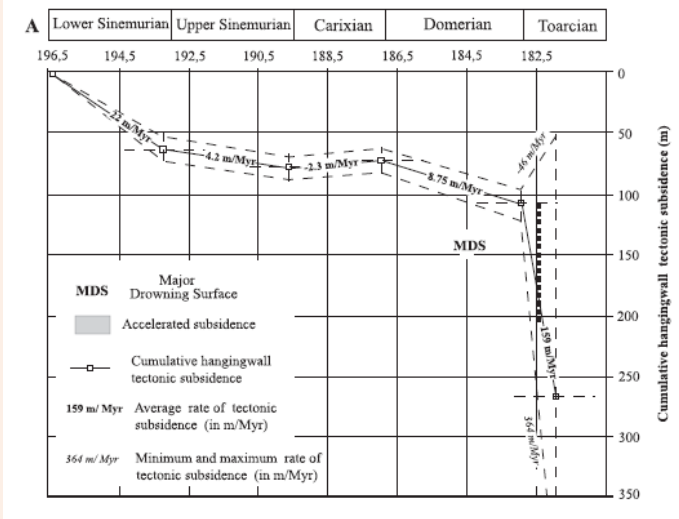




Xie & Heller, 2009



Chevalier et al, 2003



Lachkar et al., 2009

## Perspectives: depositional settings

Depositional settings distributions between the *Owenites* and *Anasibirites* ammonoids biozones (middle Smithian)

Striking **differences between southern and northern parts** of the basin:

- ⇒ **Differences between paleontological and sedimentological record**
- ⇒ **Paleogeography to be reconstructed** using this integrative set of data
- ⇒ **Impact of lithospheric control**

Depositional settings:

- Deep subtidal
- Shallow subtidal
- Subtidal to intertidal (microbial carb.)
- Transitional/coastal (red beds)

