Frontiers in Detrital Geochronology

Opportunities and Challenges in Multi-chronometer Geochronology and Thermochronology

Julie Fosdick

AGeS Workshop ▪ GSA Connects 2022

October 8, 2022

Basin Analysis & Helium Thermochronology Laboratory

https://thermochron.uconn.edu

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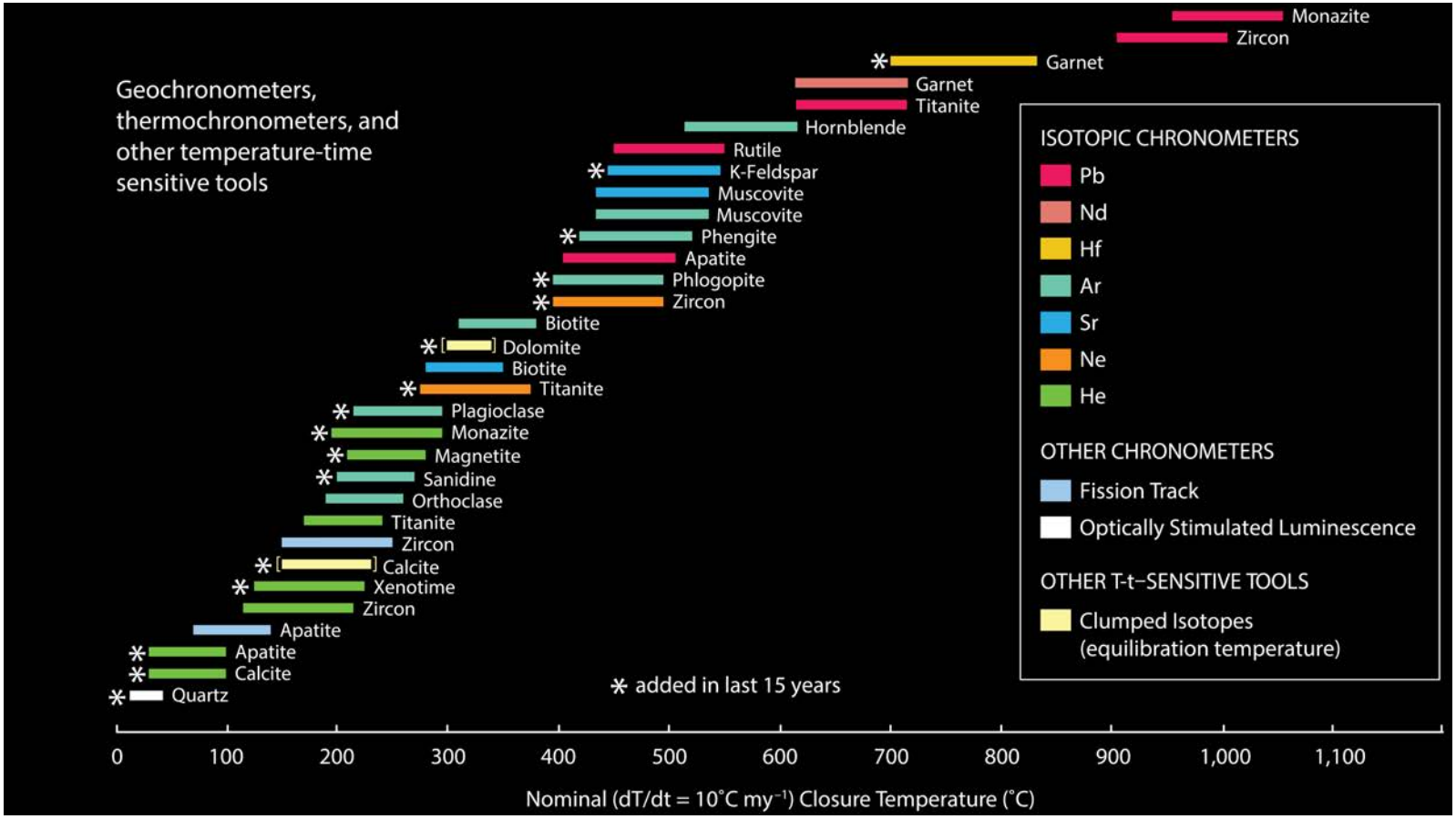
Frontiers in Detrital Geochronology

Key areas of recent development

1) Development of new chronometers in detrital studies
2) Trace element and isotopic fingerprinting
3) Multi-chronometer double and triple dating
4) Improved methods for estimating maximum depositional ages

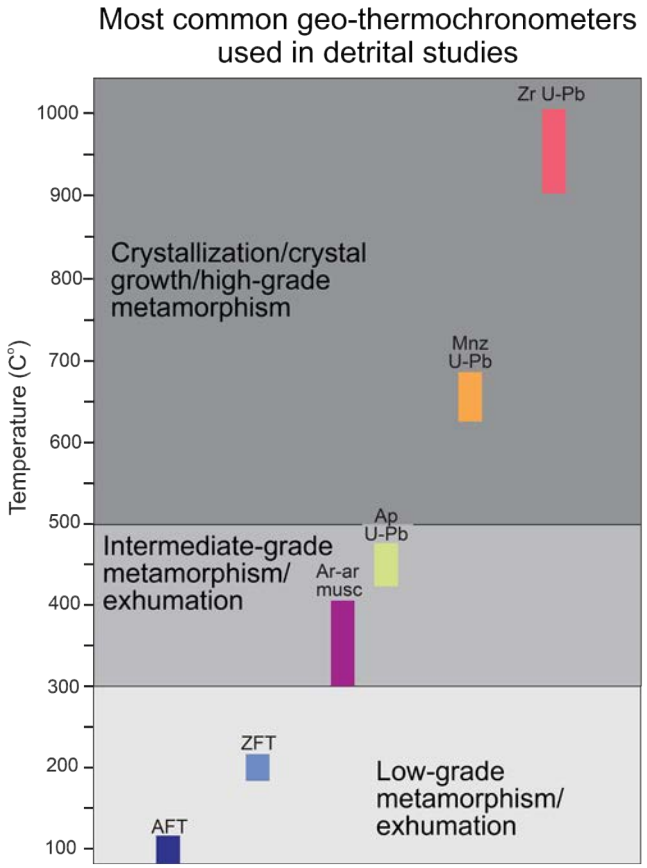
New Chronometers Petrochronology Double Dating MDA Analysis Andean tectonics

Development of new chronometers in detrital studies

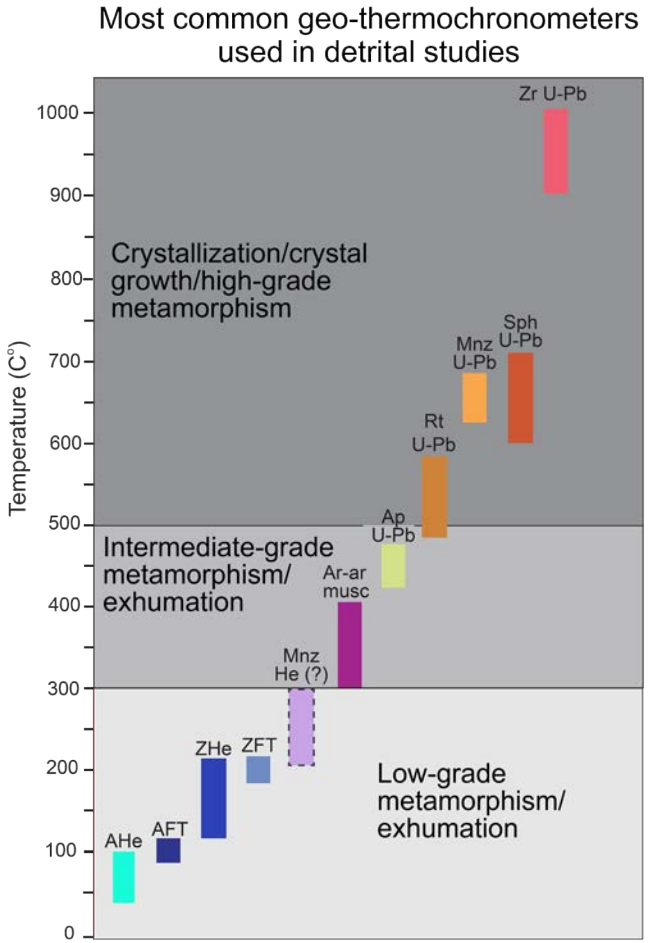


Huntington & Klepeis (2018), Community Vision Document to NSF

Development of new chronometers in detrital studies



Carrapa (2010)



Titanite U-Pb

Rutile U-Pb

Monazite (U-Th)/He

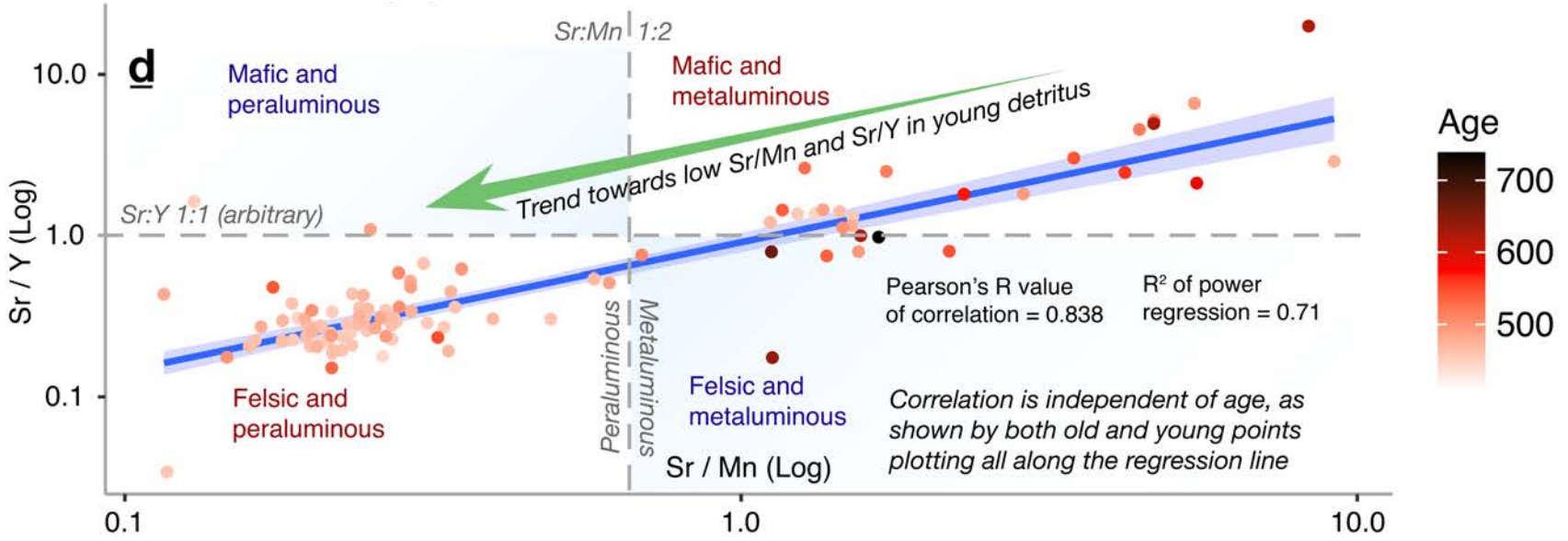
Zircon (U-Th)/He

Apatite (U-Th)/He

Trace element and isotopic fingerprinting

Detrital petrochronology

Tracking petrologic conditions, identifying parent lithology, investigating growth of cogenetic phases, fingerprinting fluid involvement, distinguishing primary igneous and altered minerals.



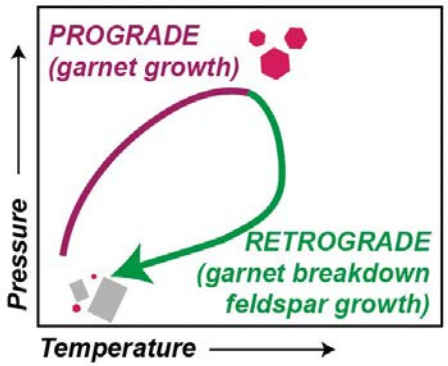
O'Sullivan and Chew (2020)

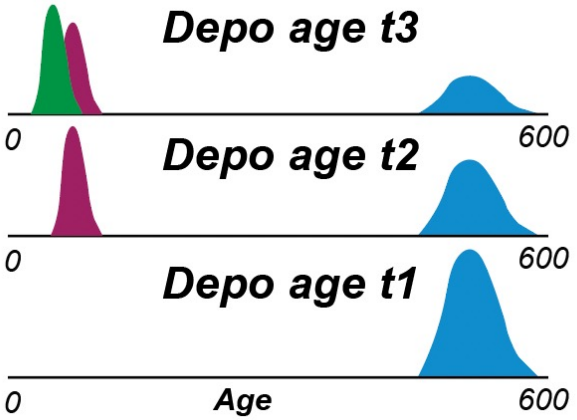
Trace element and isotopic fingerprinting

Detrital petrochronology

Tracking petrologic conditions, identifying parent lithology, investigating growth of cogenetic phases, fingerprinting fluid involvement, distinguishing primary igneous and altered minerals.

- U-Th-Pb ages + REEs → timing of prograde & retrograde conditions
- Up-section changes in provenance → timing of unroofing





Sarah George et al., *Growth and unroofing of the Himalaya from detrital monazite petrochronology*

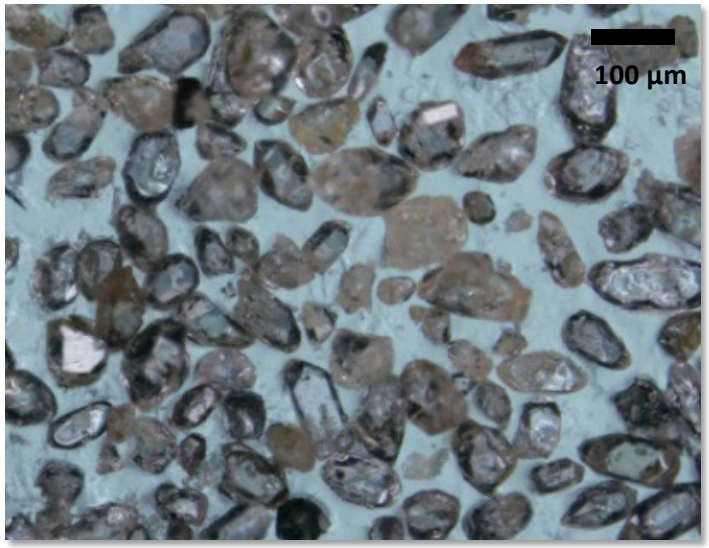
256: T81. Radiogenic Isotopes as Tracers of Geologic Processes: Dates, Rates, and Proxies II **Wed @ 2:05 pm**

Multi-chronometer double (and triple) dating

Coupling the high-T and low-T thermal evolution of sediment sources

- Conventional methods (e.g., LA-ICPMS U-Pb followed by (U-Th)/He analysis)

- Laser ablation and LADD methods



- Improved identification of source areas
- Refined lag time analysis
- Recognition of volcanic input
- Constraints on post-depositional reheating
- Better approximations of source input and sediment flux

Multi-chronometer double (and triple) dating

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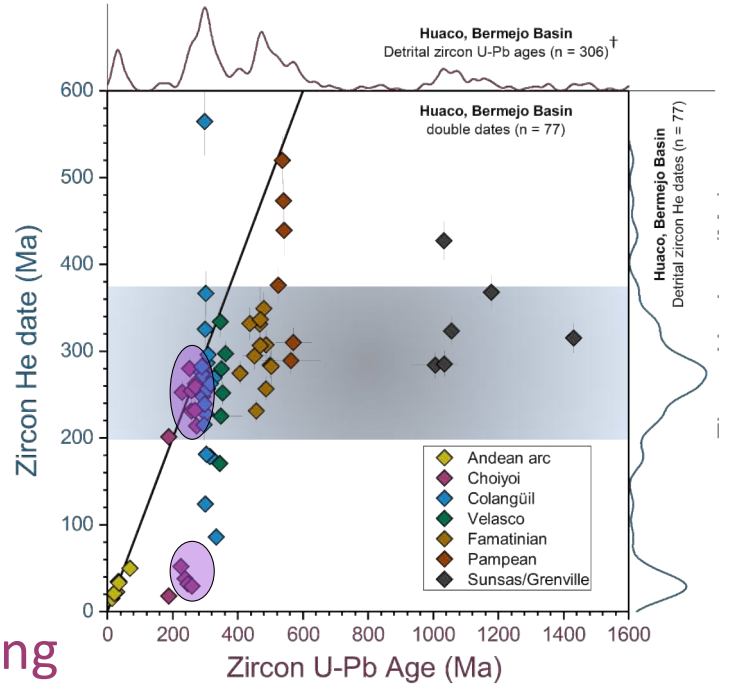
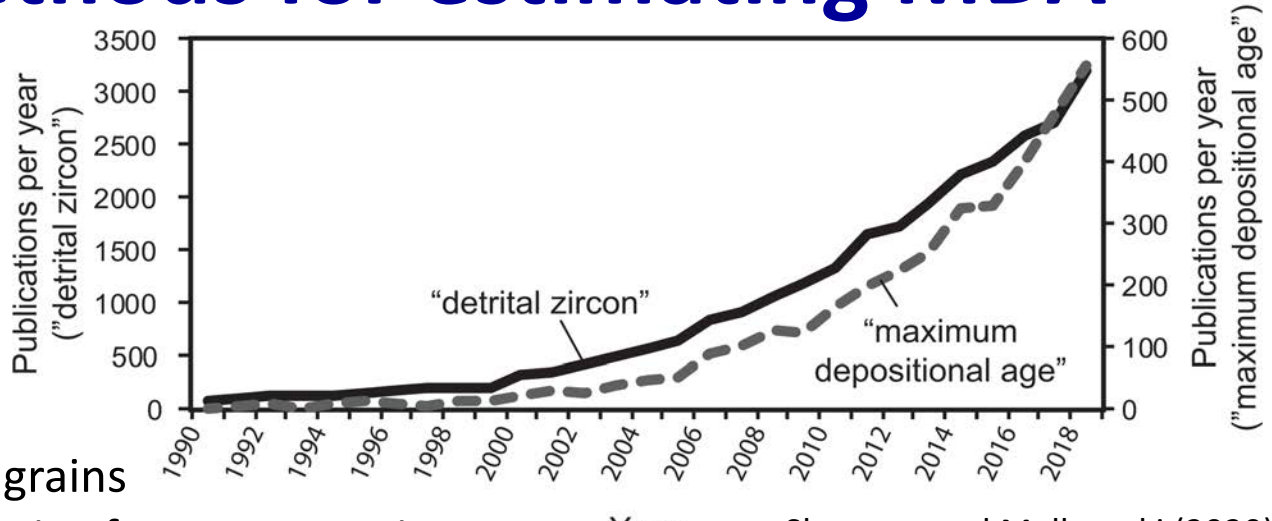


Improved methods for estimating MDA

Detrital geochronology plays a critically important role in constraining timing of sedimentation…



Sharman and Malkowski (2020), after Coutts et al. (2019)

Analytical approaches

- e.g., reanalysis of youngest grains by LA-ICPMS or CA-TIMS analysis of youngest grains

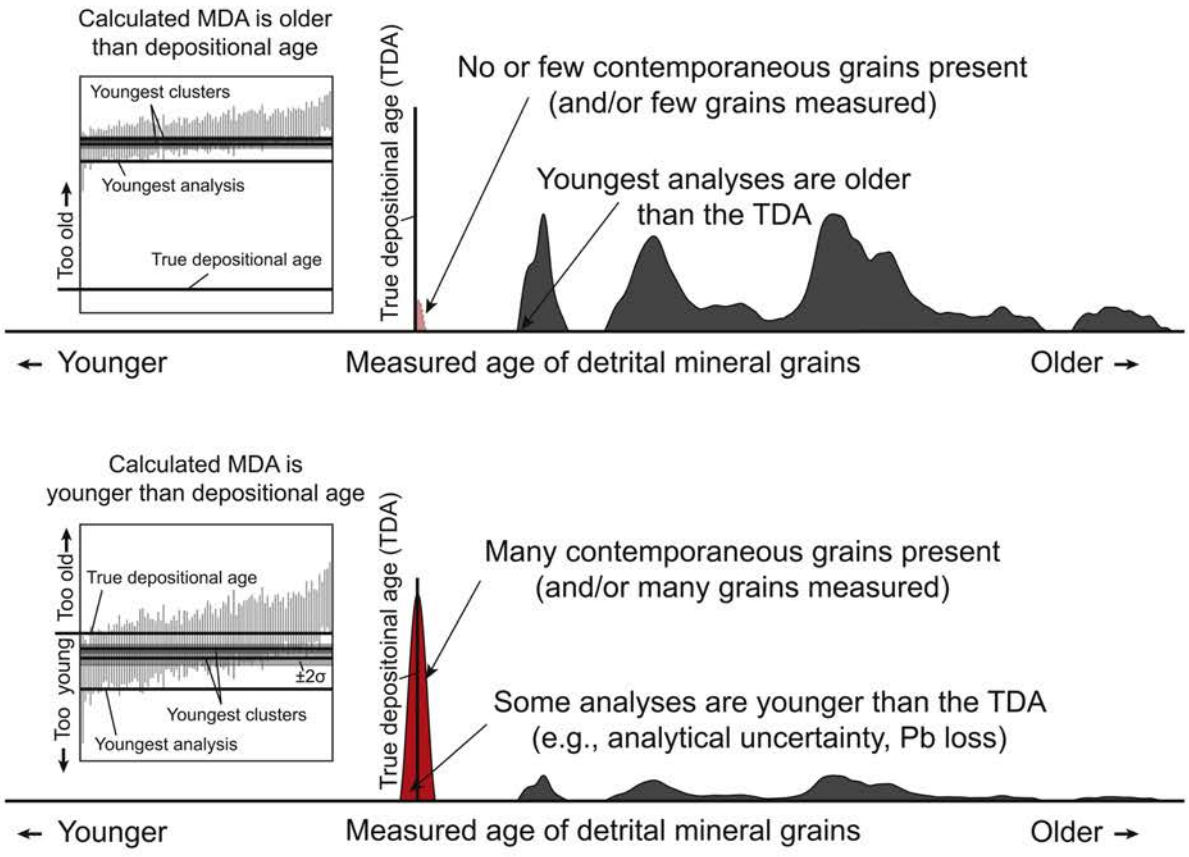
Statistical approaches

- Youngest detrital zircon (YDZ)
- Youngest single grain
- Youngest cluster (1σ overlap)
- Youngest graphical peak
- Youngest statistical population
- Youngest three grains

Integrative/philosophical approaches

- Holistic approach within stratigraphic and geologic context

Improved methods for estimating MDA

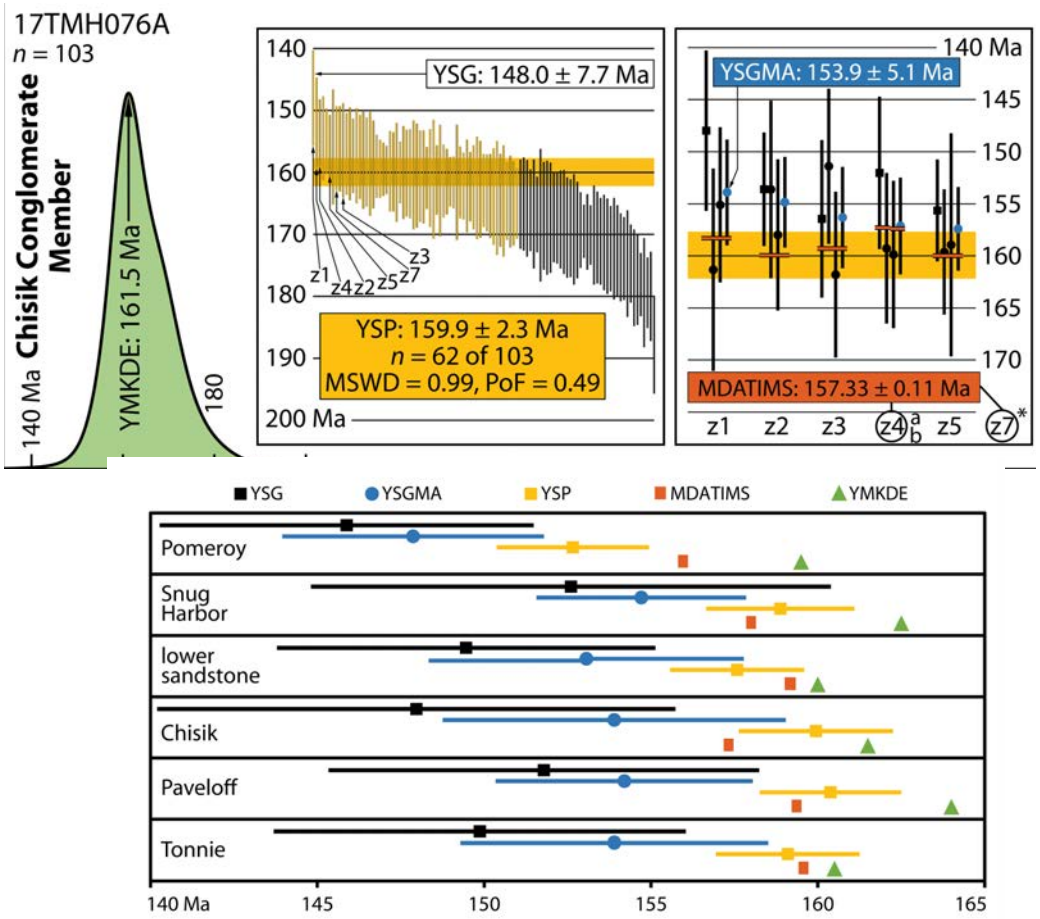


Calculated MDAs may underestimate or overestimate true depositional age

- No/few contemporaneous grains are present and/or few are measured
- Many contemporaneous grains present, with large analytical scatter

Sharman and Malkowski (2020)

Improved methods for estimating MDA



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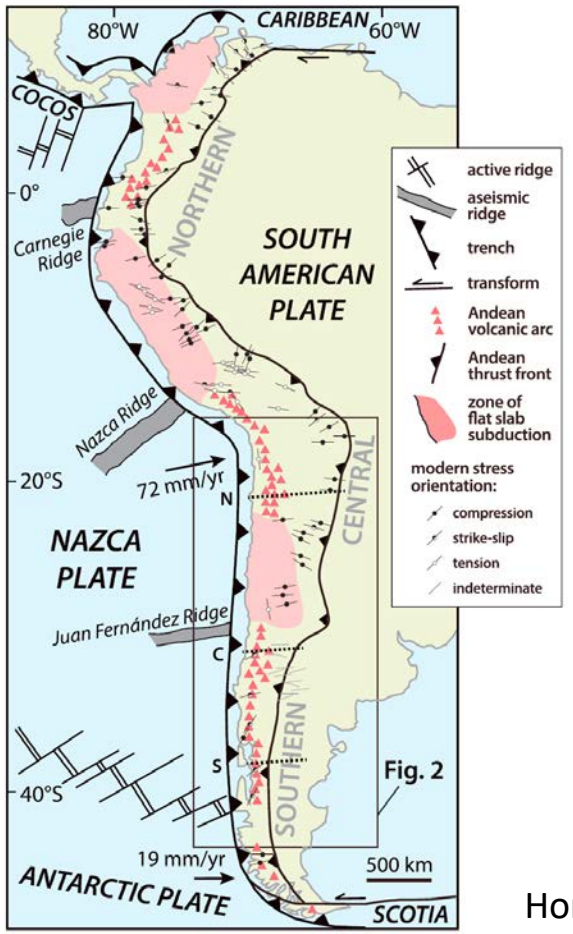
Herriott et al. (2019)

Andean tectonics & sedimentation

Paleogene Bermejo Basin, NW Argentina



Horton (2018)

Andean tectonics & sedimentation

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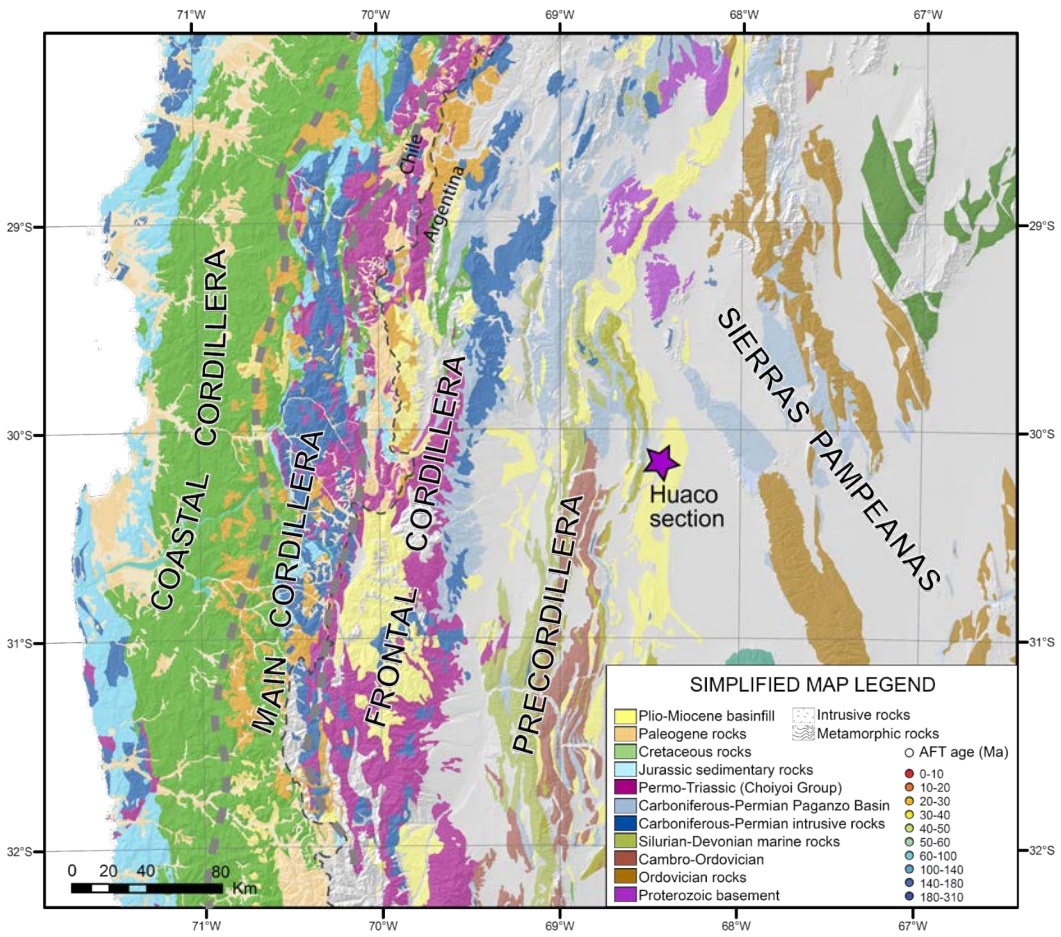

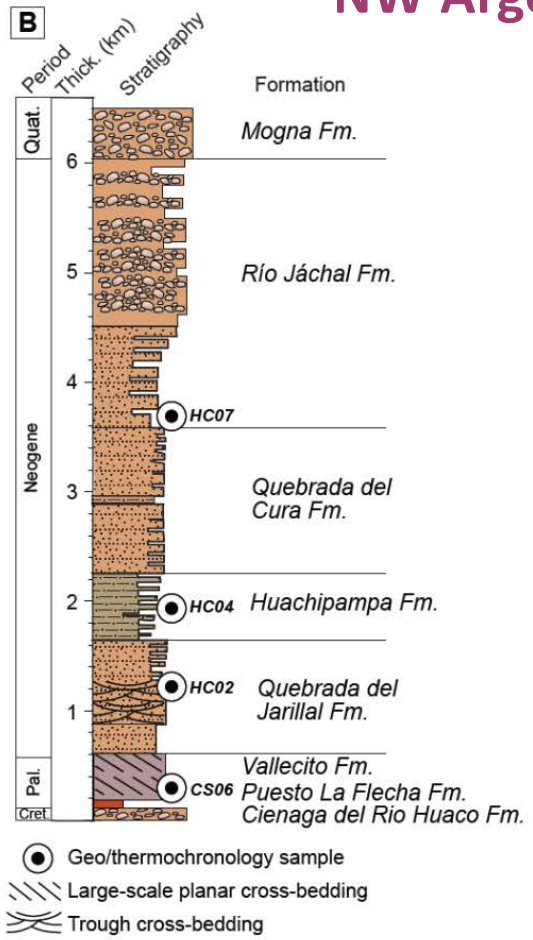

Fosdick et al., in preparation

New Chronometers Petrochronology Double Dating MDA Analysis **Andean Tectonics**

Andean tectonics & sedimentation

Paleogene Bermejo Basin, NW Argentina

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Andean tectonics & sedimentation

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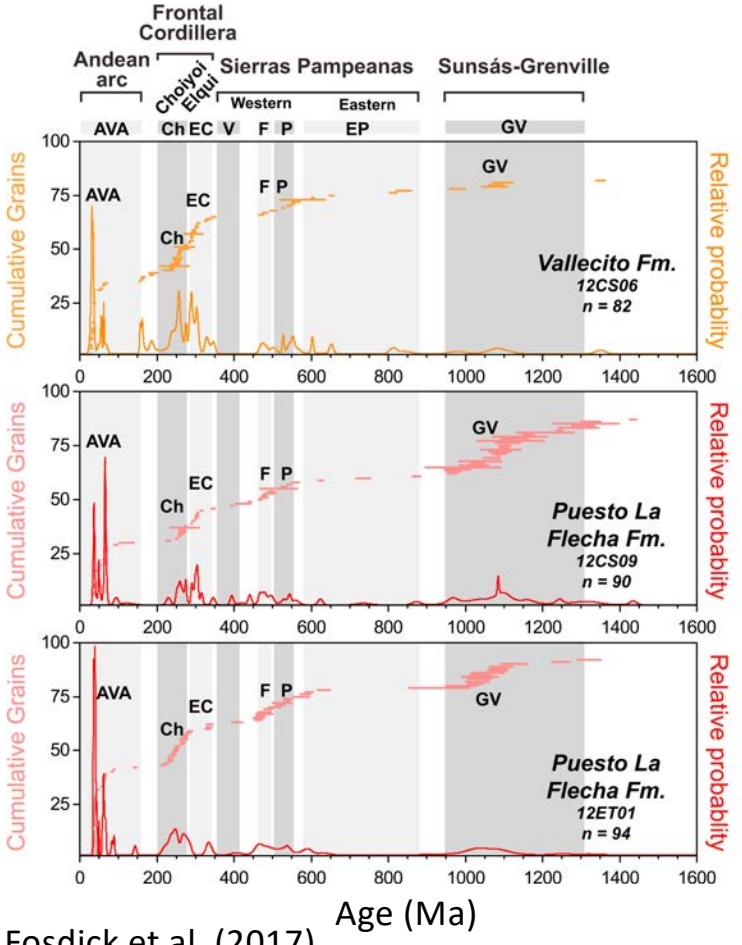
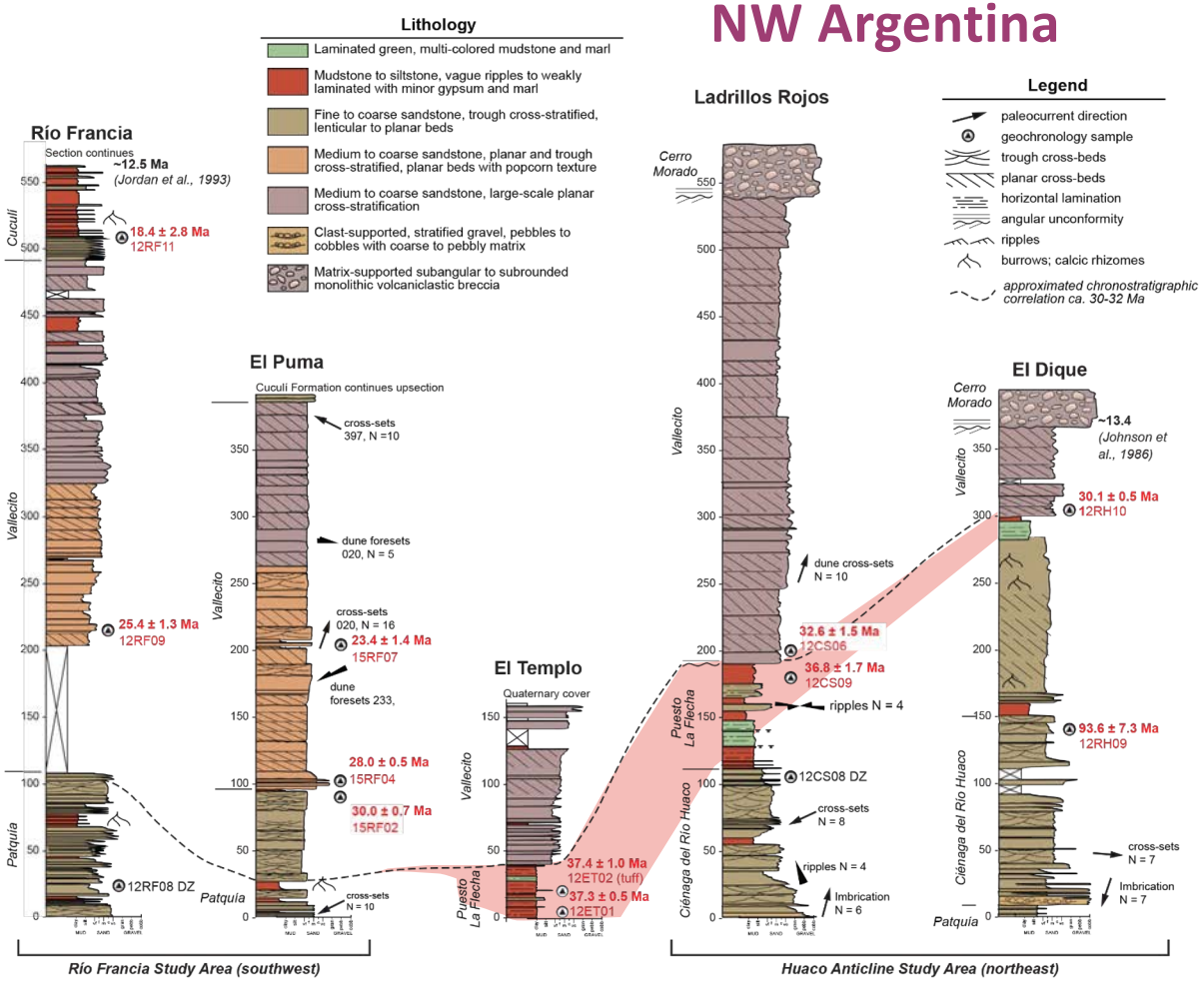


Fosdick et al. (2017)

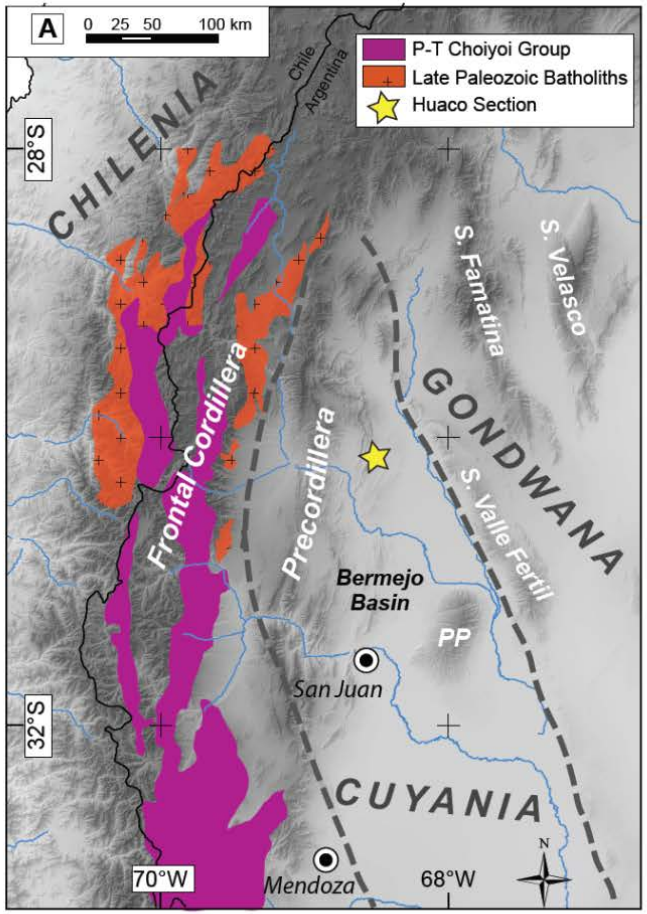


New Chronometers Petrochronology Double Dating MDA Analysis **Andean Tectonics**

Andean tectonics & sedimentation

Paleogene Bermejo Basin, NW Argentina

Herve et al. (2014)

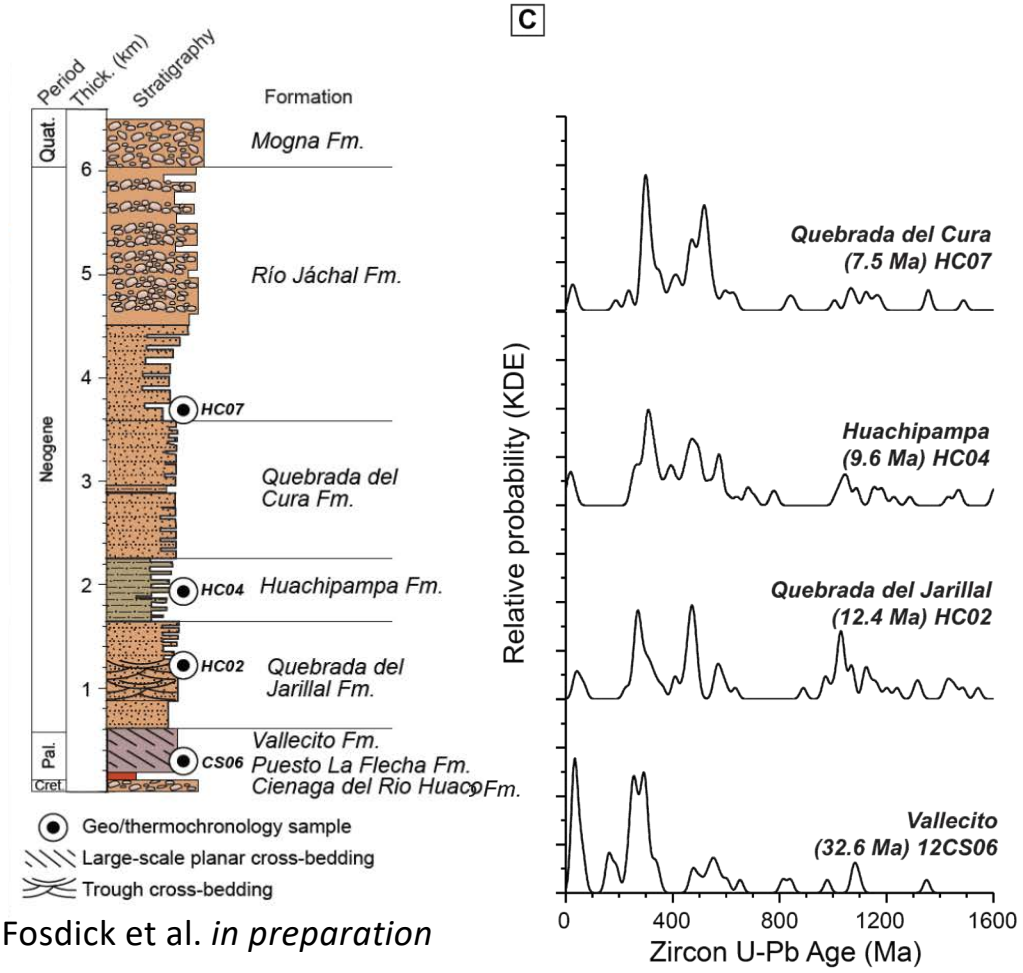


Frontal Cordillera and Main Cordillera (High Andes, 27-33 °S)

- **Carboniferous – Permian Elquí and Colangüil batholiths** associated with Cordilleran-type magmatic arc along the Gondwanan margin (*Gondwanide orogeny*)
- Followed by **Permo-Triassic (Choiyoi Group)** phase of intraplate extension and rhyolitic volcanism

Andean tectonics & sedimentation

Paleogene Bermejo Basin, NW Argentina

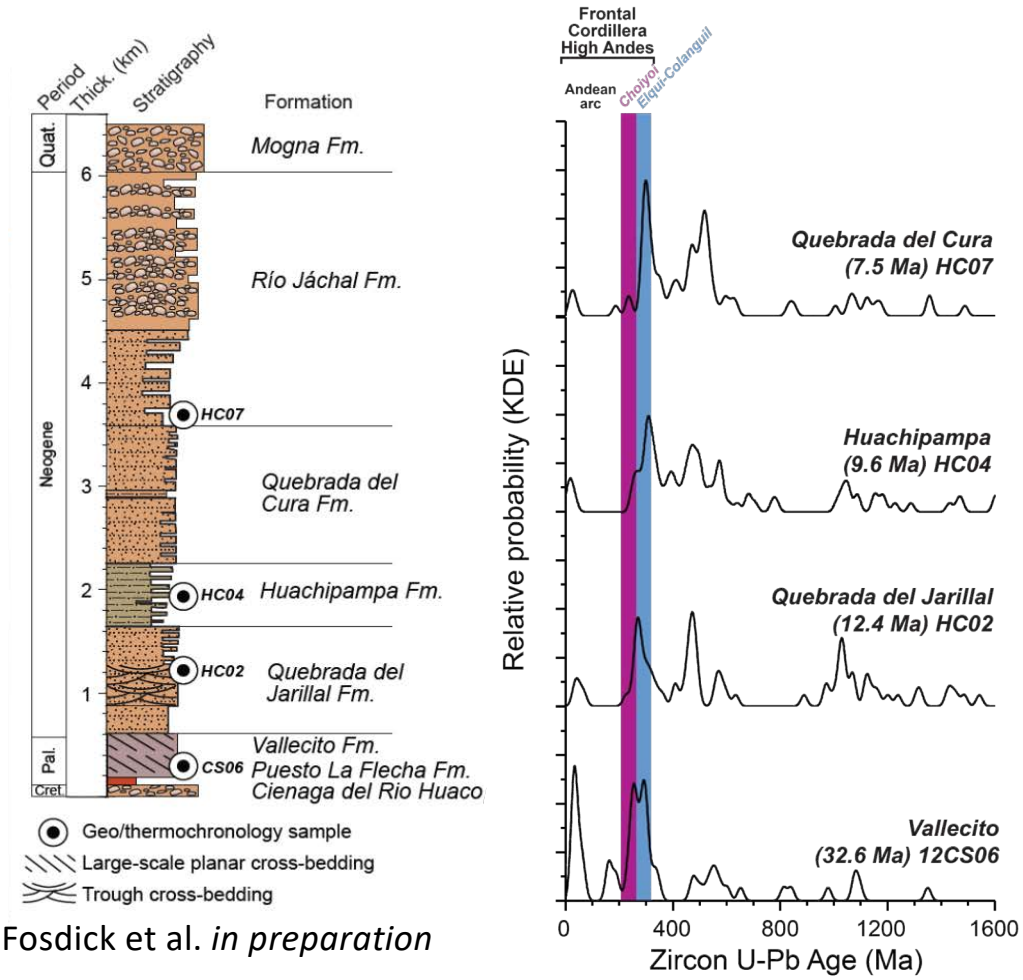


Fosdick et al. *in preparation*

U-Pb data from Fosdick et al., 2015; Val et al., 2016; Fosdick et al.(2017)

Andean tectonics & sedimentation

Paleogene Bermejo Basin, NW Argentina



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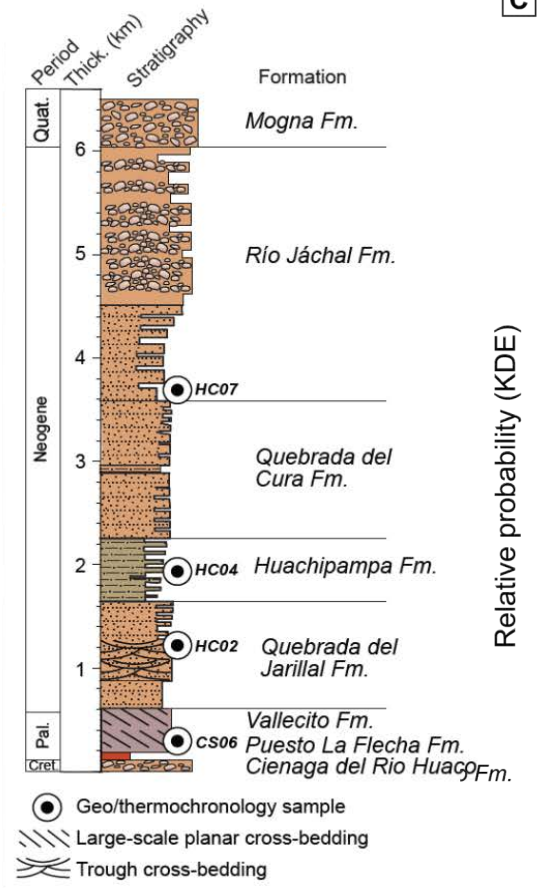
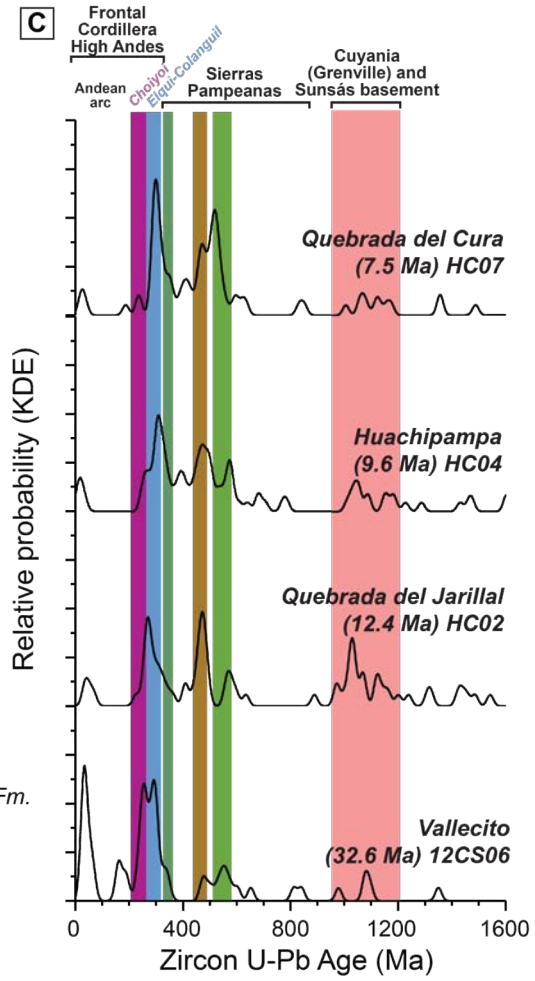
Andean tectonics & sedimentation





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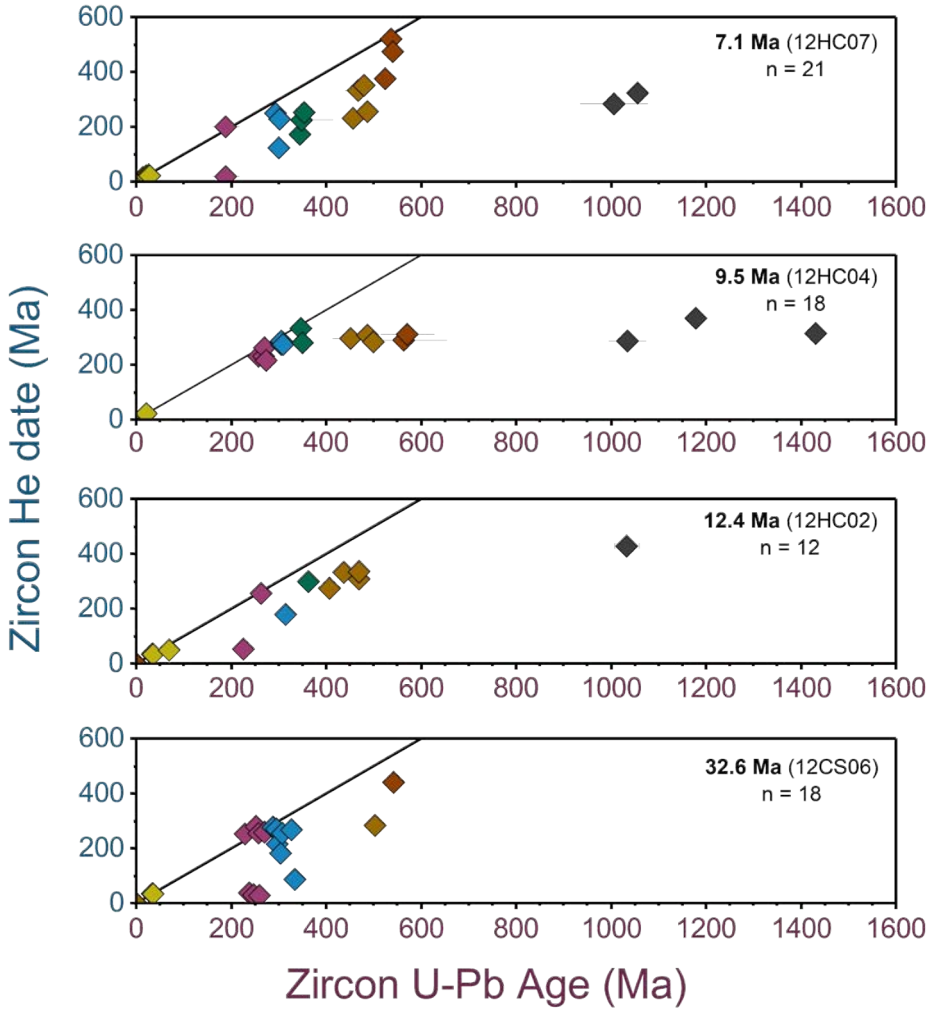

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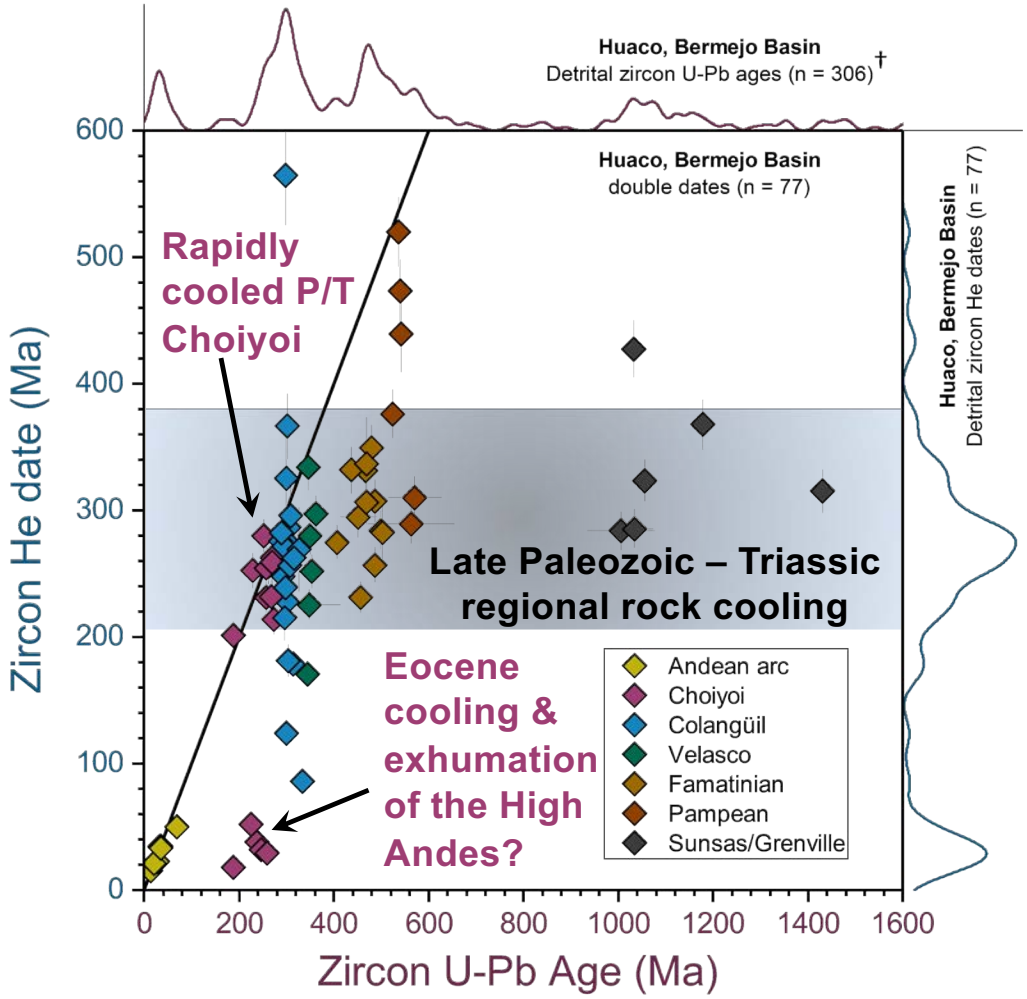
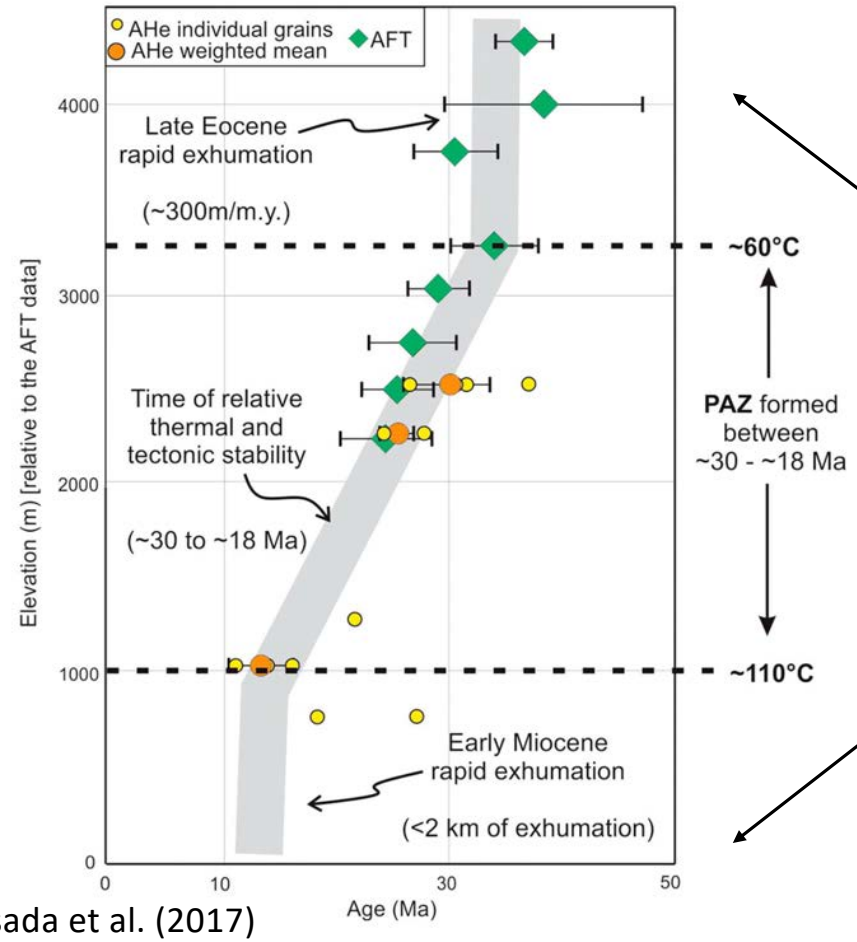


Zircon He dates reveal bimodal dates for the **Choiyoi-derived zircons**, suggesting sources with <u>two</u> distinctly different thermal histories.

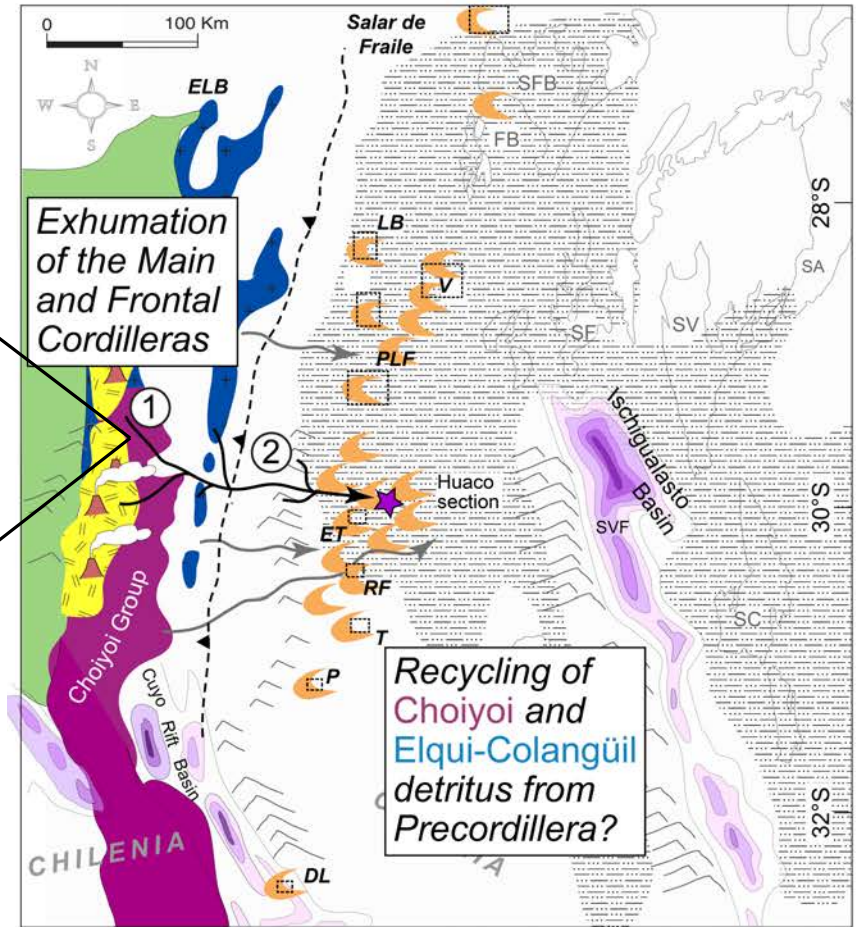
The younger zircon He cluster is synchronous with latest Eocene-Oligocene deposition, indicating **short lag times** between exhumation through the ZHe closure window, transport, and deposition.

Implications for Eocene hinterland exhumation

Fosdick et al. in prep



Lossada et al. (2017)



New Chronometers | Petrochronology | Double Dating | MDA Analysis | **Andean Tectonics**

Implications for Eocene hinterland exhumation

Fosdick et al. in prep

Choiyoi Group grains show **two distinct ZHe modes:**

(1) rapid post-emplacement P-T dates

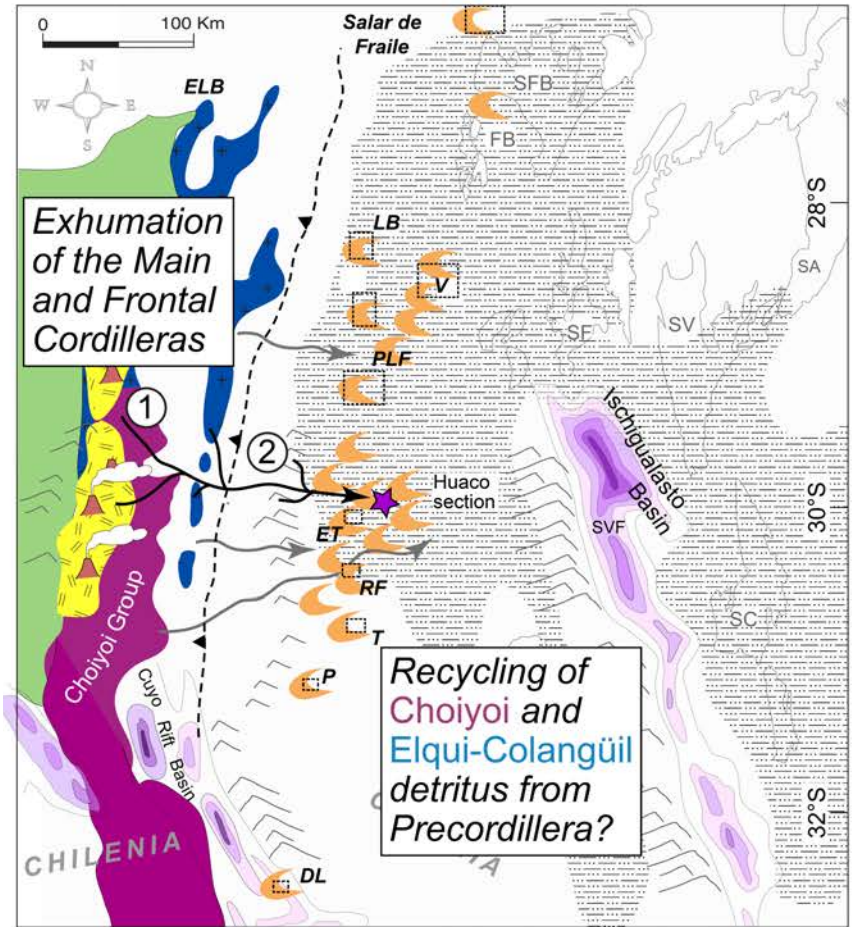
(2) reset latest Eocene – Oligocene dates

➡ **Direct unroofing versus recycled sources**

Latest Eocene – Oligocene ZHe dates are synchronous with deposition, **indicating short lag time** between cooling through the ZHe closure window and deposition.

Compatible with published structural and thermochronological evidence from the Main Cordillera pointing to a late Eocene constructional phase in the High Andes *(Lossada et al., 2017; Rodríguez et al., 2018)*

Further **thermal history modeling** of these ZHe modes and Colangüil grains from expanded sampling underway



Implications for Eocene hinterland exhumation

Fosdick et al. in prep

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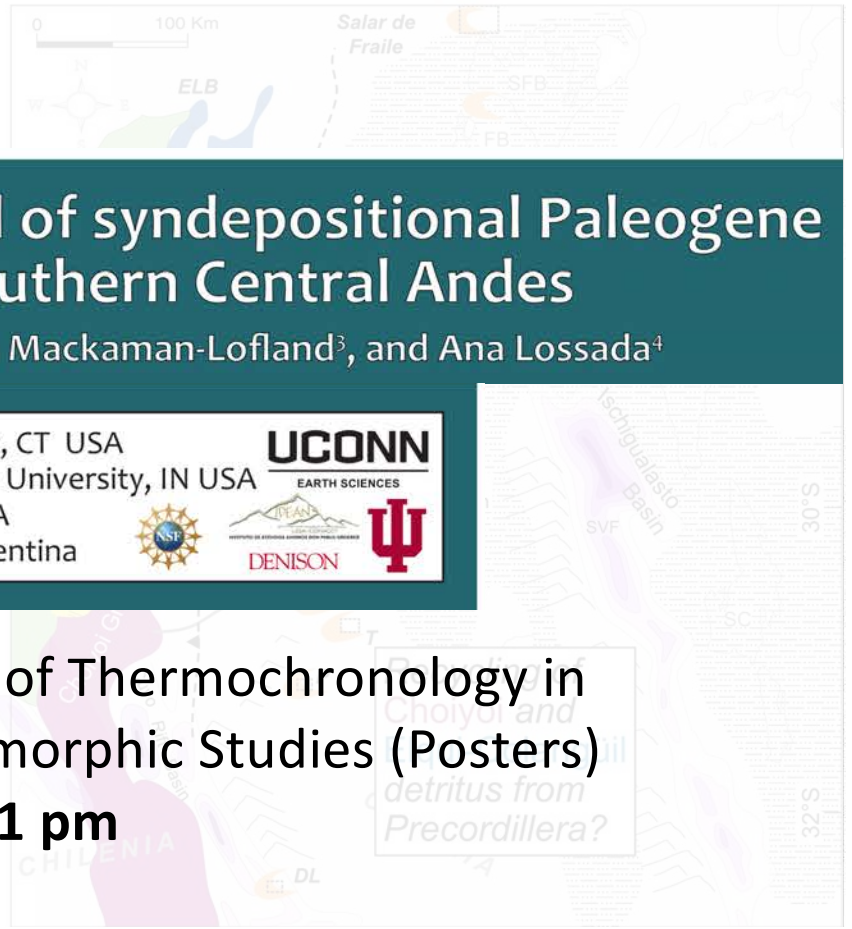

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Poster 163-T1 #19

Detrital thermochronologic signal of syndepositional Paleogene exhumation in the High Andes, southern Central Andes

Julie C. Fosdick[1], Andrea L. Stevens Goddard[2], Chelsea Mackaman-Lofland[3], and Ana Lossada[4]

[1]Dept. of Earth Sciences, University of Connecticut, CT USA
[2]Dept. of Earth and Atmospheric Sciences, Indiana University, IN USA
[3]Dept. of Geosciences, Denison University, OH USA
[4]IDEAN, CONICET, University of Buenos Aires, Argentina

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cooling through the Z

Compatible with pub
thermochronological
pointing to a late Eocene constructional phase in the High Andes *(Lossada et al., 2017; Rodríguez et al., 2018)*

Further **thermal history modeling** of
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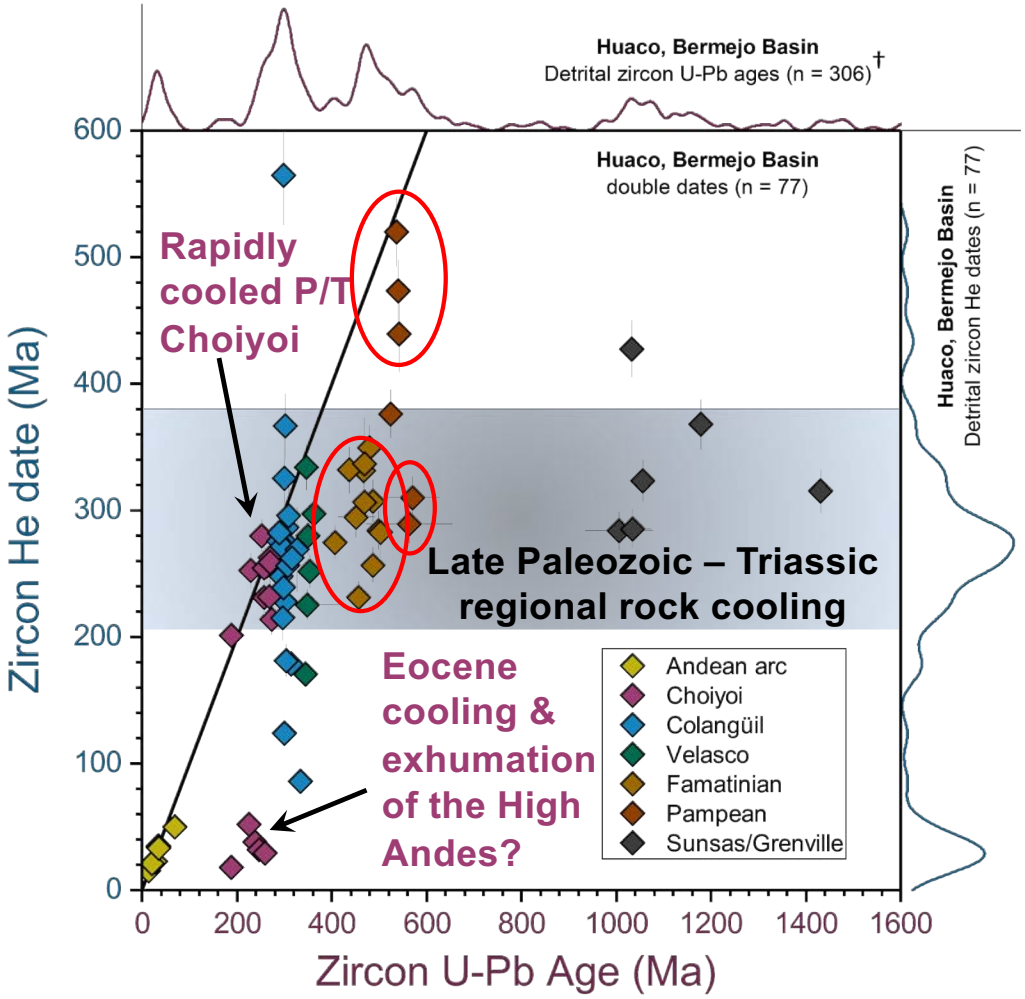
163: T1. Advances and Applications of Thermochronology in Tectonic, Magmatic, Basin, and Geomorphic Studies (Posters)

Tuesday 9 am – 1 pm

New Chronometers | Petrochronology | Double Dating | MDA Analysis | **Andean Tectonics**

Ongoing challenges and new directions



Challenges…

What about the other detrital age modes?

How to distinguish sediment derived from Sierras Pampeanas uplifts versus recycled SP detritus in younger terranes, basins?

Complexities that arise from **sediment recycling** pose challenges to the utility of sedimentary provenance analysis in multicyclic orogenic settings…

Streamlined analytical workflow for **double dating detrital monazite** U-Th-Pb geochronology, T/REE analysis, and He thermochronology.

Acknowledgements

Andrea Stevens Goddard
Chelsea Mackaman-Lofland
Ana Lossada
Pia Rodriguez
Mauricio Calderón
Barbara Carrapa
Gustavo Ortiz
Patricia Alvarado
Greg Hoke
Ellen Reat
Elizabeth Balgord

Parque Ciénaga del Rio Huaco
Universidad Nacional de San Juan
Arizona LaserChron Center
Arizona Radiogenic Helium Dating Laboratory (ARDHL)
CU Thermochronology and Instrumentation Laboratory
NSF EAR Awards 1049605 (Tectonics) and 2045695 (CAREER)

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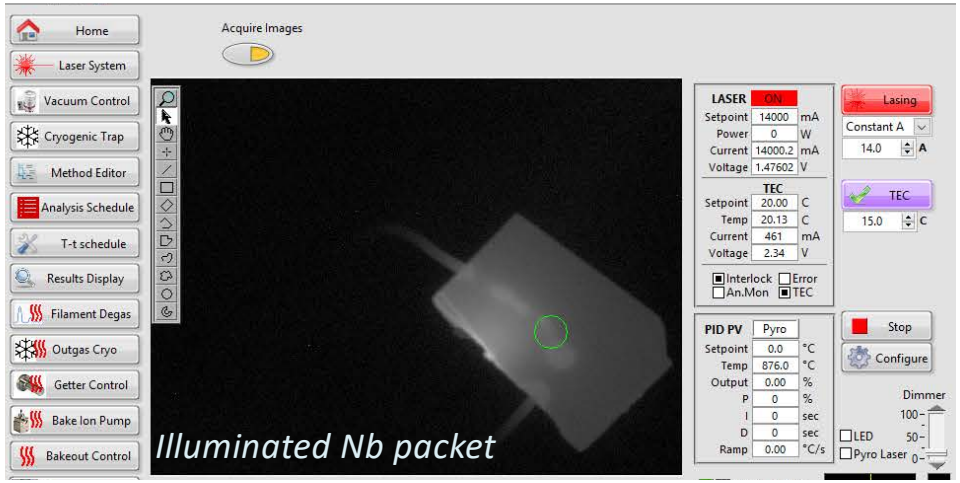
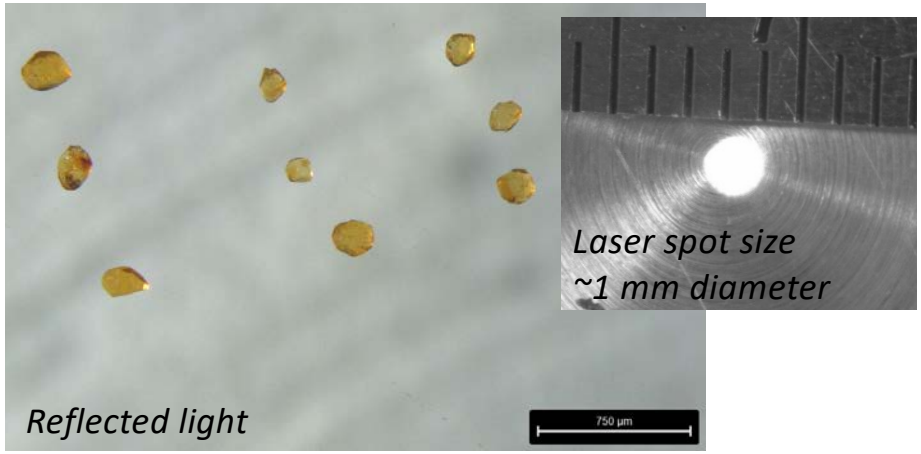
Many thanks for your attention.

Questions?

Bermejo Basin, southern central Andes

Ongoing and new directions





Working on development of monazite for detrital Th-Pb chemical age mapping, LA-ICPMS and (U-Th)/He dating

Overarching question: ***what are the signals of recycling on the thermal histories of detrital minerals during the polycycle orogenic evolution of continental landmasses?***

Collaborative Team "Monazite Madness"

Julie Fosdick, Julian Biddle, Megan Mueller, and Cullen Kortyna (UConn)
Dave Moecher (University of Kentucky)
Michael Jercinovic (UMass Amherst)
Becky Flowers, Jim Metcalf (University of Colorado)
Sarah George (University of Arizona)
Emily Peterman (Bowdoin College)
Juan Otamendi (Universidad de Nacional de Río Cuarto, Argentina)

Ongoing and new directions

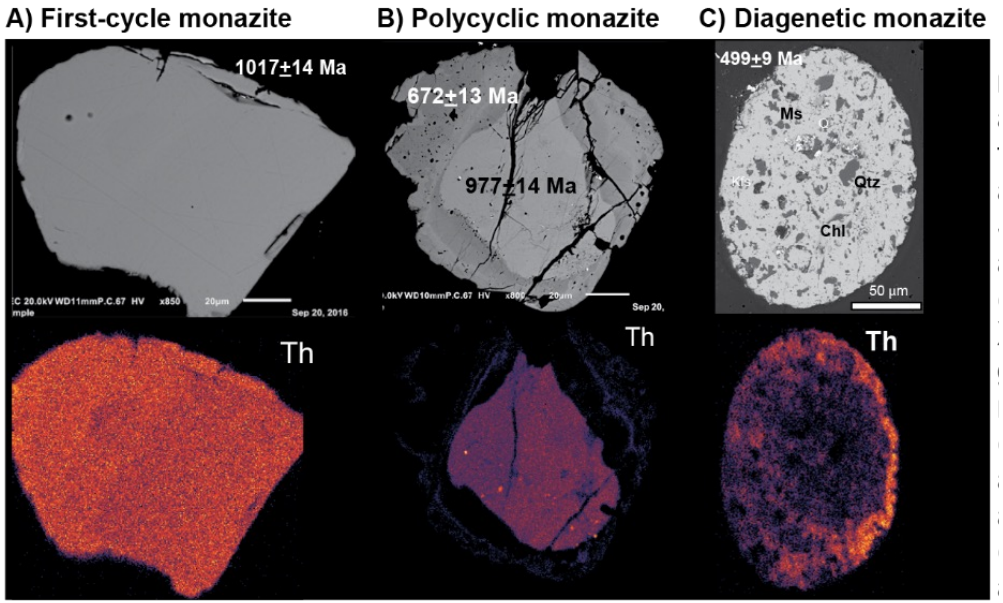
Monazite, a rare-earth phosphate mineral has a high potential to resolve issues related to sediment recycling:

Monazite is mined for its cerium, lanthanum, neodymium, & thorium

Texture: The ability to recognize textural differences in first-cycle igneous, metamorphic, and <u>particularly diagenetic or authigenic</u> monazite.

Temperature sensitivity: Monazite's closure temperature for He diffusion (~260-290 °C) is comparable to the zircon (U-Th)/He thermochronometer, and it thus provides a <u>comparative metric</u> for equivalent magnitude of crustal exhumation.

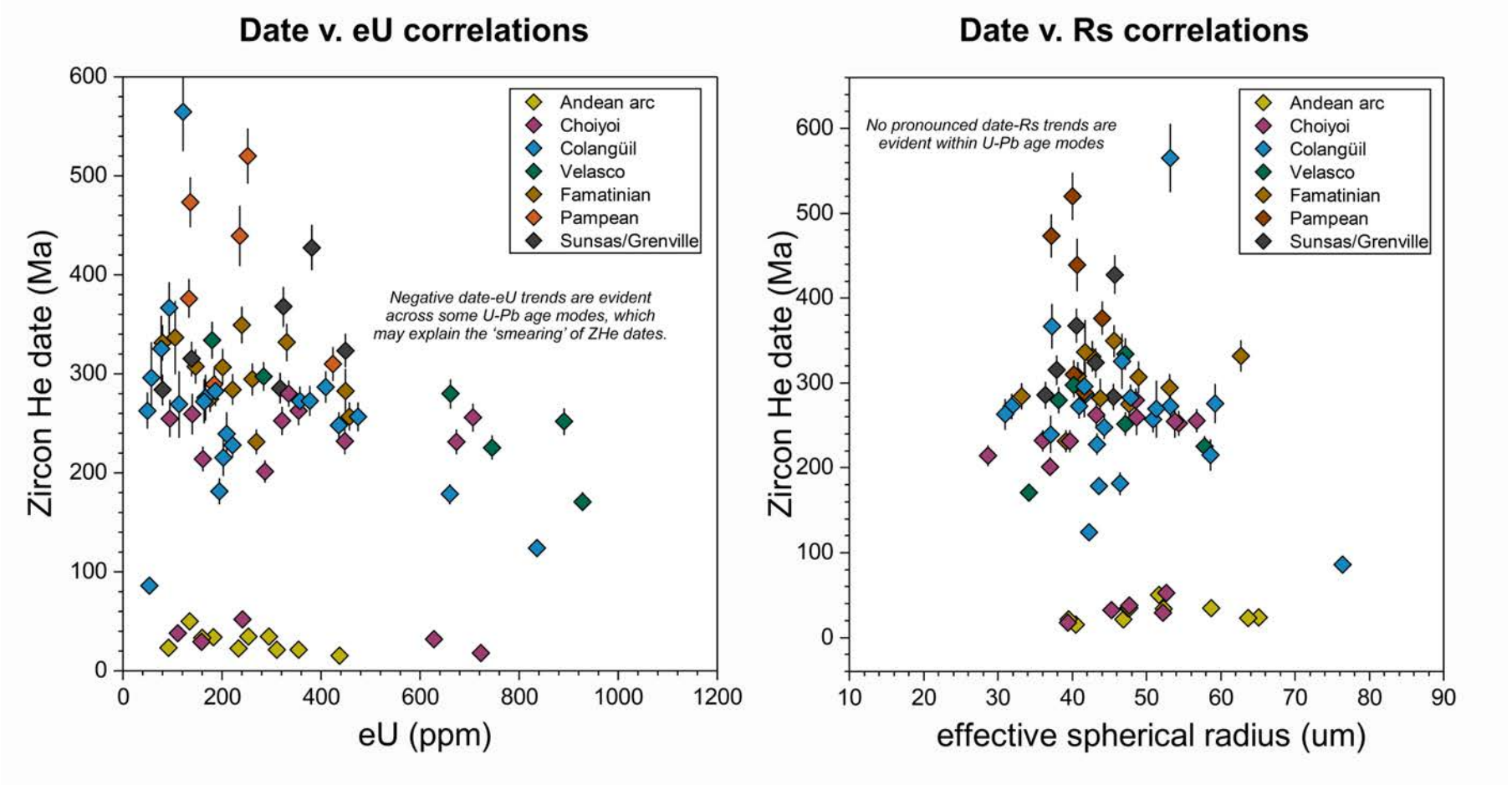
Preservation potential: Like zircon, monazite is moderately physically resistant to abrasion and dissolution during polycyclic phases of transport and erosion.



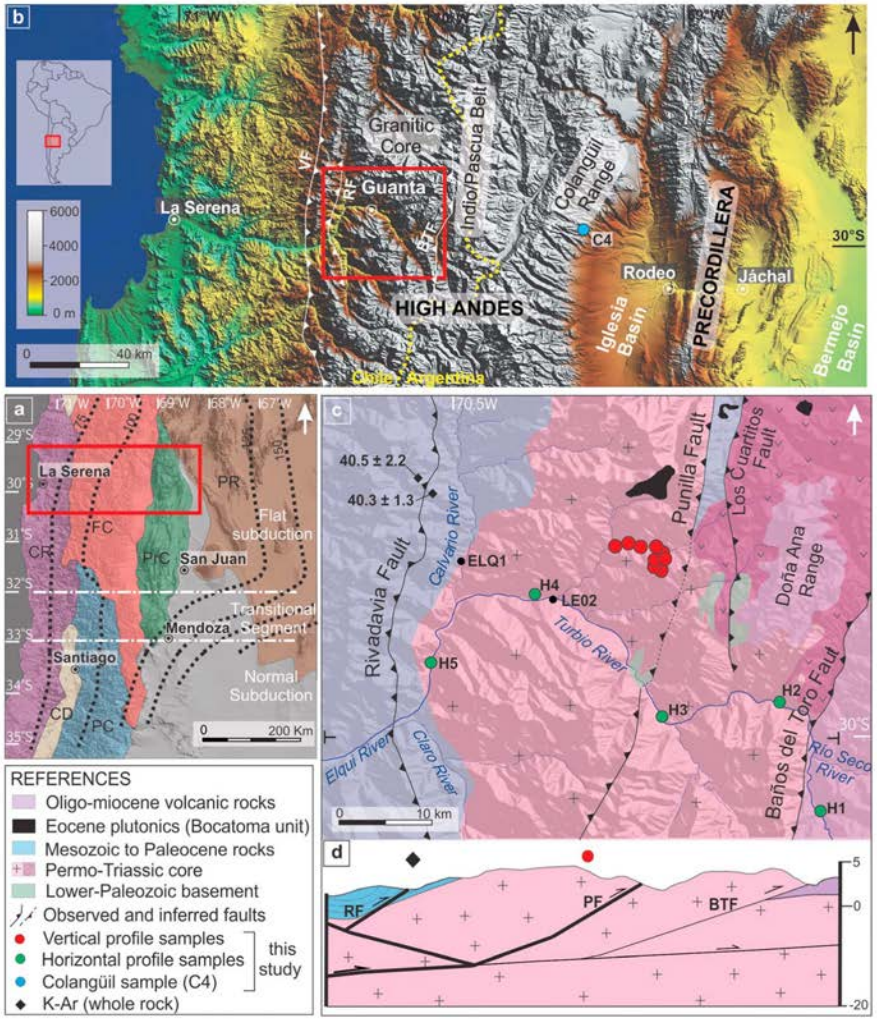
Above: Representative examples of monazite textures and geochemistry from Pennsylvanian-Permian quarts arenites, Great Smoky Mountains (modified from **Moecher et al., 2019**)

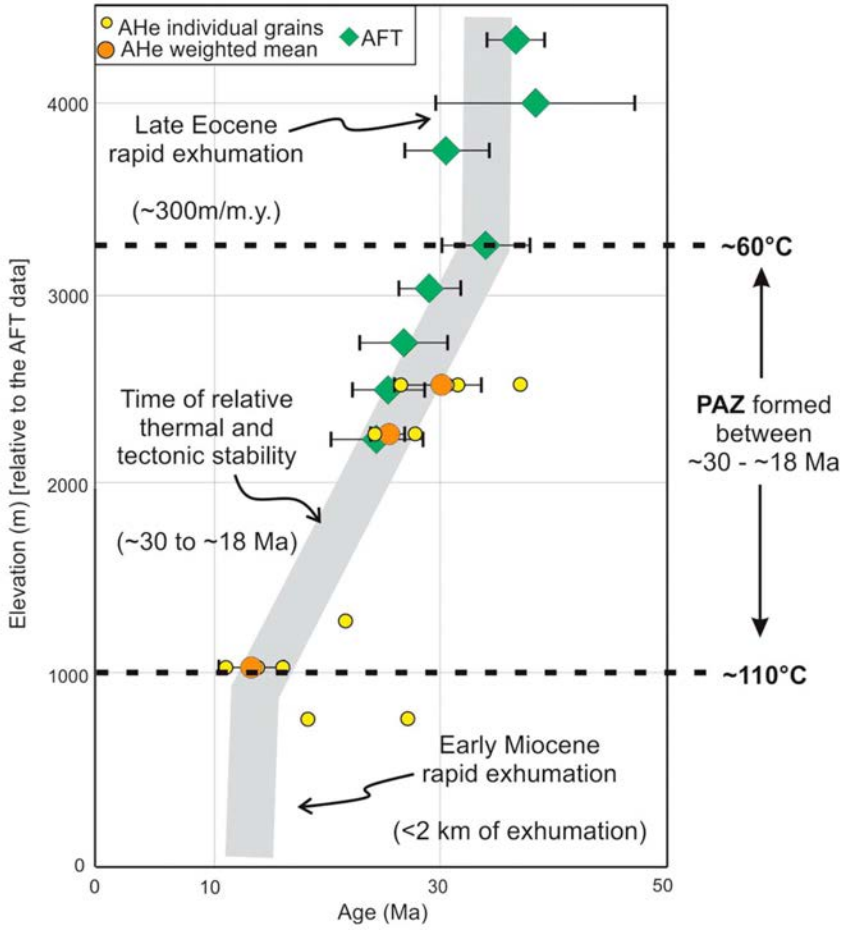
Andean tectonics & sedimentation

Paleogene Bermejo Basin, NW Argentina



Implications for Eocene hinterland exhumation

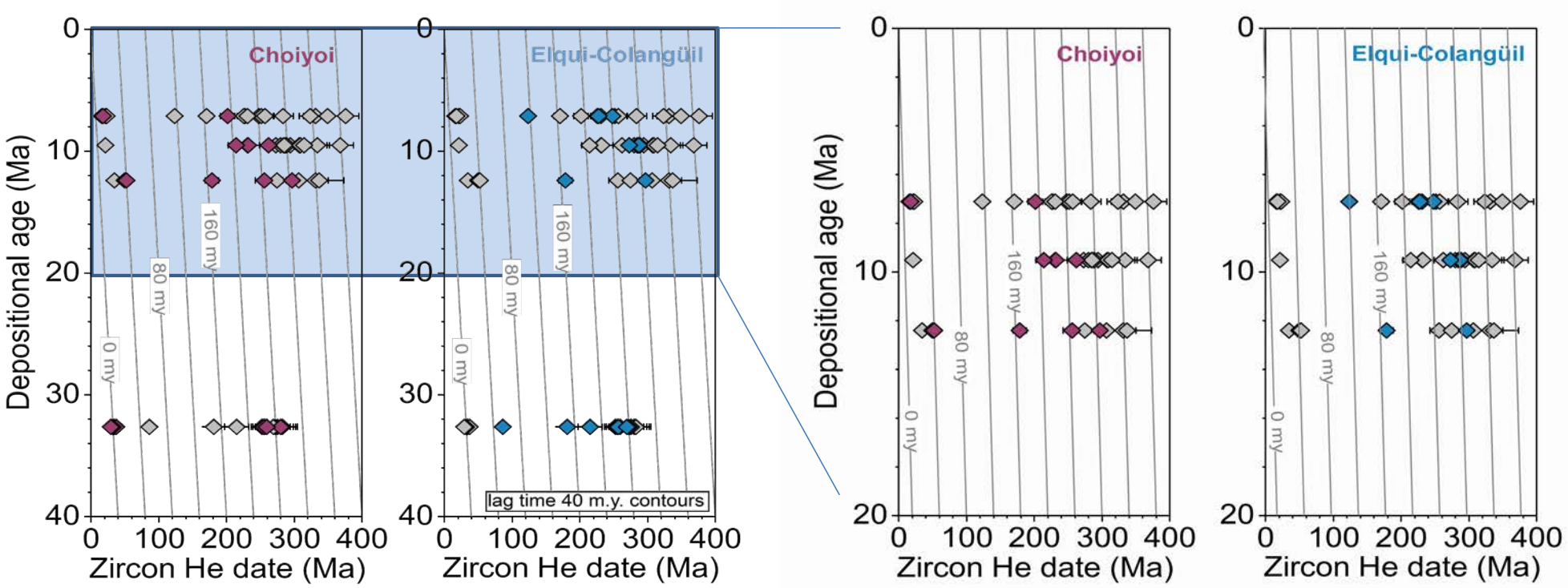




~238-286 Ma zircon U-Pb sources

Lossada et al. (2017)

Lag time analysis: detrital zircon (U-Th)/He thermochronology of key age modes Choiyoi Group (Permo-Triassic) and Elqui-Colangüil Batholith (Carboniferous-Permian)



CAREER: Resolving the detrital thermal signatures of sediment recycling in the Sierras Pampeanas, Argentina

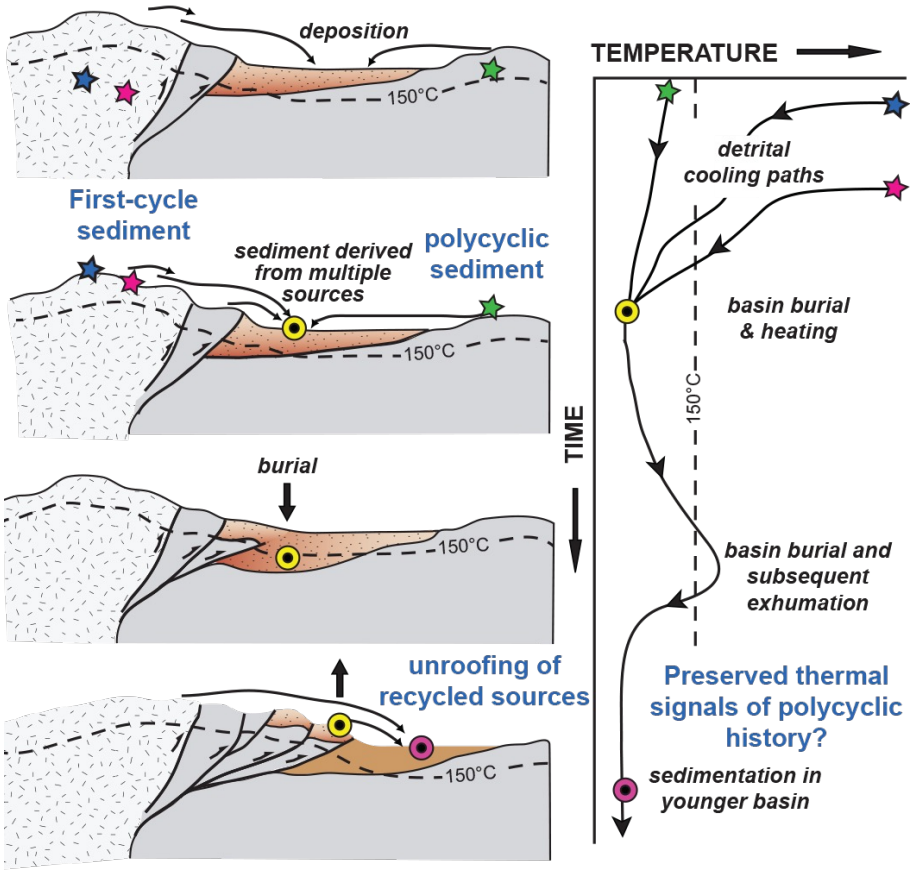
Overarching question: ***what are the signals of recycling on the thermal histories of detrital minerals during the polycycle orogenic evolution of continental landmasses?***

Collaborative Team:

Julie Fosdick, Julian Biddle and **Tony Edgington** (UConn)
Patricia Ciccioli (Universidad de Buenos Aires – CONICET, Argentina)
Becky Flowers, Jim Metcalf (University of Colorado)
George Gehrels, Sarah George (University of Arizona)
Michael Jercinovic (UMass Amherst)
Dave Moecher (University of Kentucky)
Juan Otamendi (Universidad de Nacional de Río Cuarto, Argentina
Emily Peterman (Bowdoin College)
Susana Ulloa (University College Access Program, UConn)

Bermejo Basin, southern central Andes

CAREER: Overview of Project Research Goals



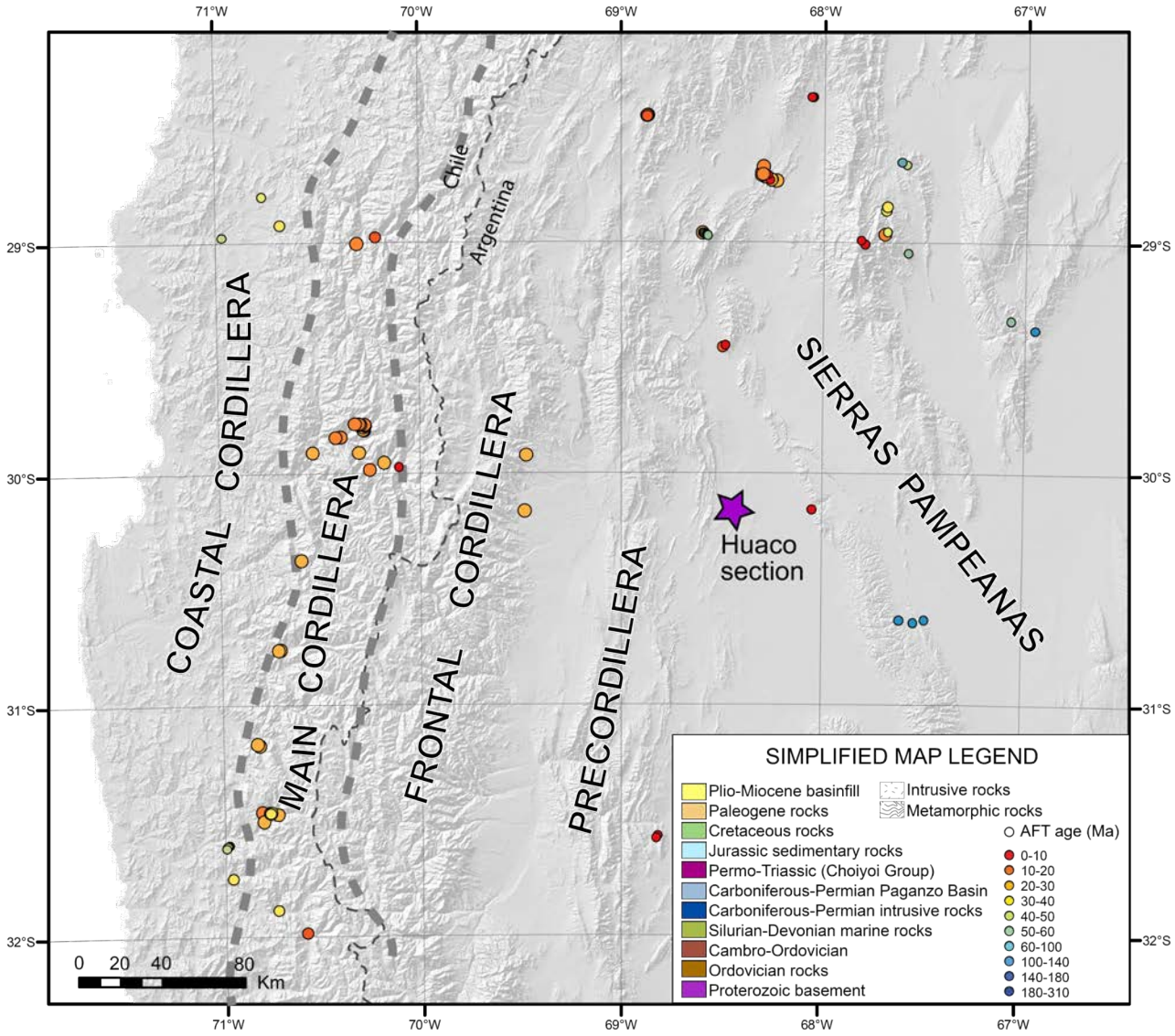
Modified from Fosdick et al. (2015)

(1) Integrated detrital fingerprinting and source characterization of the **Paganzo Basin, Sierras Pampeanas**, and intervening sedimentary depocenters.

(2) Streamlined analytical workflow for **detrital monazite** U-Th-Pb geochronology, T/REE analysis, and He thermochronology.

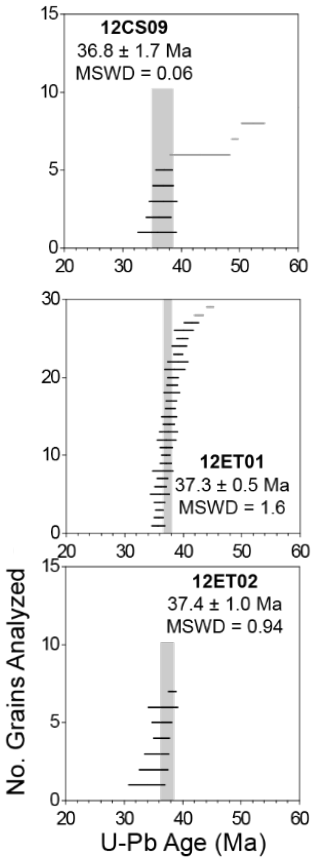
(3) Development of a new multiproxy **'RISE' (Recycling Index of Sedimentation and Erosion) matrix** that will complement existing weathering and erosion indices to provide a semi-quantitative metric for recycling in polycyclic settings.

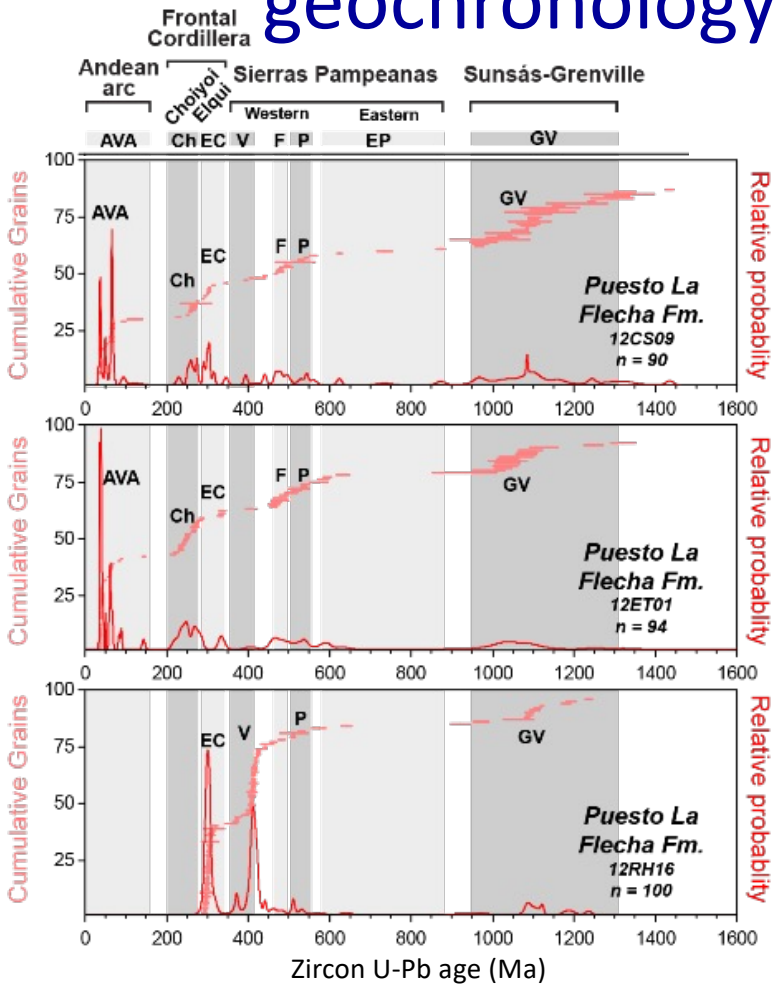
(4) Improved treatment of more complete and thus, representative mineralogical, geo-thermochronologic signatures from the basin record (spanning zircon, monazite, heavy minerals, and mudstone geochemistry).


71°W
70°W
69°W
68°W
67°W
29°S
30°S
31°S
32°S
Chile
Argentina
COASTAL CORDILLERA
MAIN CORDILLERA
FRONTAL CORDILLERA
PRECORDILLERA
SIERRAS PAMPEANAS
Huaco section
0 20 40 80
Km
SIMPLIFIED MAP LEGEND
Plio-Miocene basinfill
Paleogene rocks
Cretaceous rocks
Jurassic sedimentary rocks
Permo-Triassic (Choiyoi Group)
Carboniferous-Permian Paganzo Basin
Carboniferous-Permian intrusive rocks
Silurian-Devonian marine rocks
Cambro-Ordovician
Ordovician rocks
Proterozoic basement
Intrusive rocks
Metamorphic rocks
AFT age (Ma)
0-10
10-20
20-30
30-40
40-50
50-60
60-100
100-140
140-180
180-310

Timing of sedimentation from detrital zircon U-Pb geochronology

Maximum Age



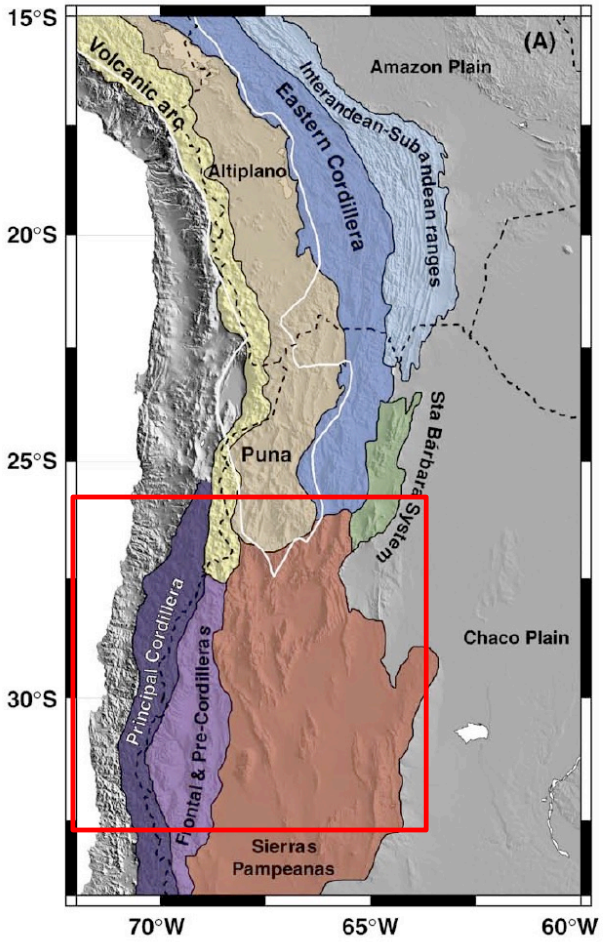


Revised basin chronology reveals a late Eocene phase of sedimentation

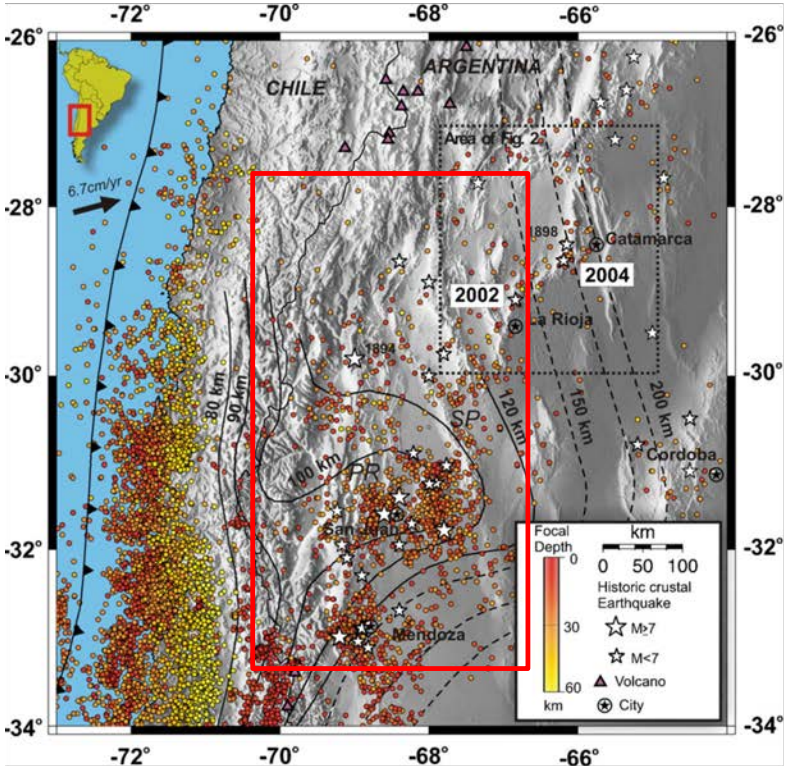
Puesto La Flecha Fm.

(Fosdick et al., 2017)

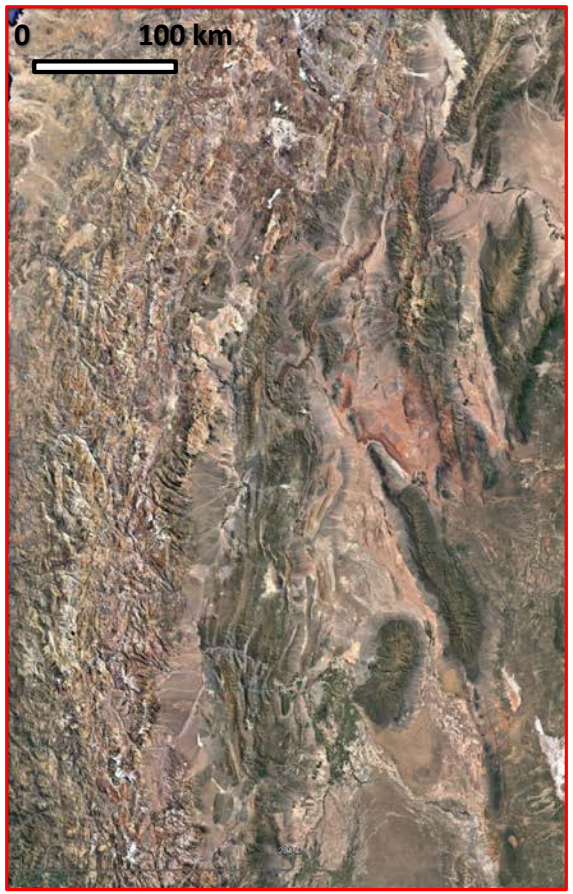
Geologic Setting: Central Andes, Pampean flat-slab segment



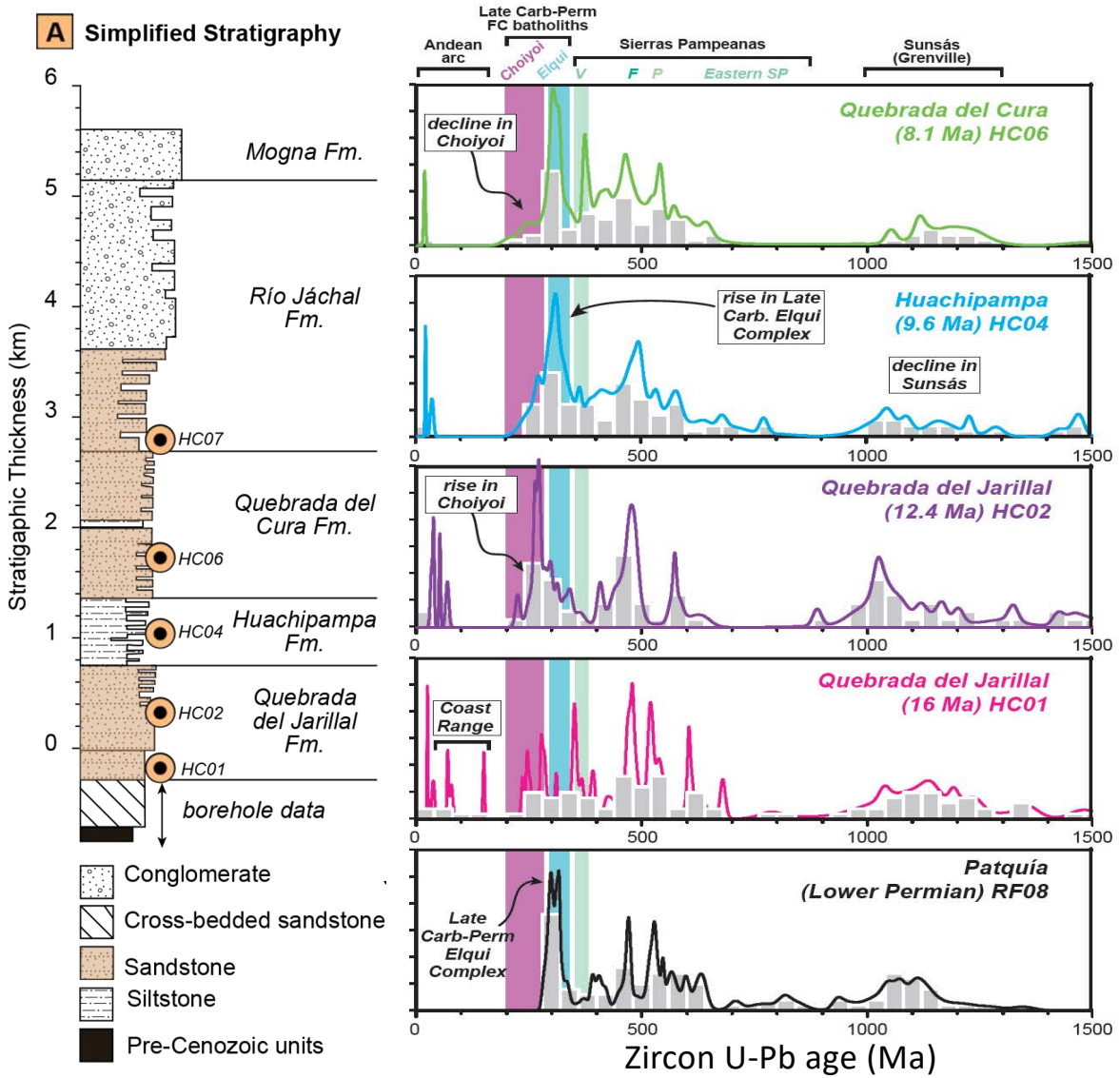
Hilley and Coutand (2009)



Alvarado & Ramos (2011)



Thanks, Google Earth!



Detrital zircon U-Pb geochronology

- Andean arc sources, Frontal Cordillera (Choiyoi and Elquí batholith).
- Substantial component of recycled Sierras Pampeanas (eastern) sediments.
- Pronounced shift between 12.4-9.6 Ma towards more Elquí batholith source, consistent with drainage reorganization interpreted from sedimentary facies analysis and provenance.

Fosdick et al. (2015) EPSL