Monazite fission-track dating of the Catalina metamorphic core complex, AZ, USA

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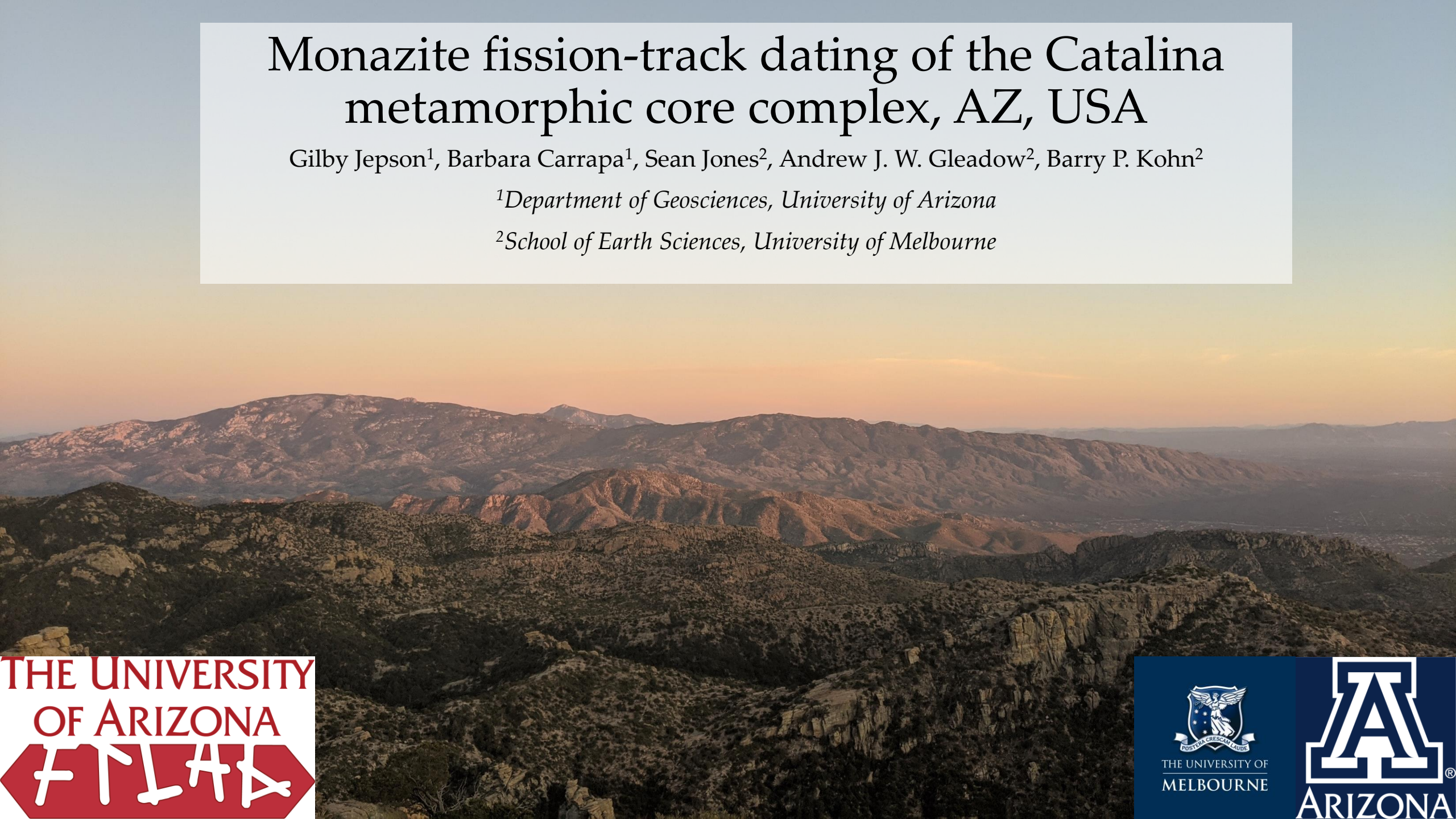
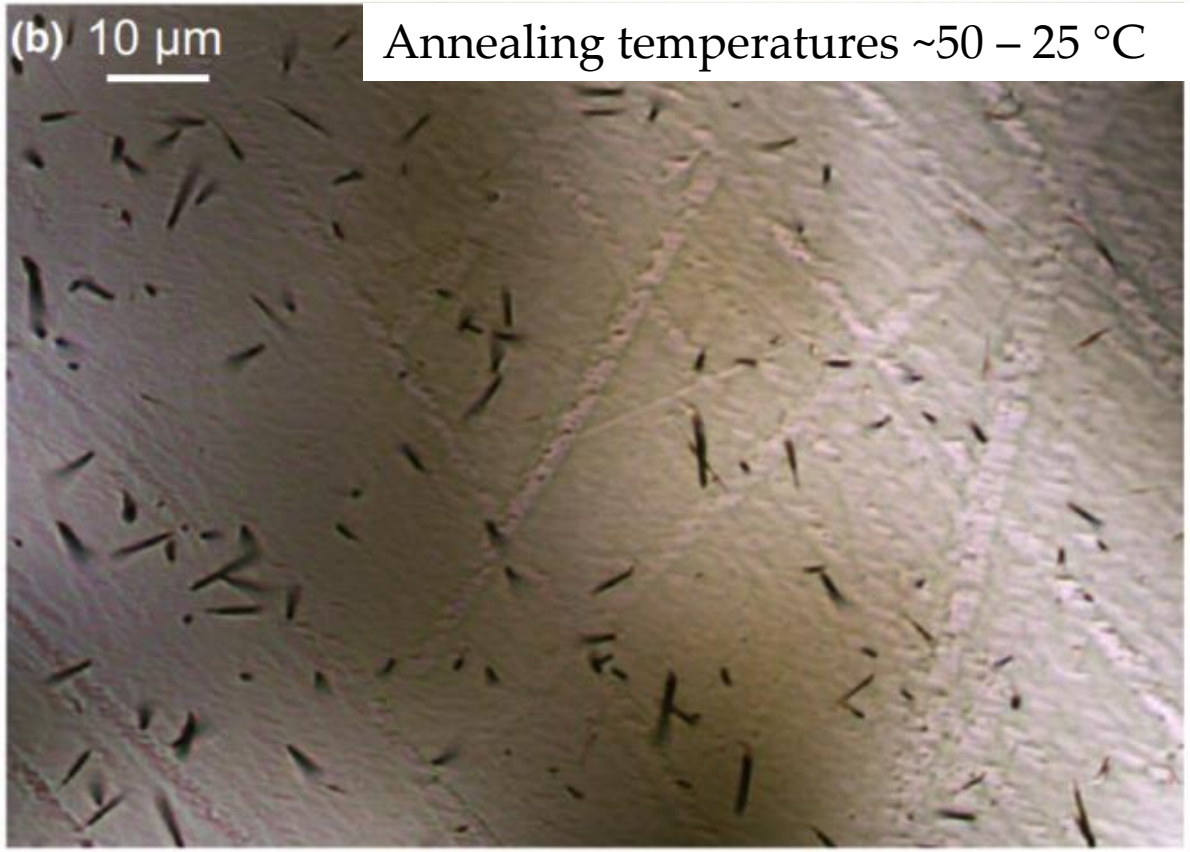


If we can etch monazite, we should be able to date it!*

Madagascar Monazite: Weise et al. 2009

Annealing temperatures < 100 °C

Harcourt monazite: Jones et al. 2019



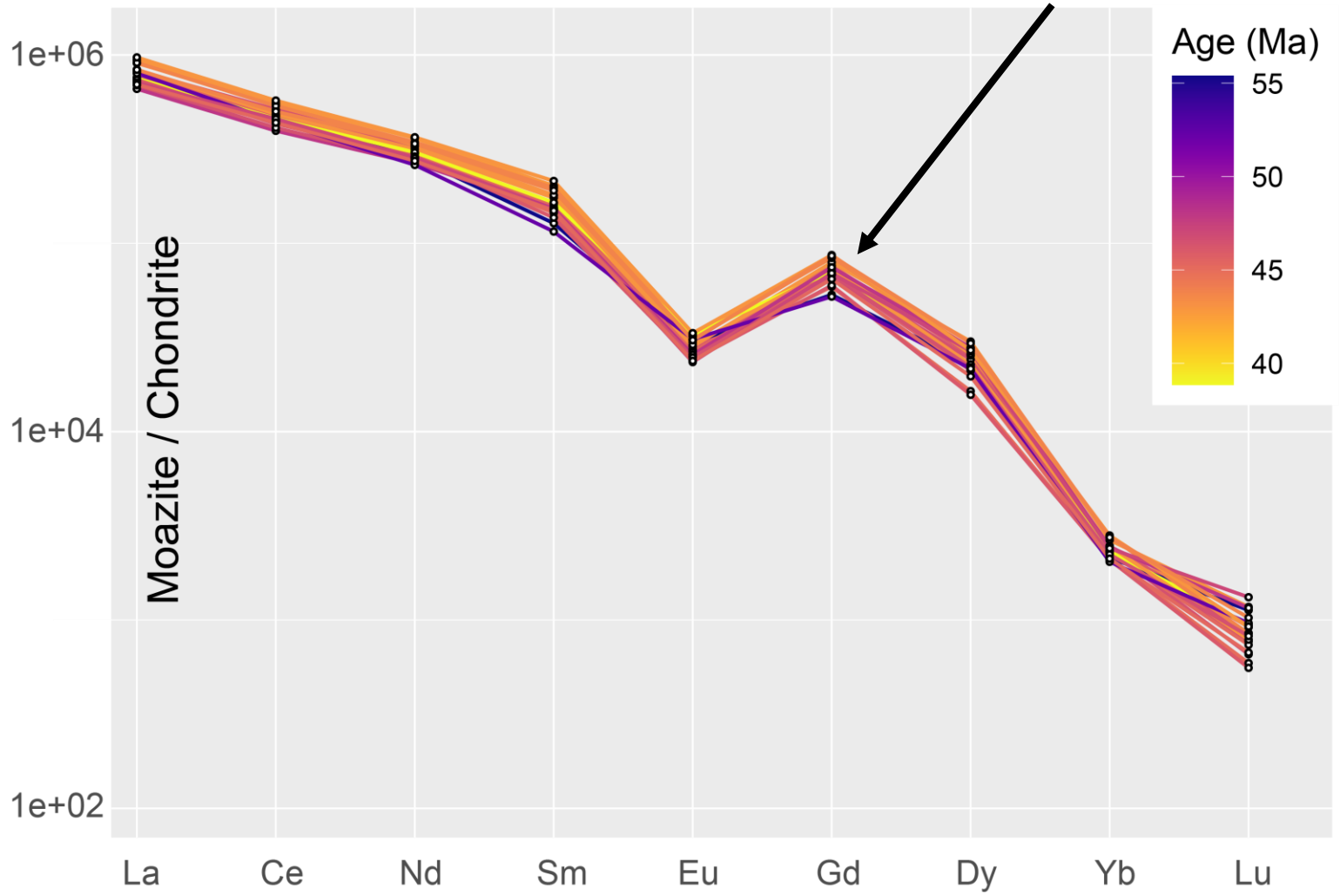
Annealing temperatures ~50 – 25 °C

*But not with EDM

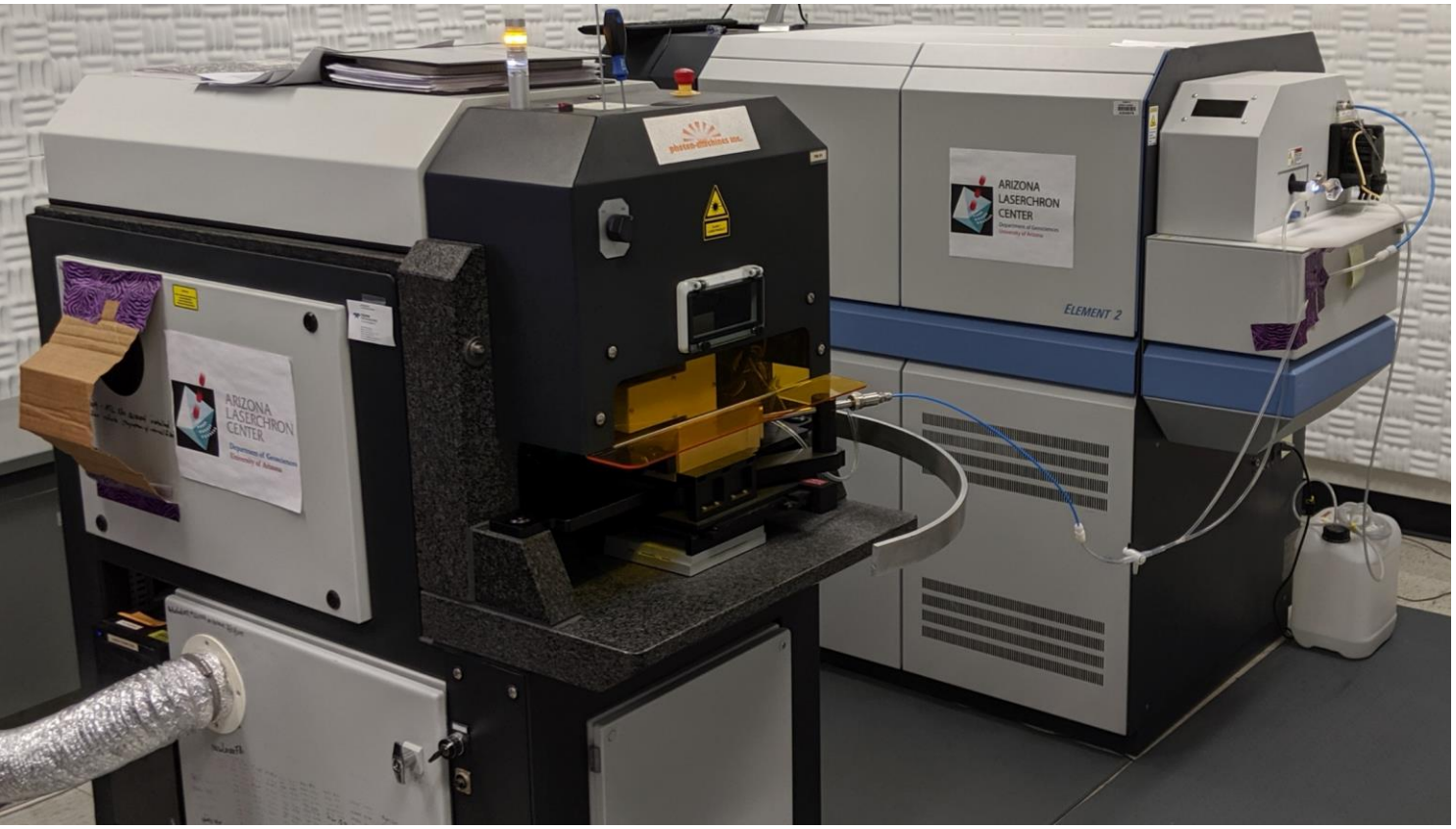
Monazite: a REE phosphate
$(Ce,La,Nd,Th)(PO_4,SiO_4)$

Blocks slow thermal neutron bombardment (Weise et al. 2009)

https://www.mineralatlas.eu

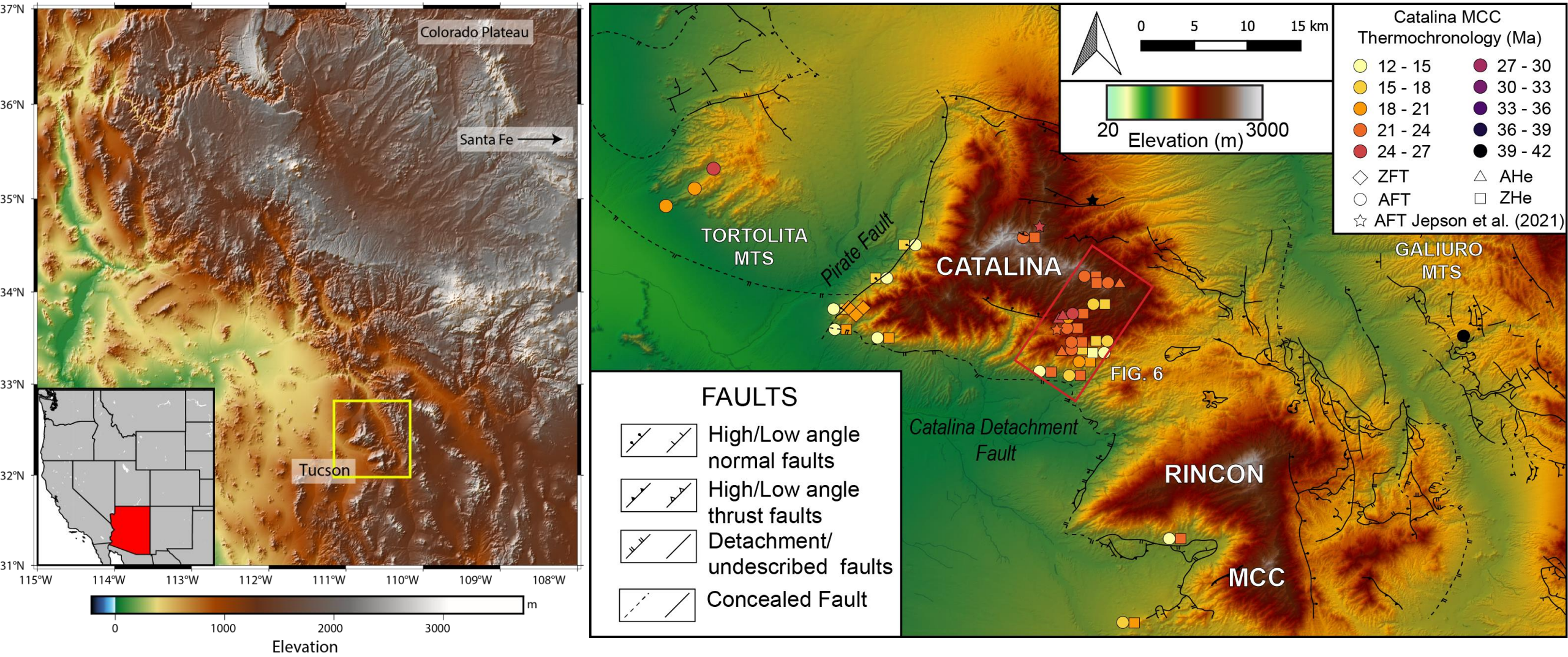


Approach: Laser Ablation FT



LA-ICP-MS set-up allows for single-grain monazite U-Pb and ^{238}U determination (Fayon, 2008).

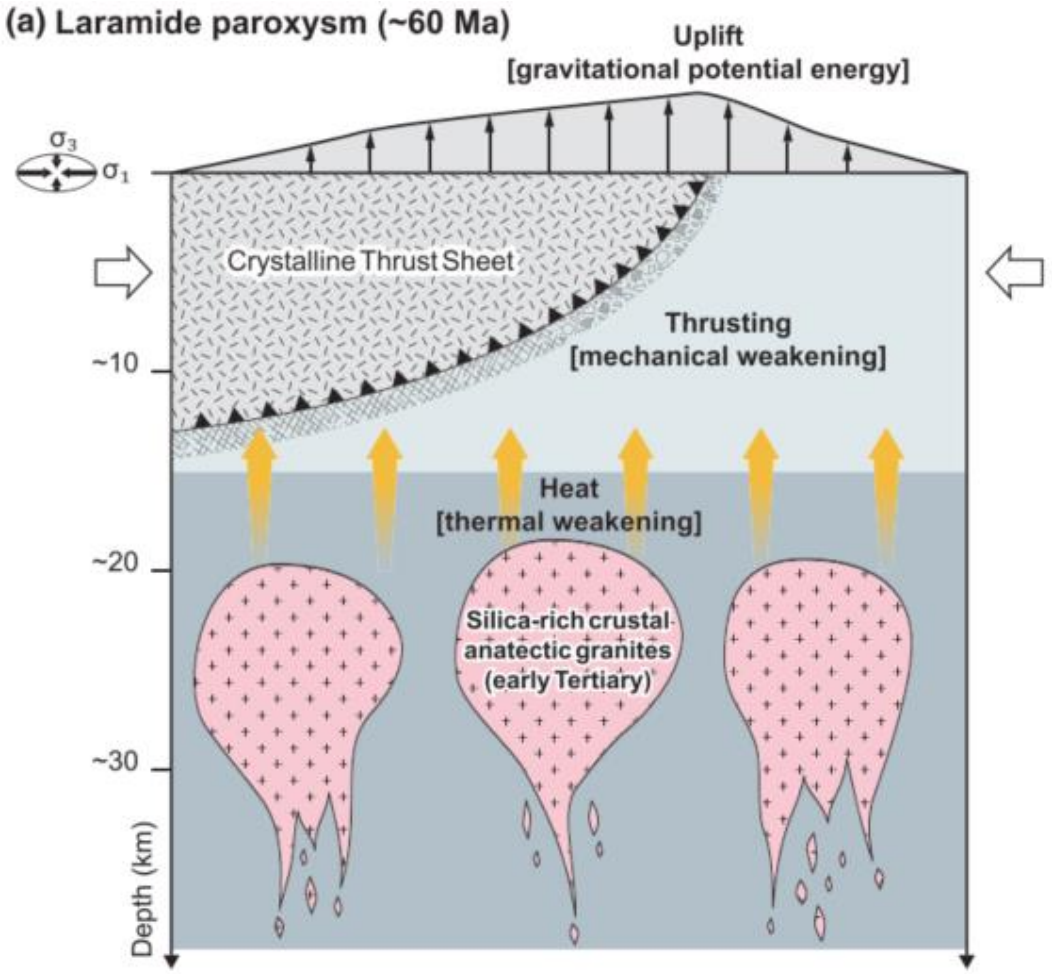
Location: Catalina metamorphic core complex

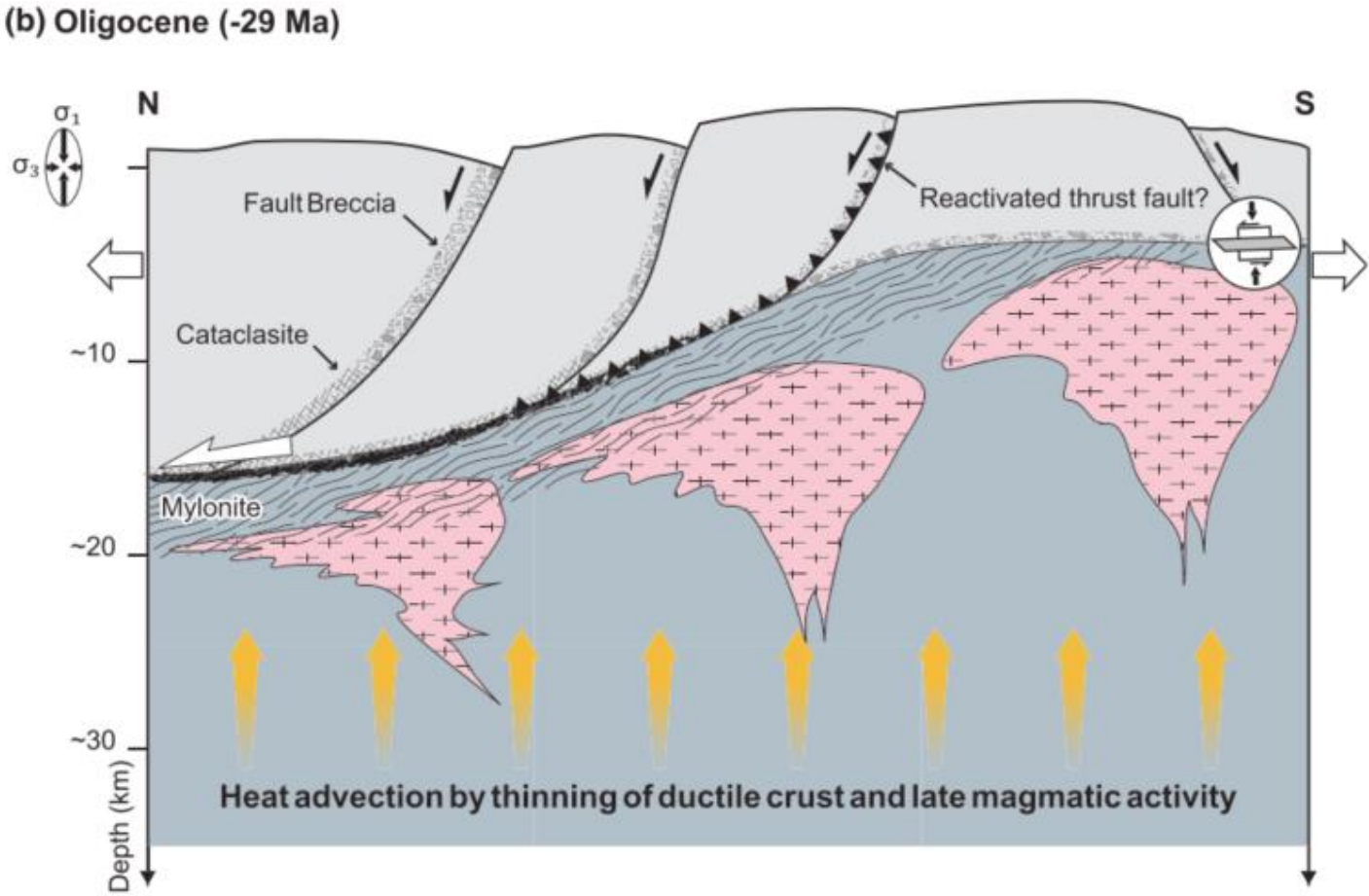


High-relief, geologically young, and covered with thermochronometric dates!*

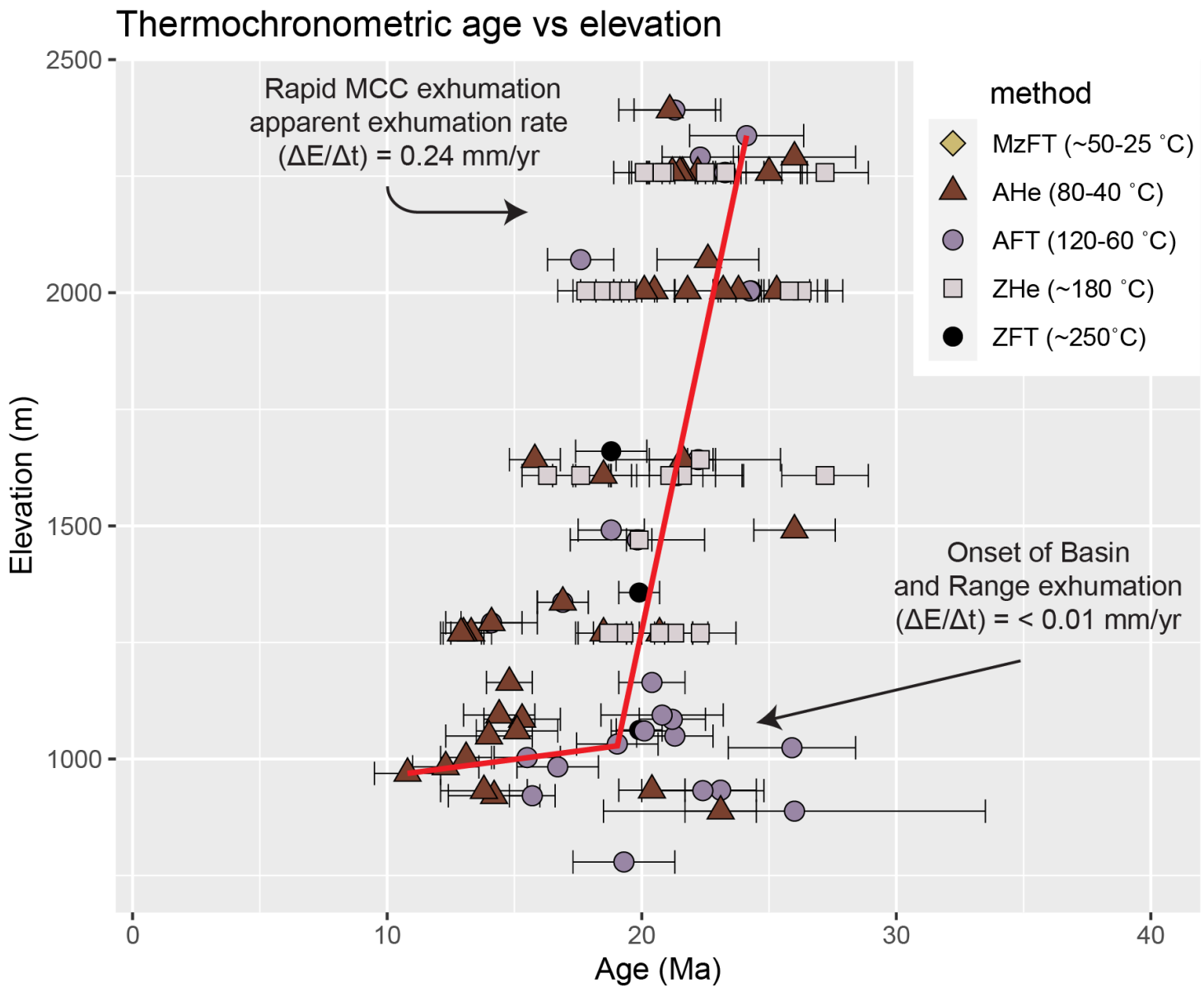
*also nice and close for all the re-sampling required..

A metamorphic core complex



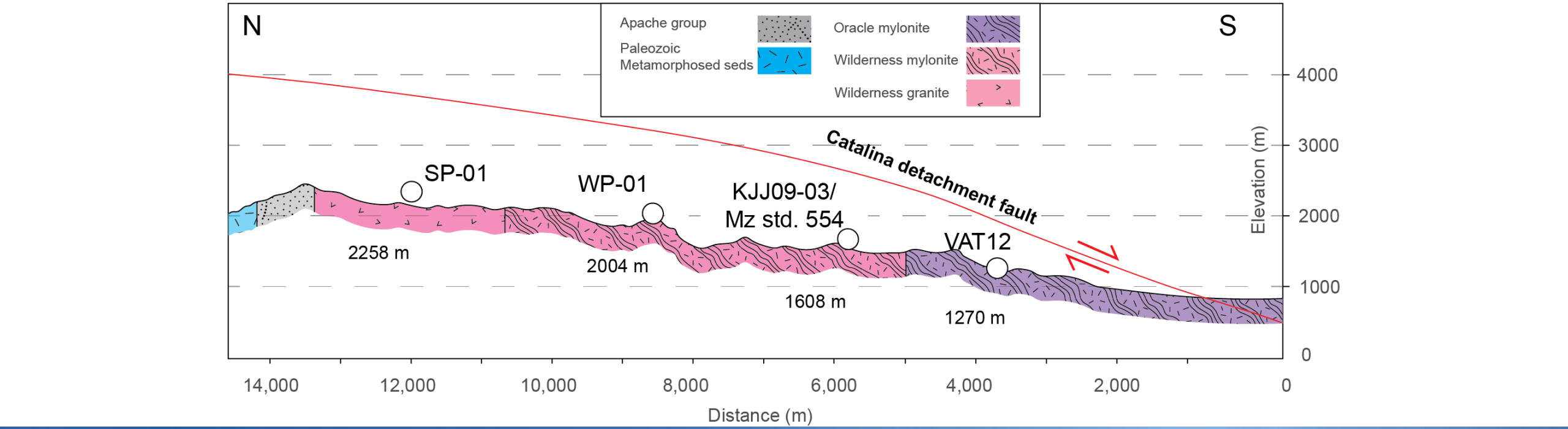


Gottardi et al. 2020



1) 26-19 Ma phase of rapid cooling observed in higher temperature thermochronometers and at higher elevations.

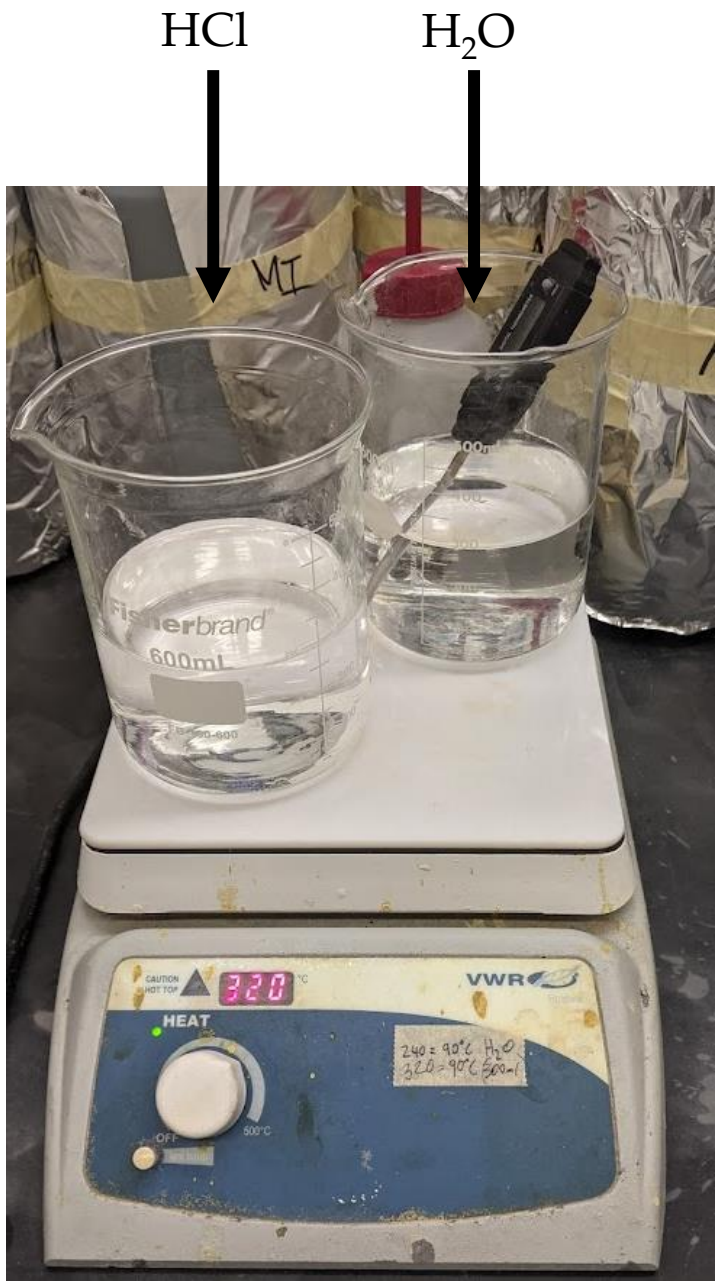
2) 19-11 Ma phase of slower cooling observed in lower temperature thermochronometers and at lower elevations


N
S
Apache group
Paleozoic
Metamorphosed seds
Oracle mylonite
Wilderness mylonite
Wilderness granite
Catalina detachment fault
SP-01
WP-01
KJJ09-03/
Mz std. 554
VAT12
2258 m
2004 m
1608 m
1270 m
Elevation (m)
4000
3000
2000
1000
0
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Distance (m)

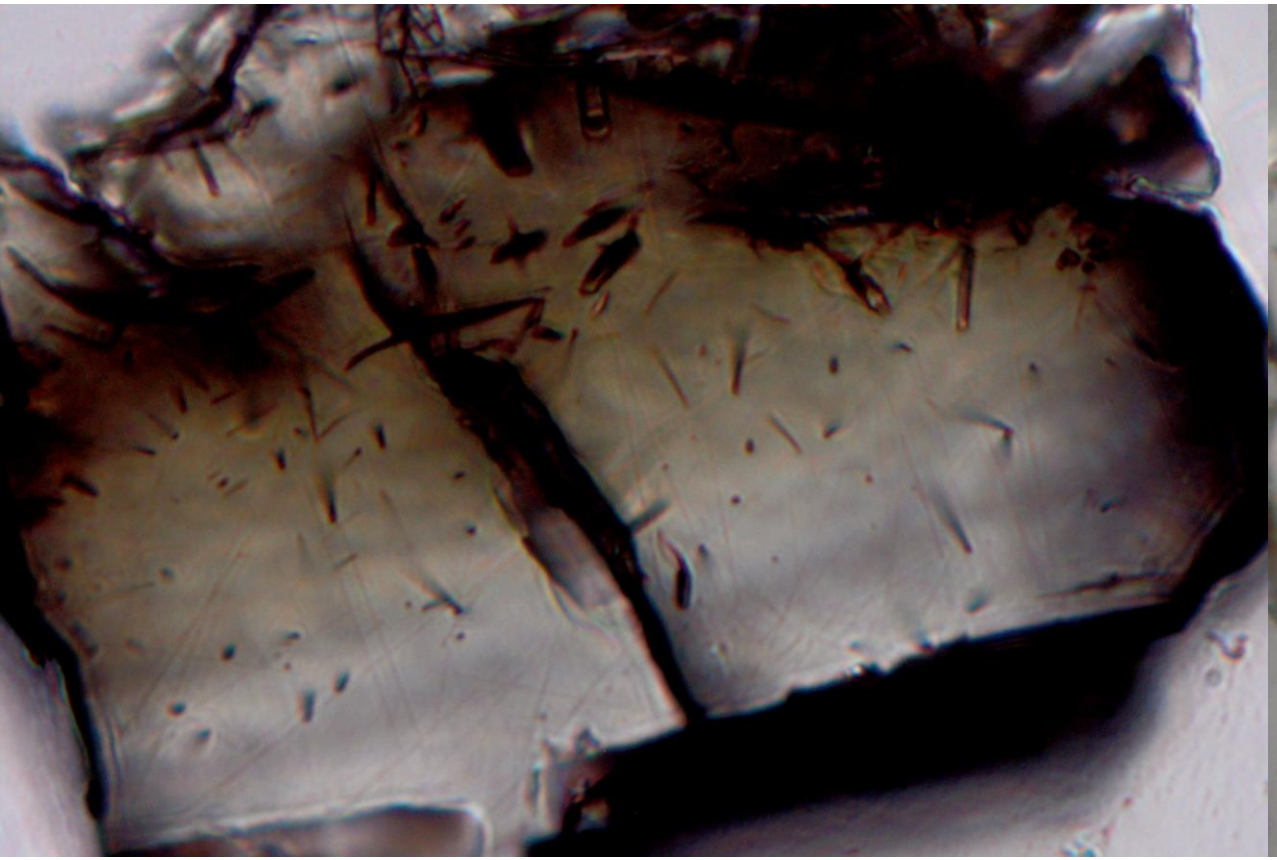

S
N

Etching:

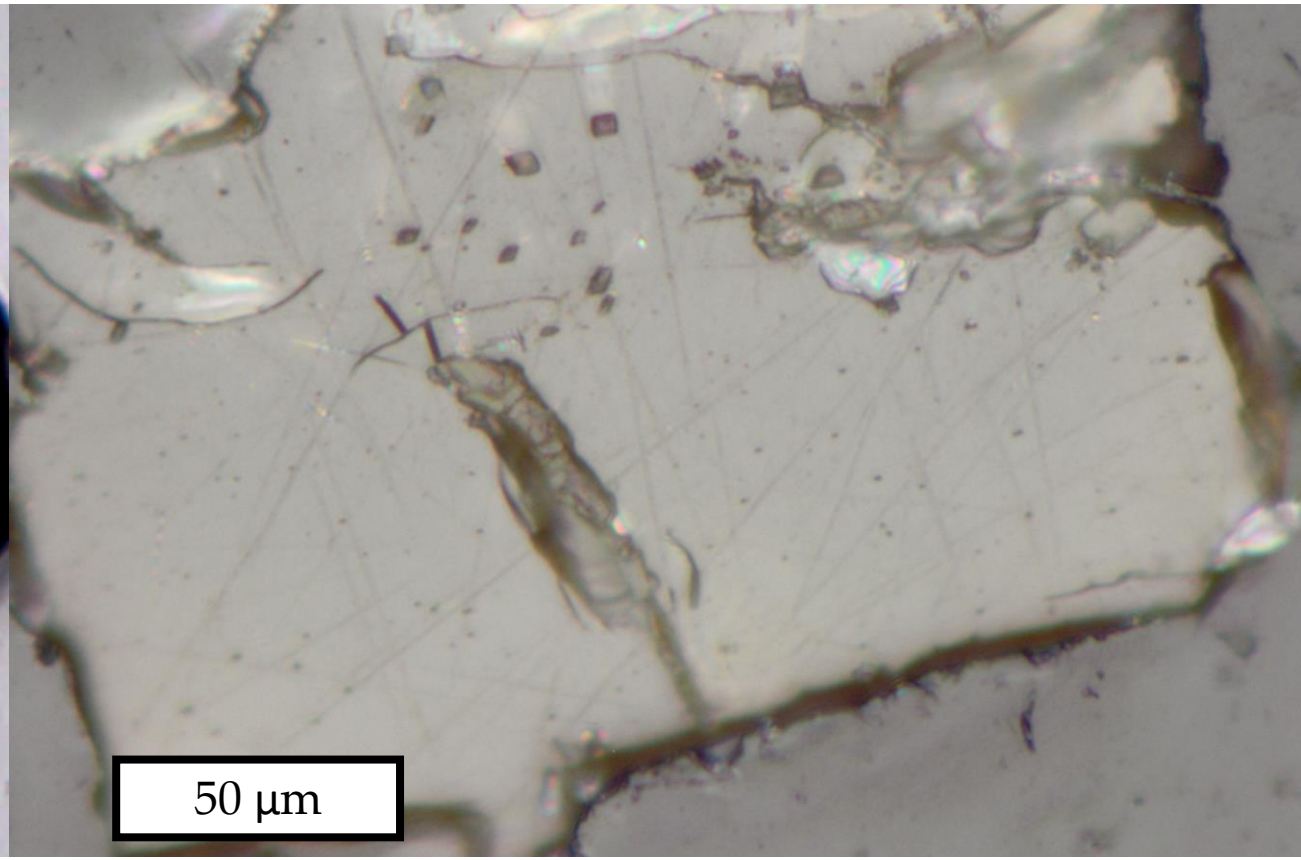
- Used 1 inch plastic ring form – reduces the expansion of epoxy
- Etched for 30 – 60 minutes in 6M HCl at 90 °C



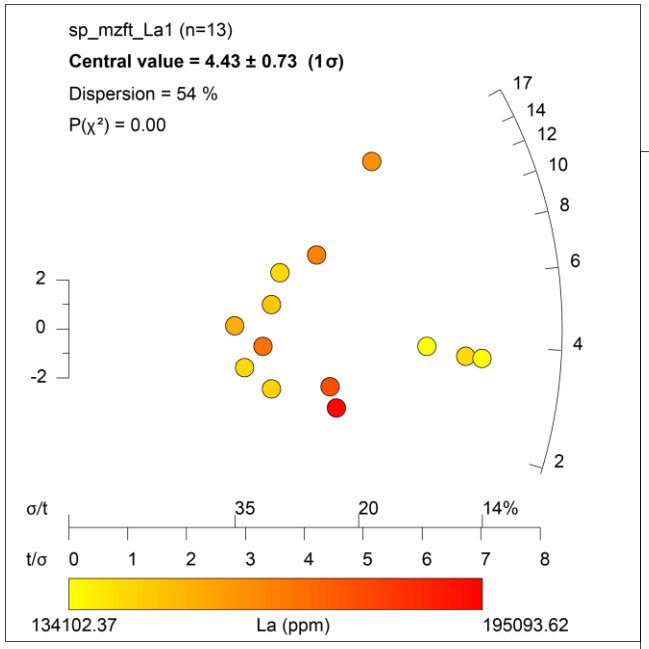
Etching:



Monazite transmitted light

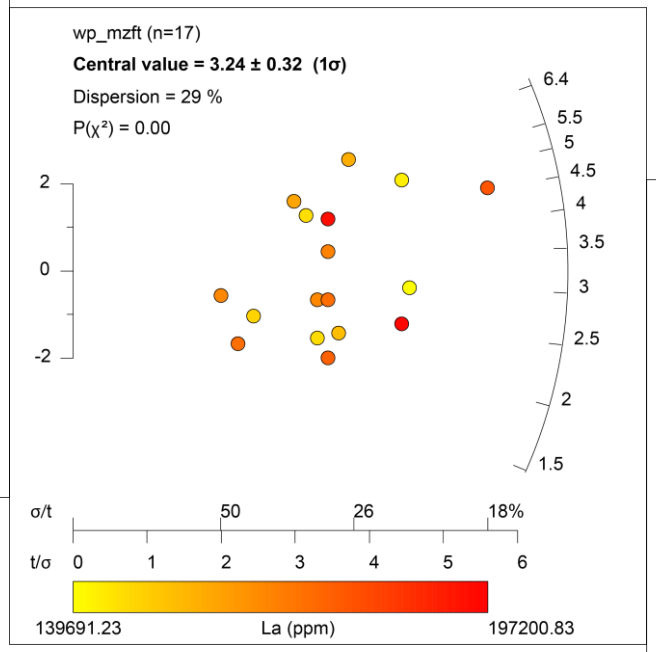


Monazite reflected light



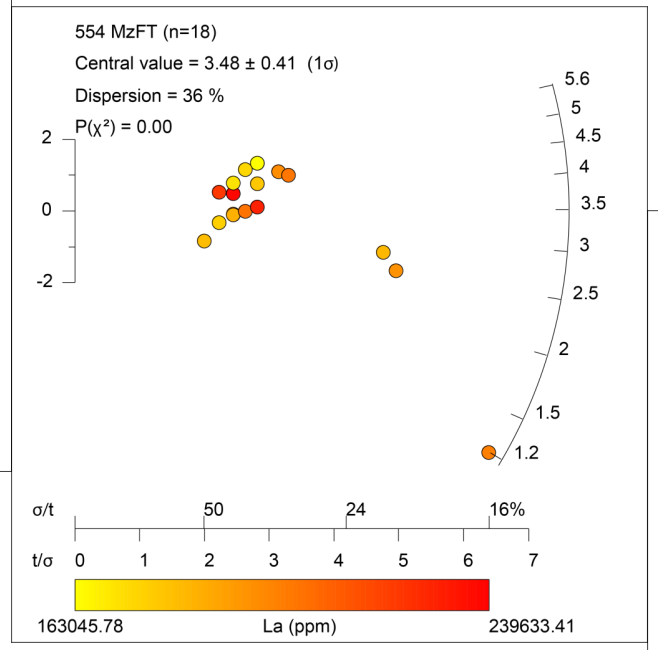
Mz FT date: 4.4 ± 0.7 Ma

Elevation: 2,258 m



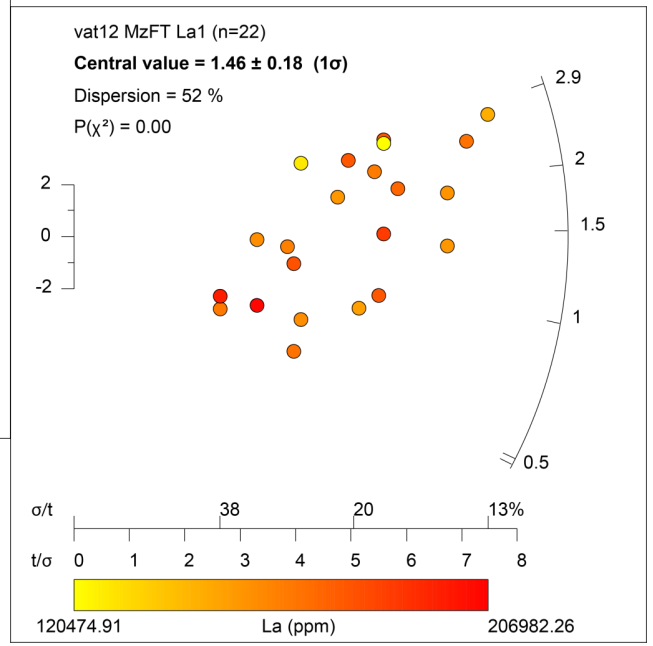
Mz FT 3.2 ± 0.3 Ma

Elevation: 2,004 m



Mz FT 3.5 ± 0.4 Ma

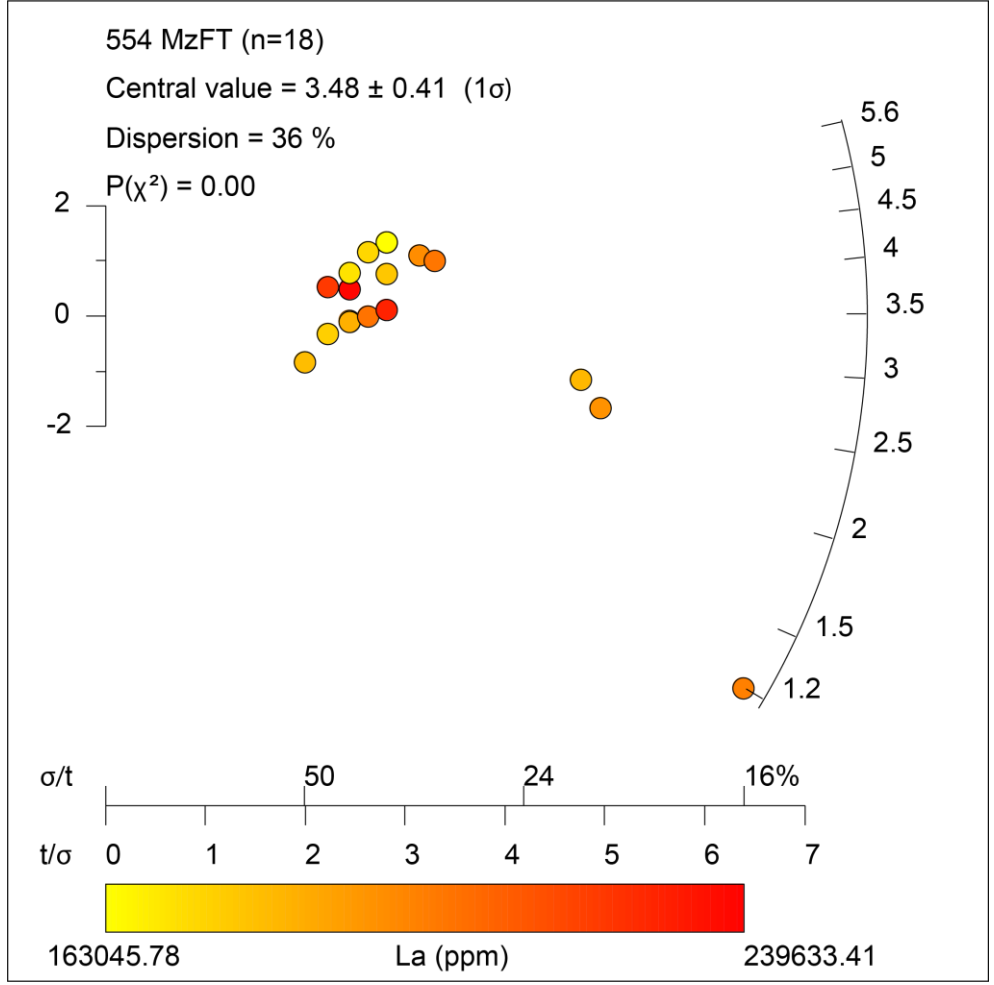
Elevation: 1,608 m



Mz FT 1.5 ± 0.2 Ma

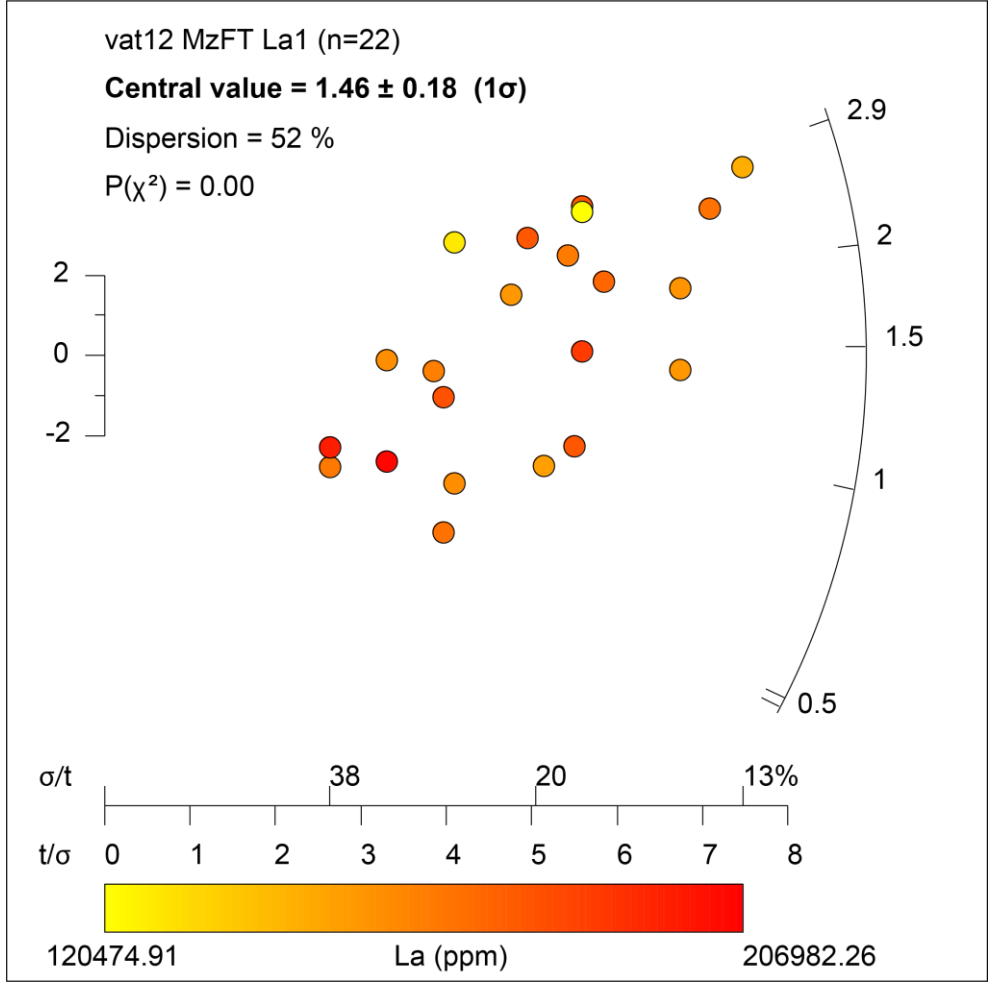
Elevation: 1,270 m

Calculated using an initial track length of 10.6 um (Weise et al. 2009, Jones et al. 2020)



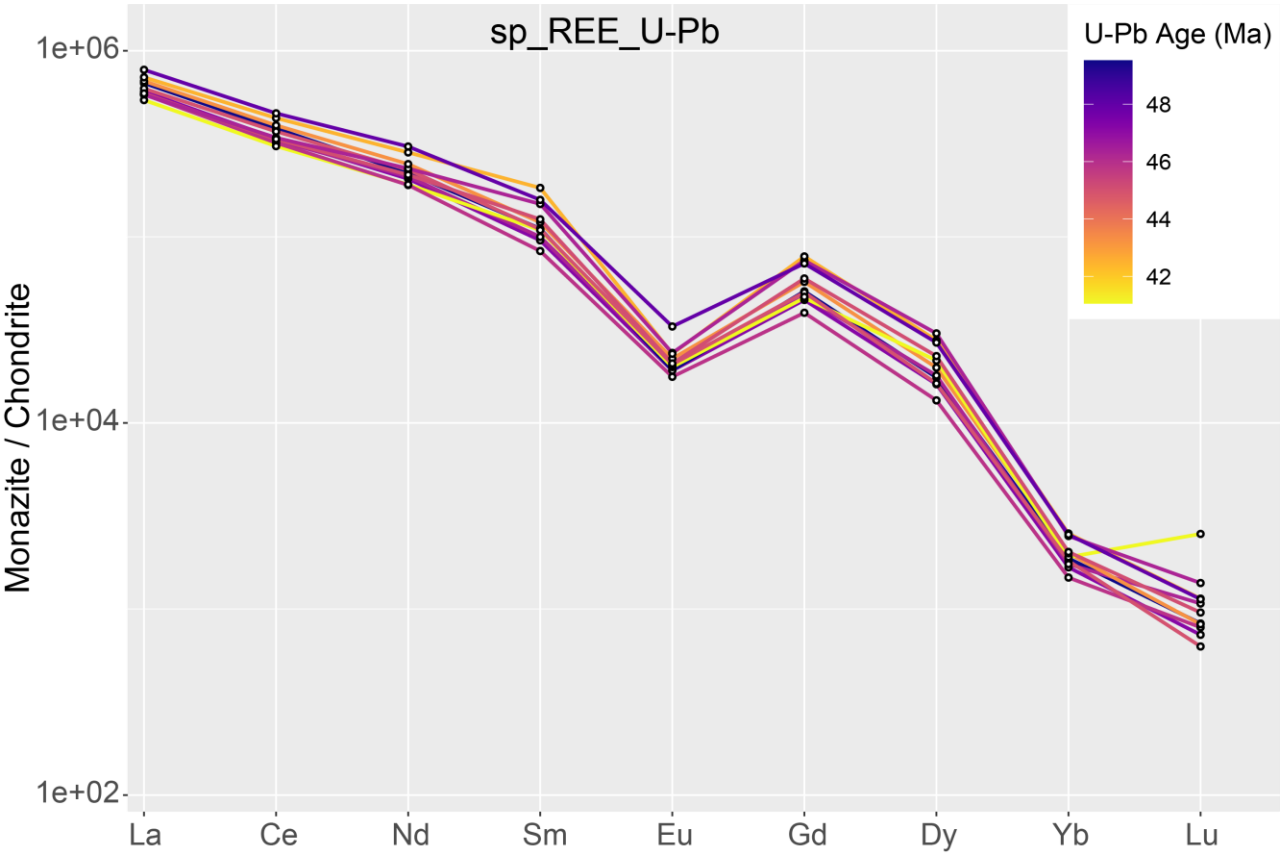
Mz FT 3.5 ± 0.4 Ma

Elevation: 1,608 m

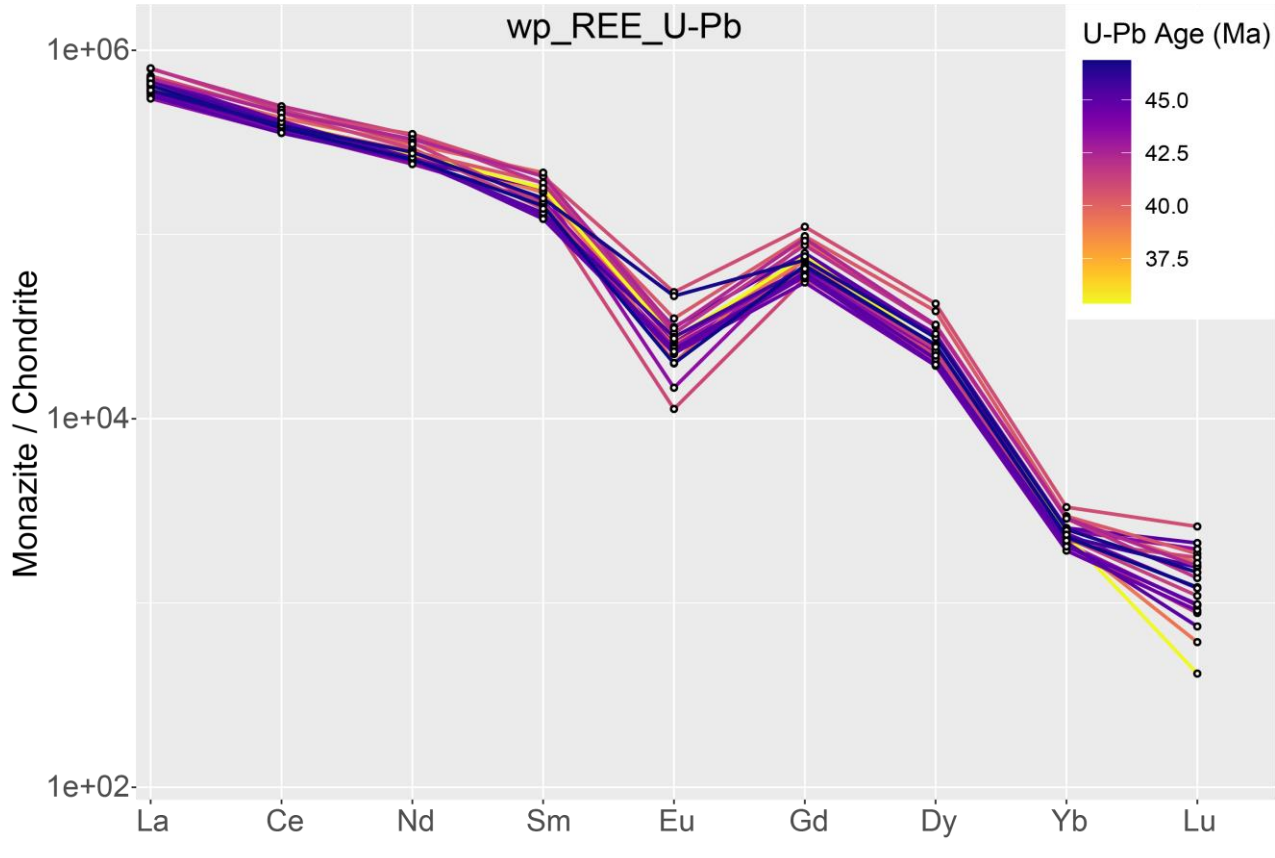


Mz FT 1.5 ± 0.2 Ma

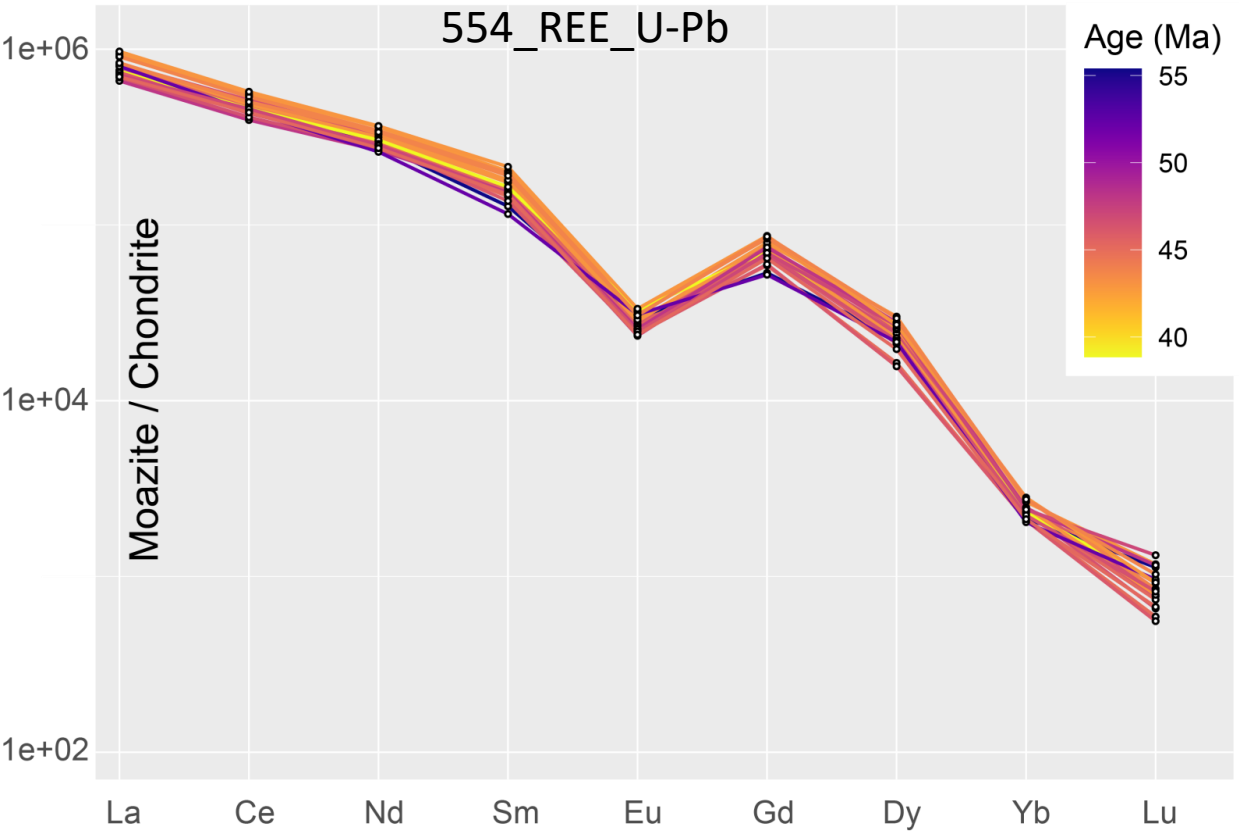
Elevation: 1,270 m



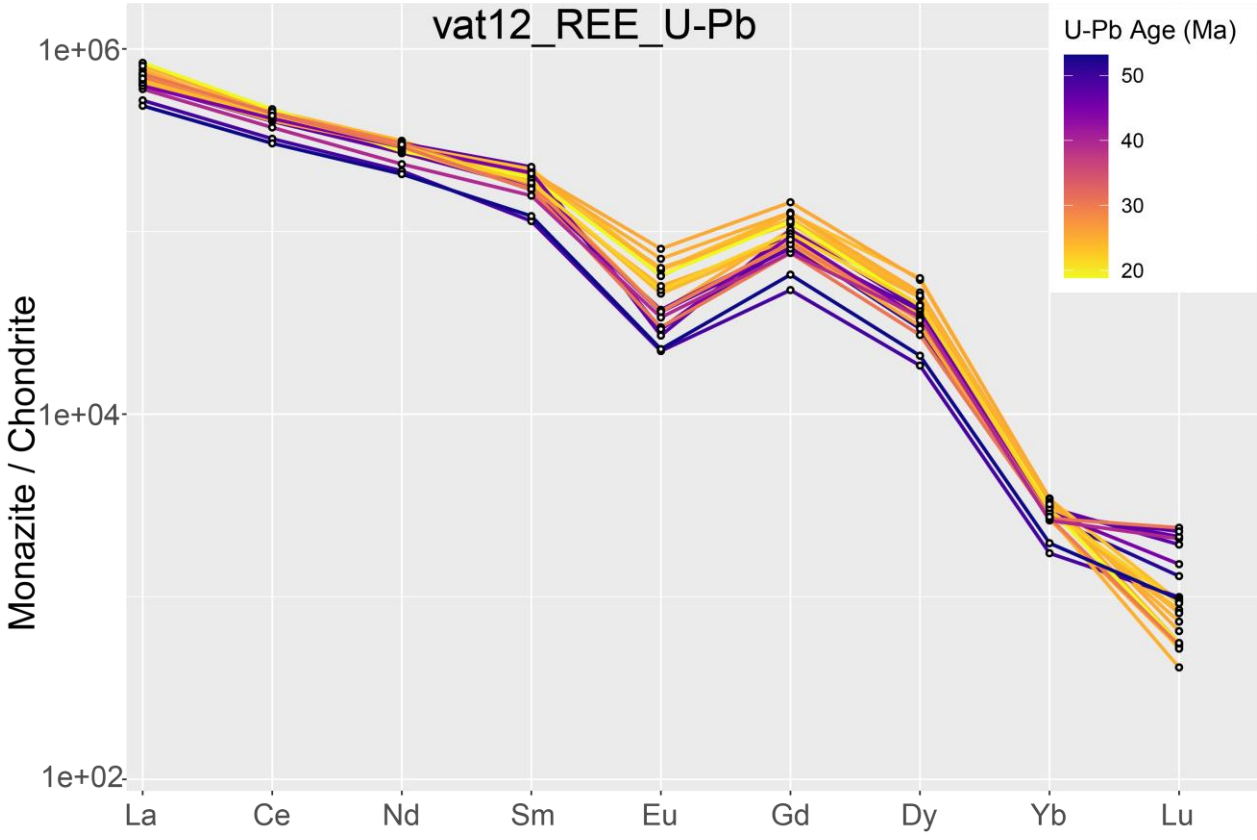
Elevation: 2,258 m



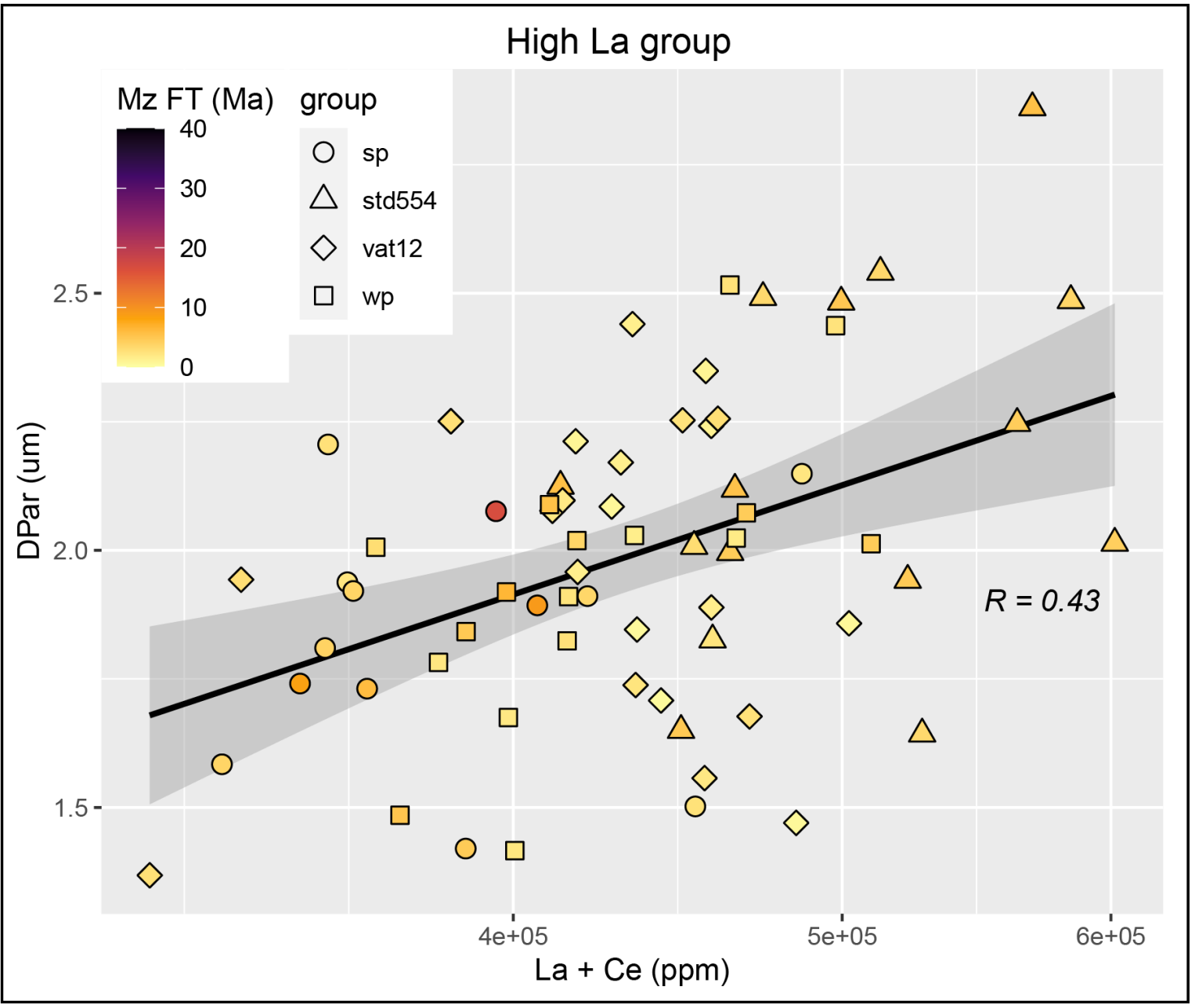
Elevation: 2,004 m



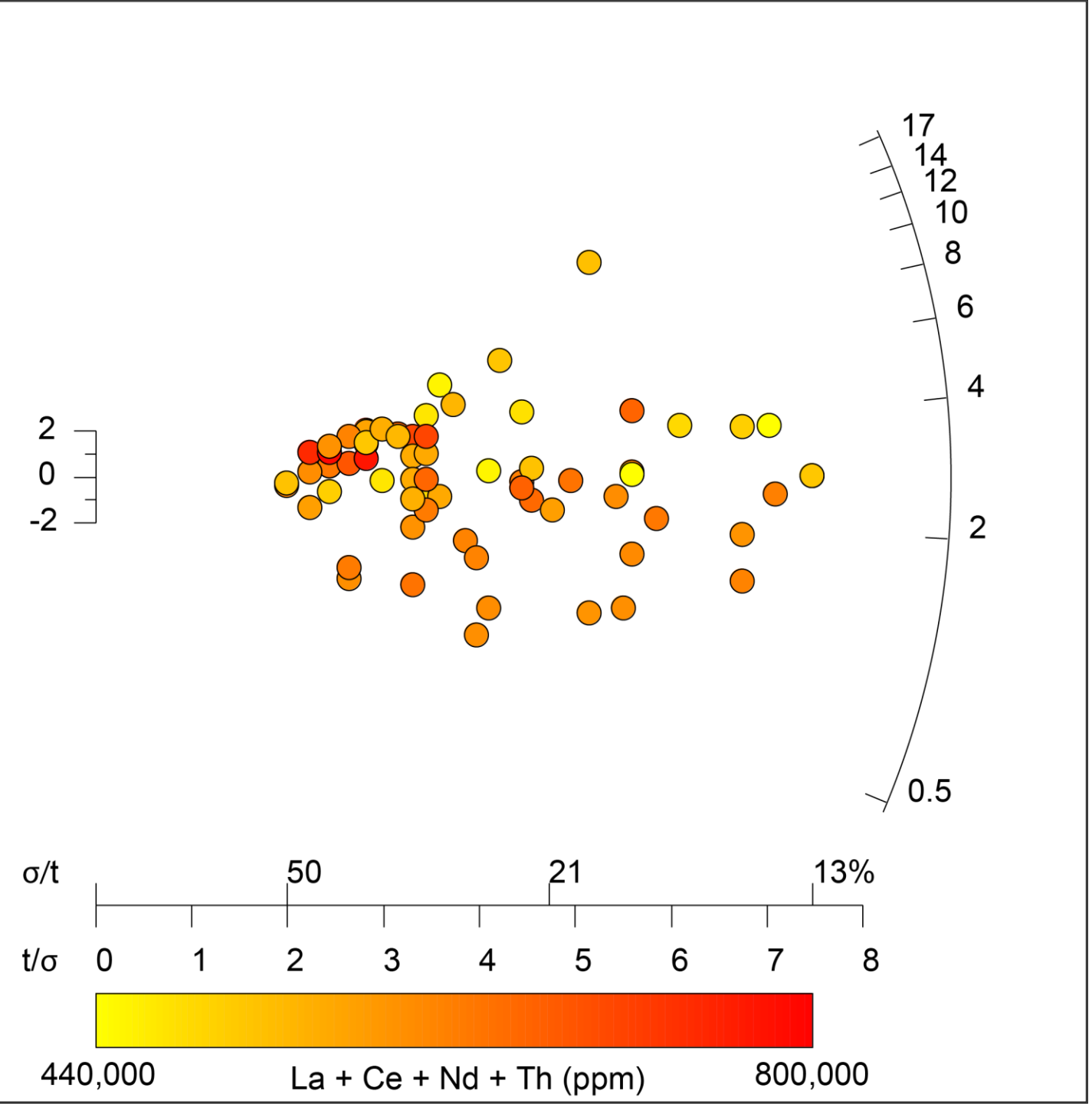
Elevation: 1,608 m



Elevation: 1,270 m

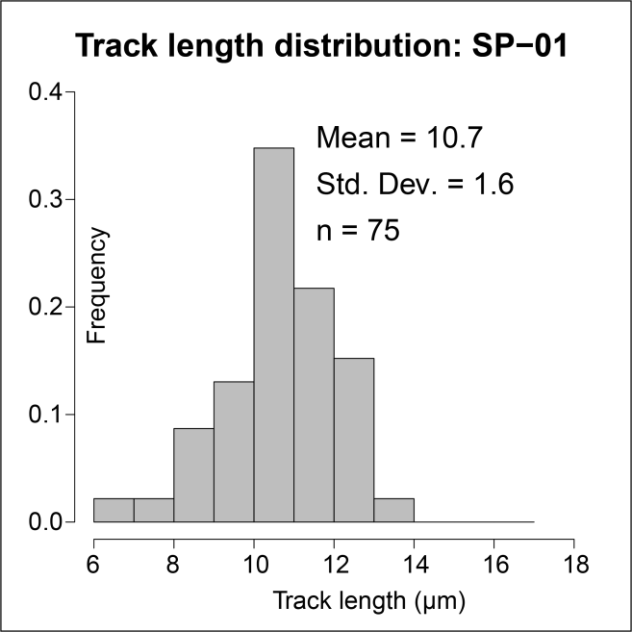


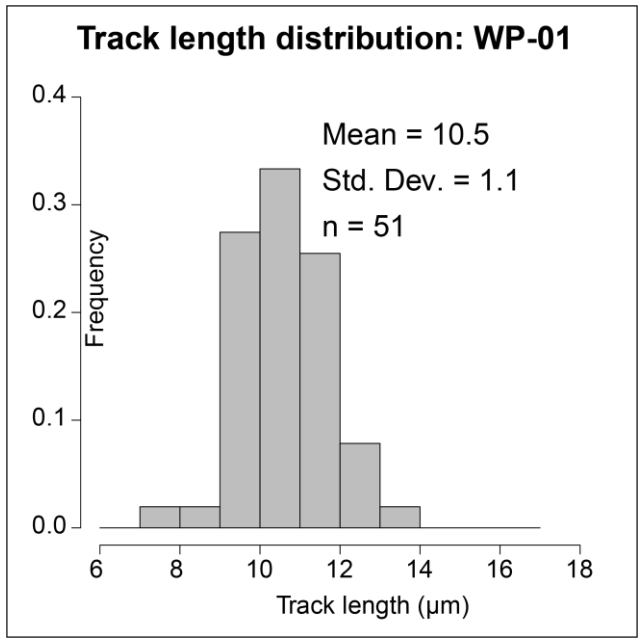
At high La and Ce concentrations,
DPar loosely correlates with light REEs

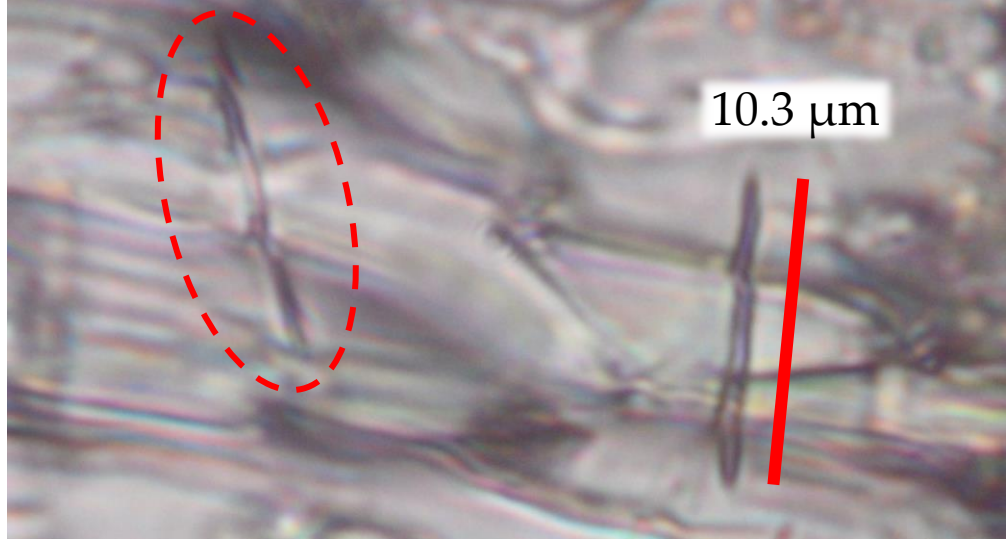


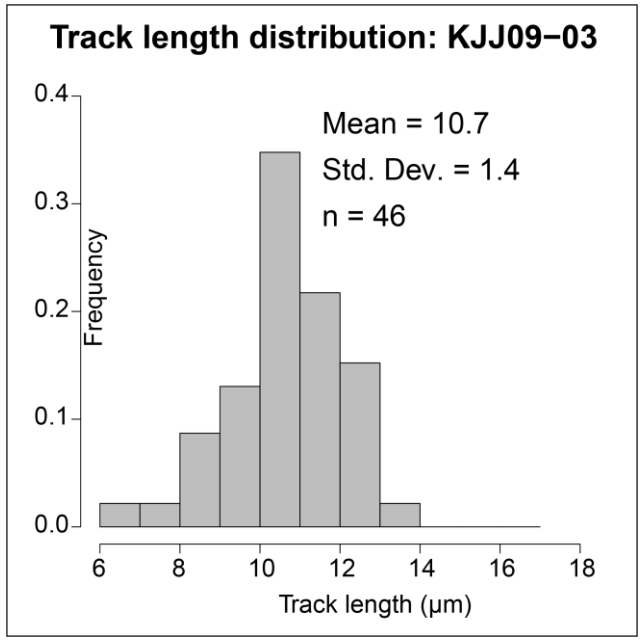
Monazite: a REE phosphate
$(Ce,La,Nd,Th)(PO_4,SiO_4)$

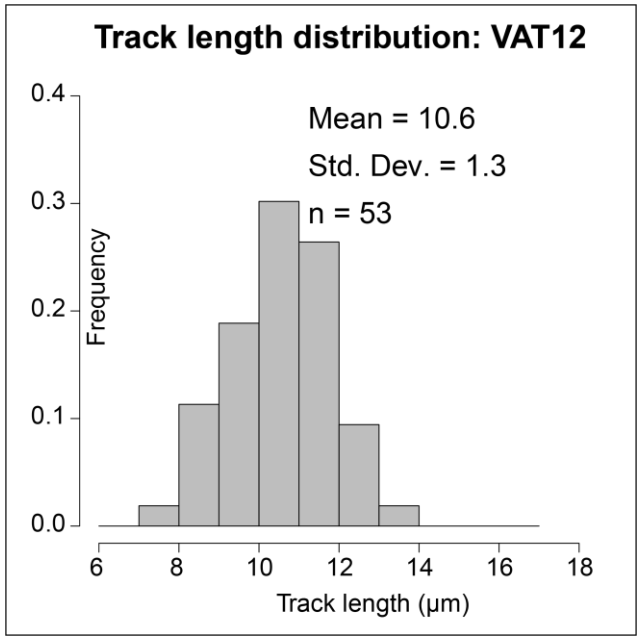
Weak trend of younger dates with high REE + Th concentrations.



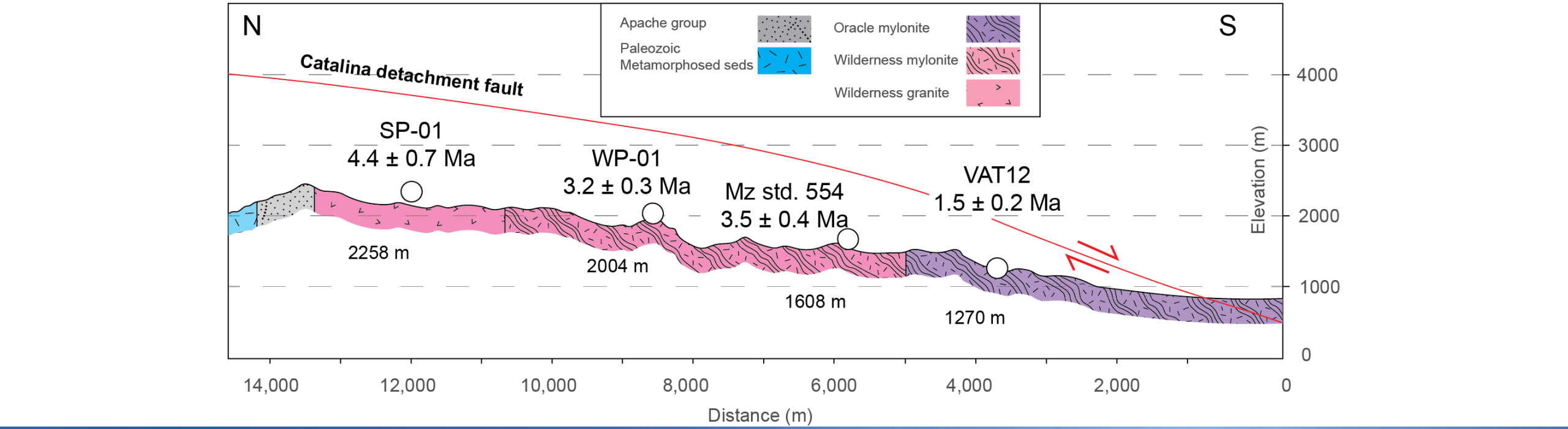






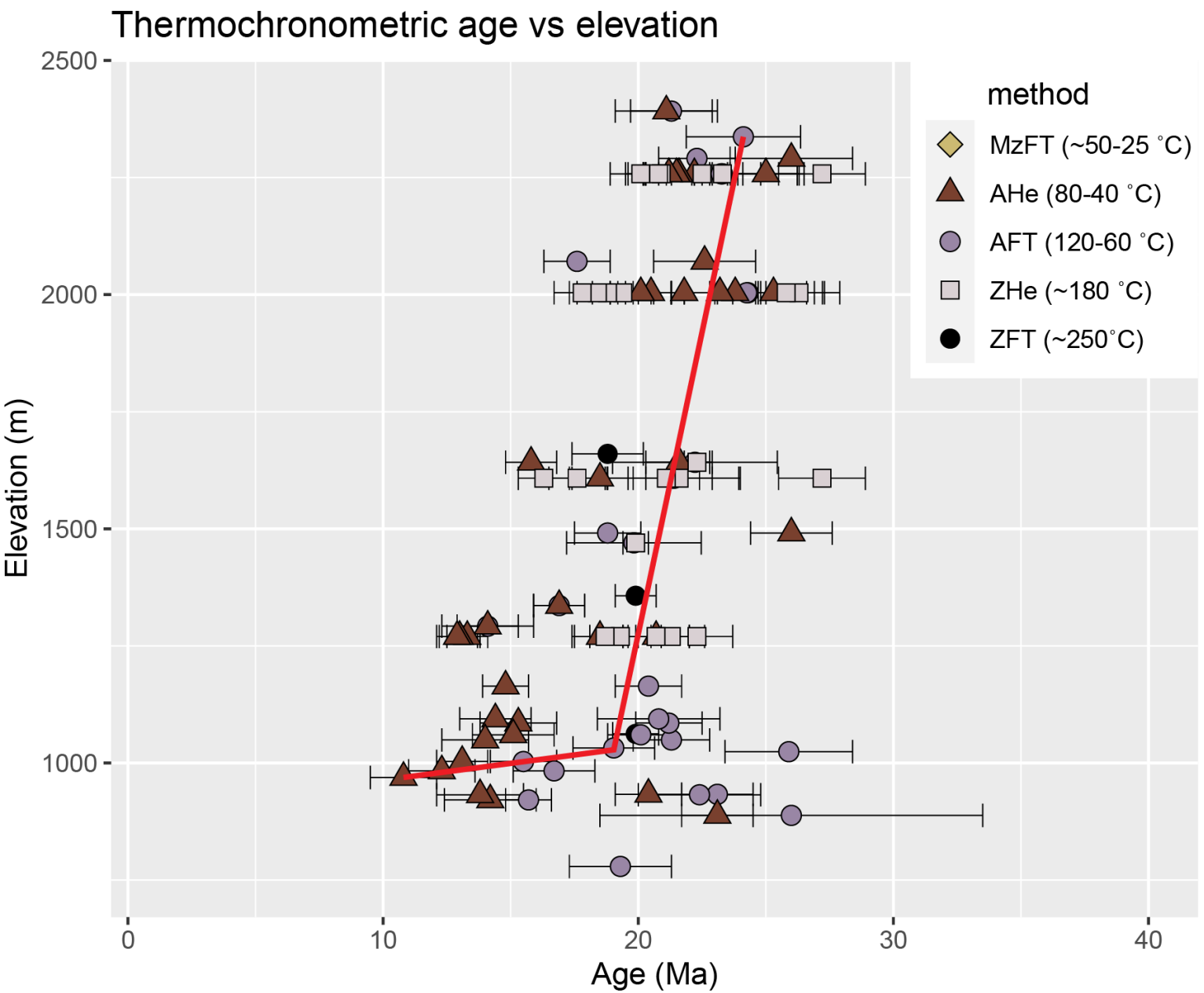


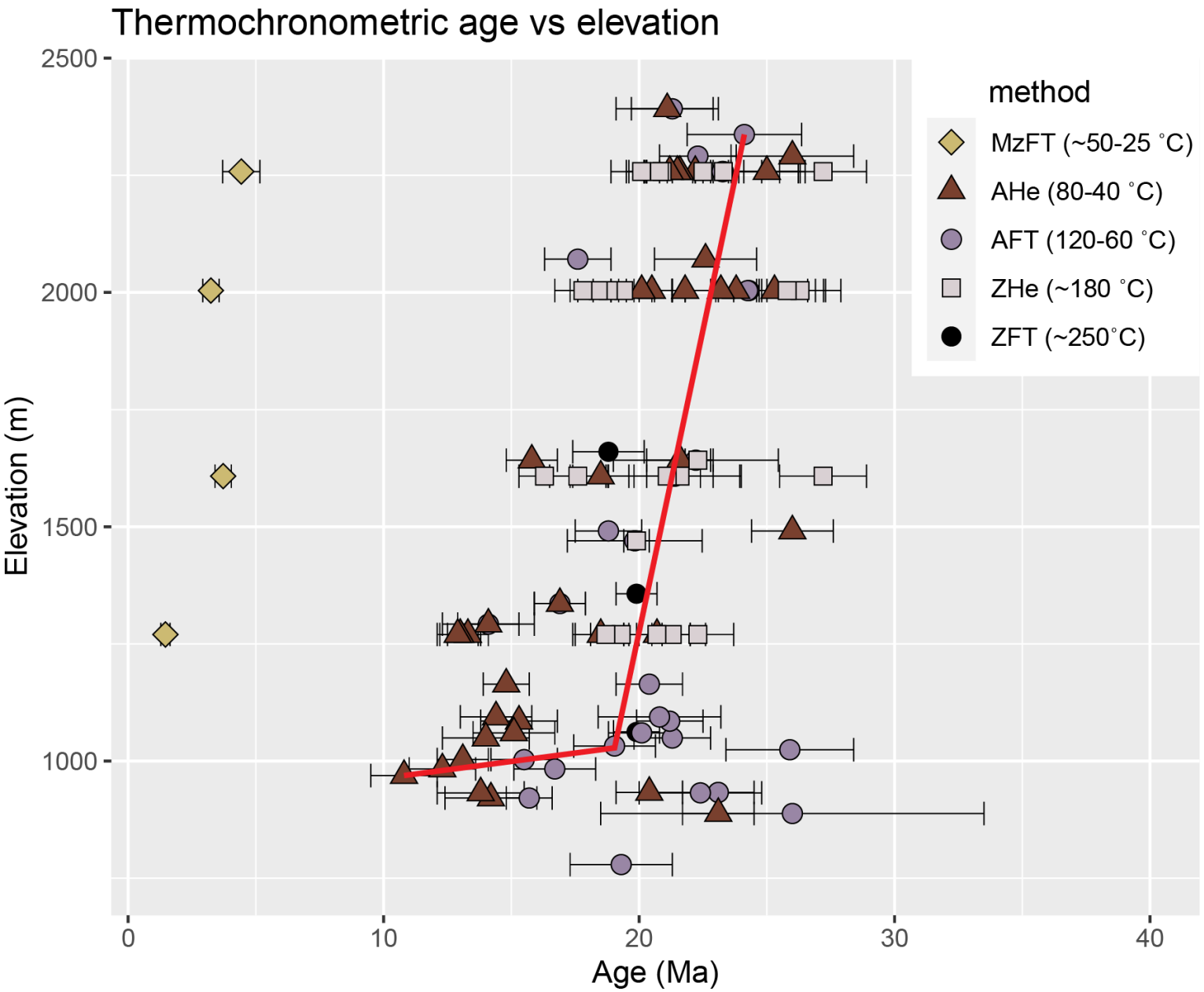
Consistent with the measured length of ~ 10 μm fossil confined tracks (Weise et al. 2009)


N
S
Catalina detachment fault
Apache group
Paleozoic
Metamorphosed seds
Oracle mylonite
Wilderness mylonite
Wilderness granite
SP-01
4.4 ± 0.7 Ma
WP-01
3.2 ± 0.3 Ma
Mz std. 554
3.5 ± 0.4 Ma
VAT12
1.5 ± 0.2 Ma
2258 m
2004 m
1608 m
1270 m
Elevation (m)
4000
3000
2000
1000
0
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Distance (m)


S
N

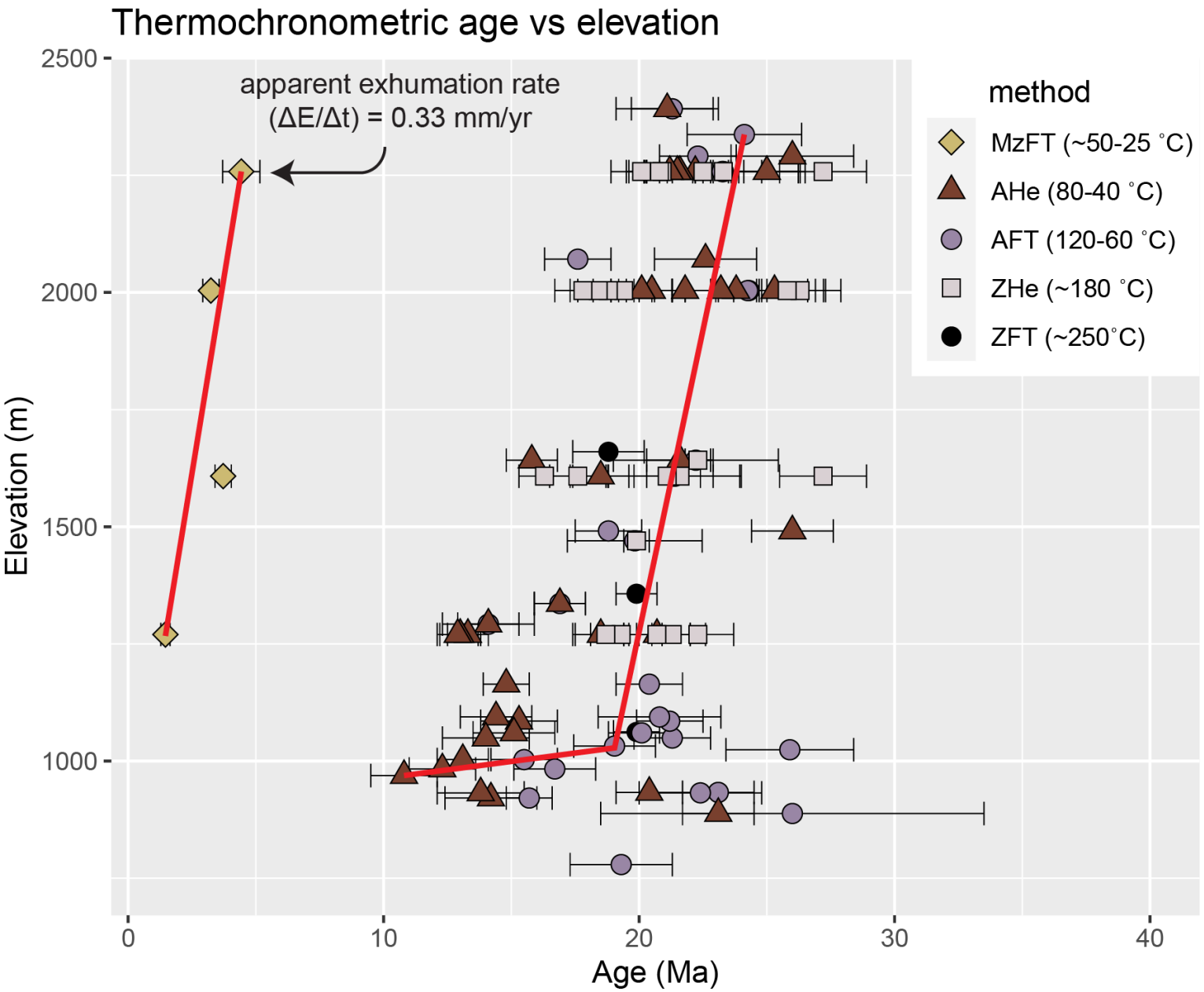
Interpreting the results: closure temperature





- Monazite FT (~2-5 Ma) dates are younger than all traditional thermochronometric dates observed in the Catalina Rincon (~10 – 26 Ma).

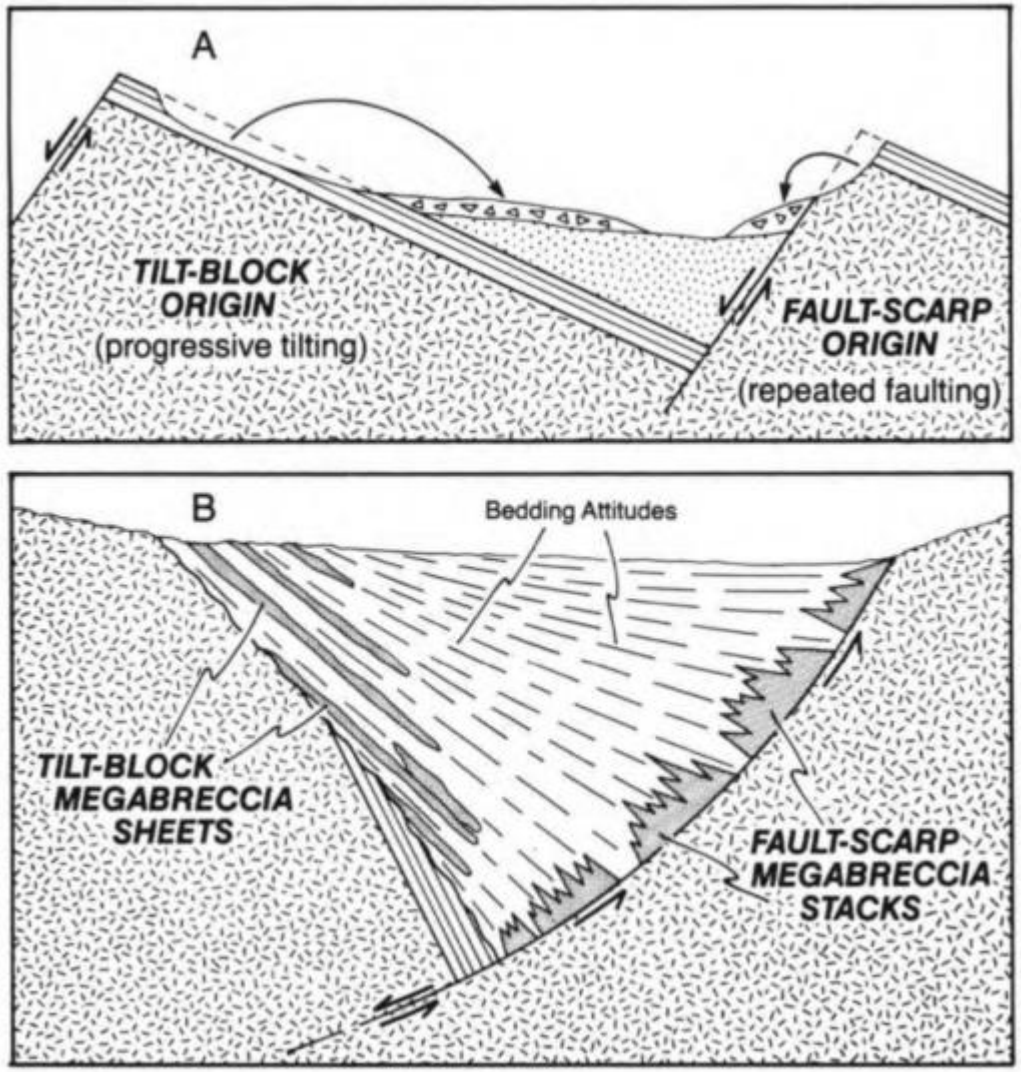
- As a result, the MzFT thermochronometer must sensitive to lower temperatures (< 40 °C, Jones et al 2020).



- Extremely rapid apparent exhumation rate. Faster than what is observed for the MCC detachment faulting.

What's driving Plio-Plistocene thermochronometric dates?

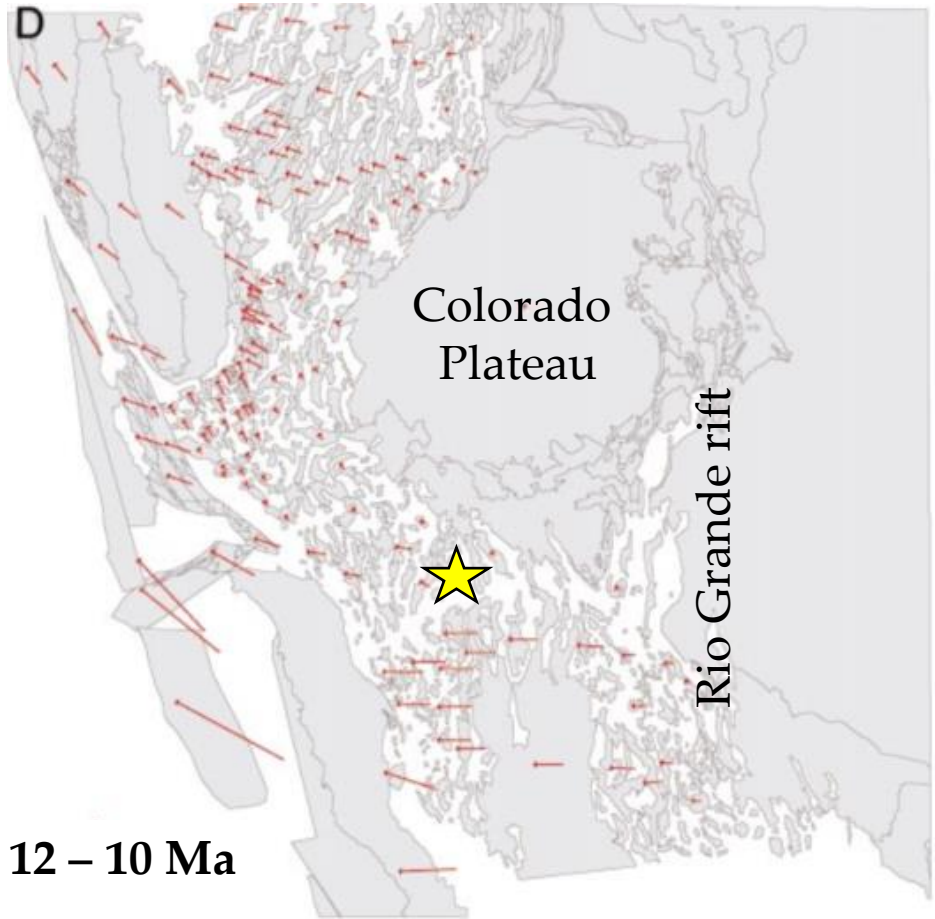
Interpreting the results: ~6 Ma



Dickinson 1991

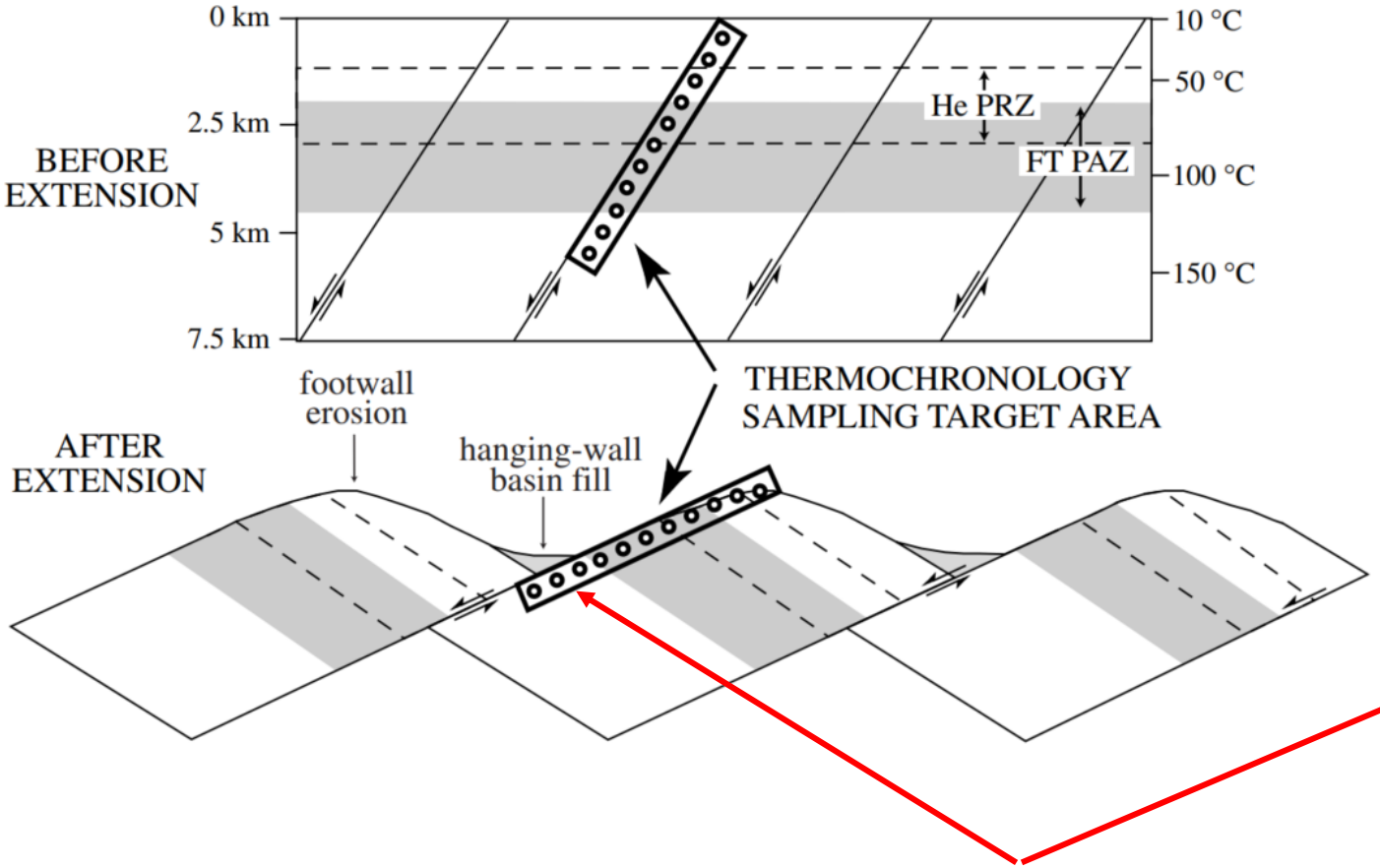
- Major Basin and Range extension occurs at ~ 18-12 Ma across southwestern North America.

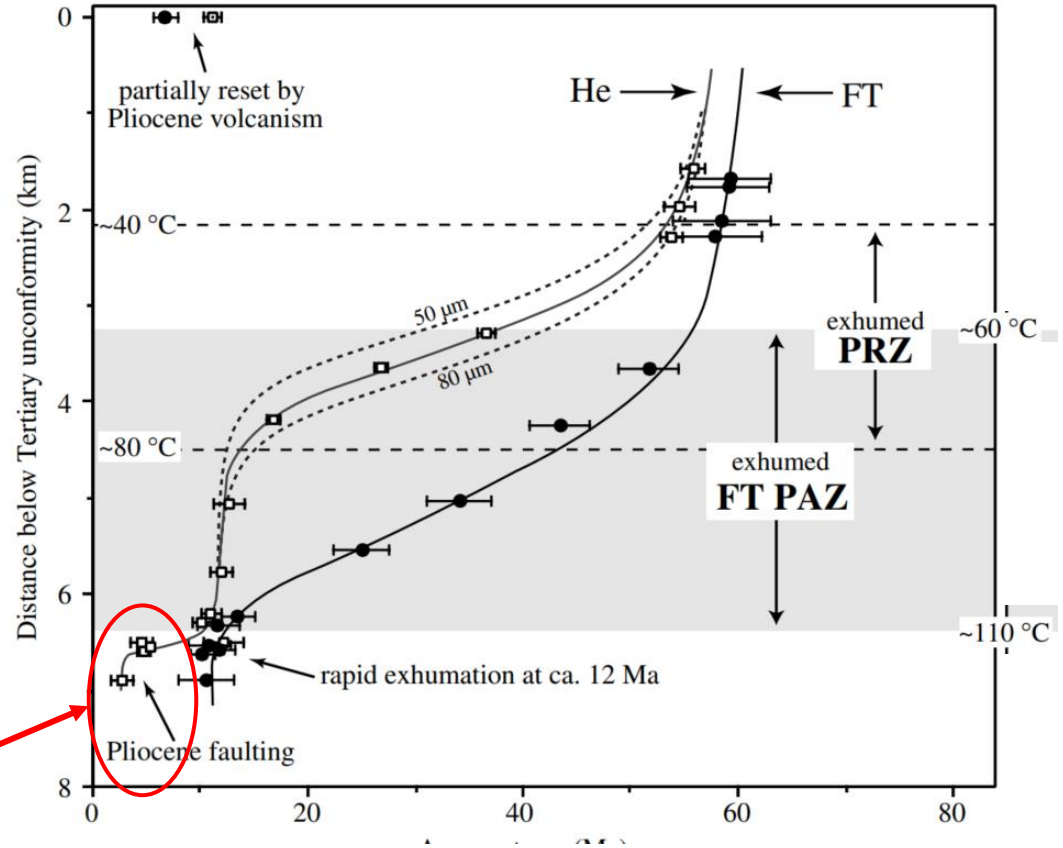
McQuarrie and Wernicke, 2005



12 – 10 Ma

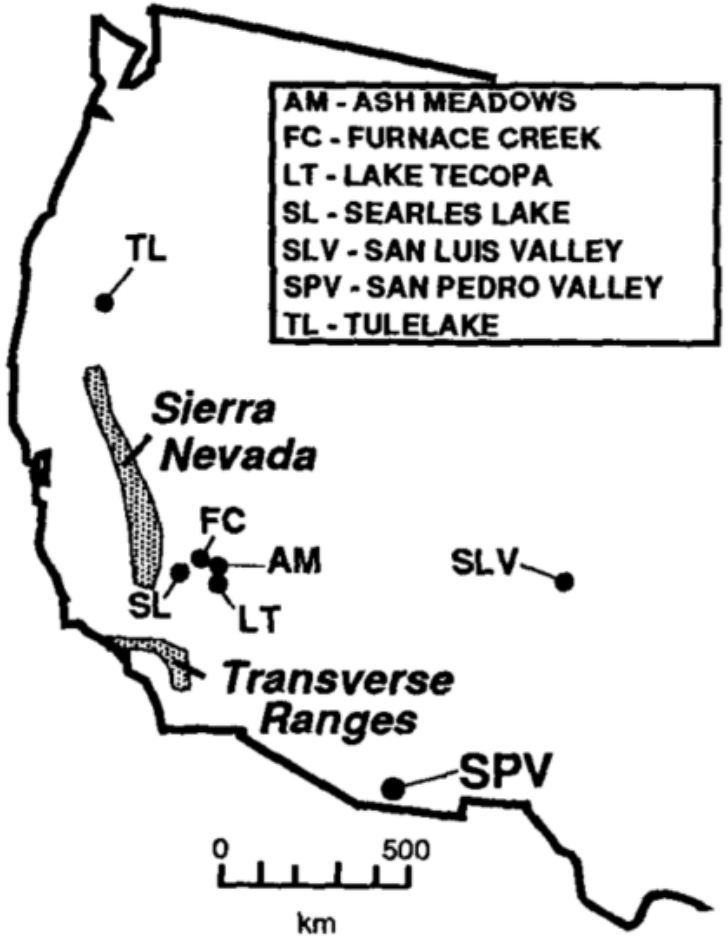
Interpreting the results, tectonics: Stockli et al 2000 (White Mountains, California)

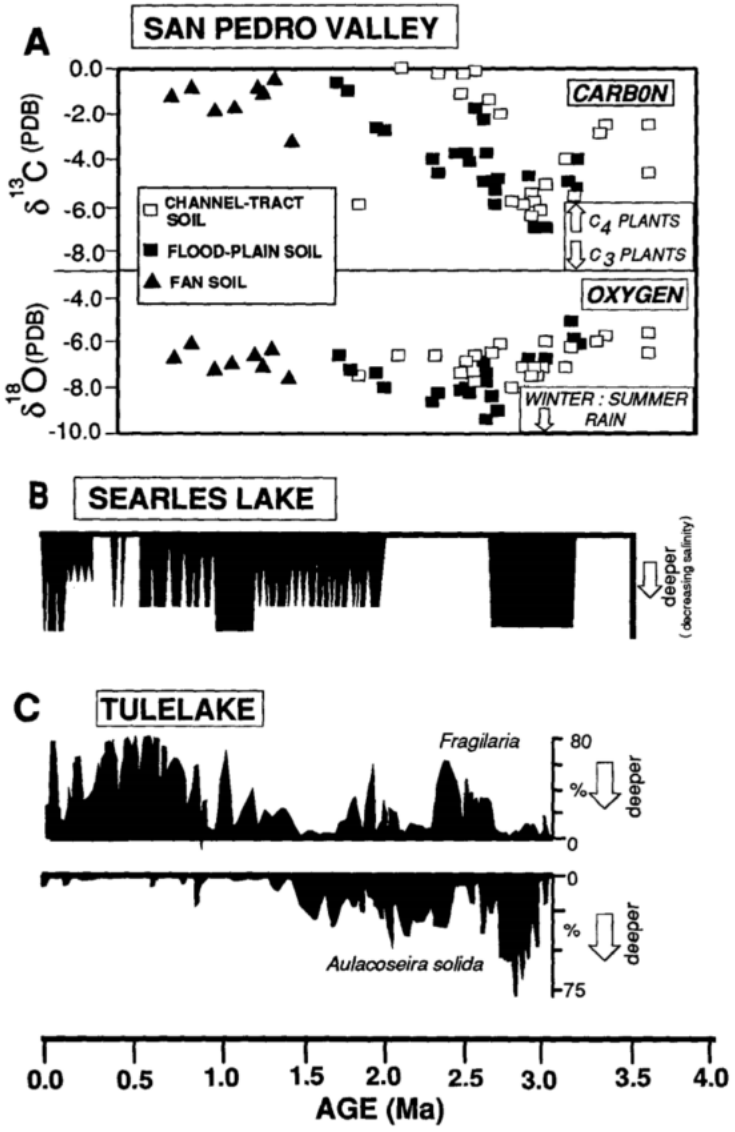




~ 5 Ma AHe dates suggesting more recent extensional events

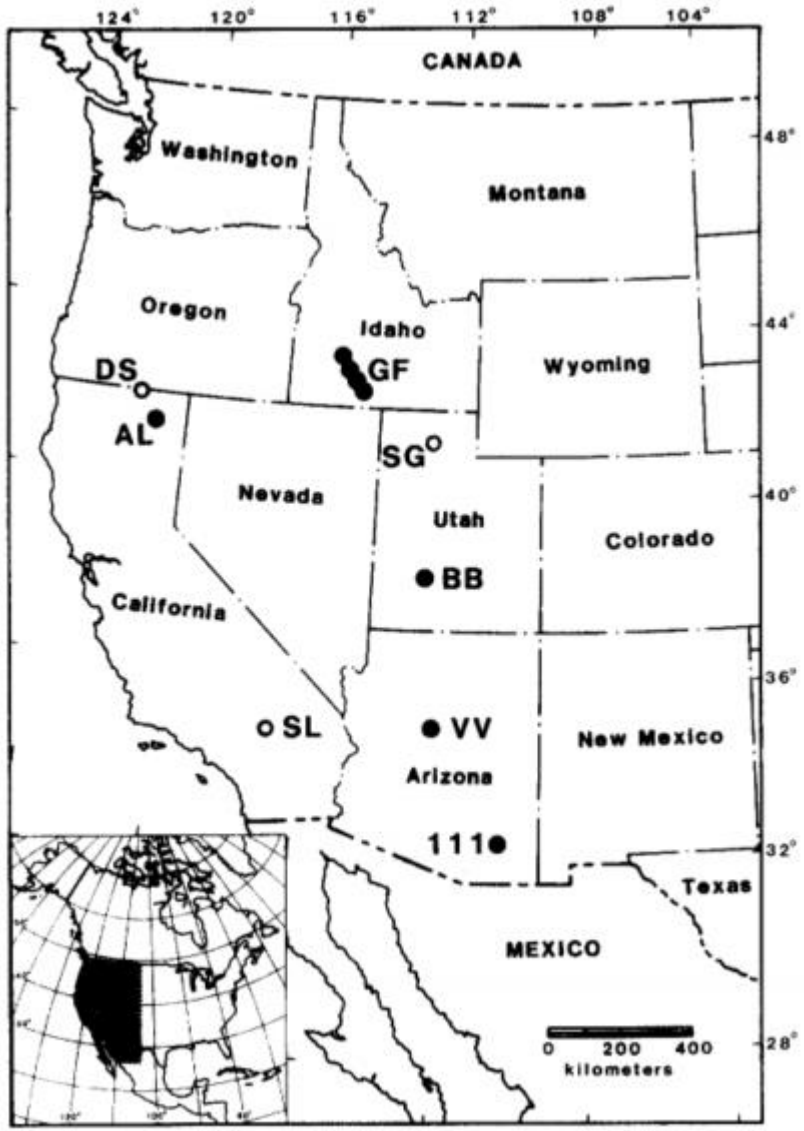
Interpreting the results, climate: Smith et al. 1993





Cool, wet conditions between 3.2 and 2.8 Ma

Interpreting the results, climate: Forester, 1991



Evidence from lacustrine ostracodes:

- Increased precipitation from 4.5-3.5 Ma
- High precipitation/low evaporation at 3.5-2.5 Ma
- Return to a more modern hydroclimate at 2.5 Ma

Take home points

- Monazite fission-track dates are (mostly) far younger than traditional thermochronometers. Supporting closure temperatures ~25-50 °C

- Monazite chemistry (specifically La/Ce/Nd/Ce concentrations) impacts monazite DPar and perhaps annealing.

- Monazite fission-track dates correspond to a young exhumational event, highlighting applicability for dating geomorphological and geologically young tectonic processes

- Watch out for titanite….