Eocene exhumation of the High Andes differentiated by detrital multimethod U-Pb-He thermochronology and thermal history modeling

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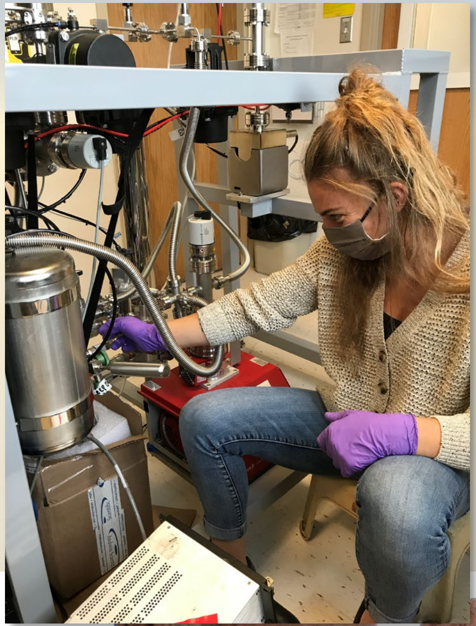


The Central Andean Orogenic Belt

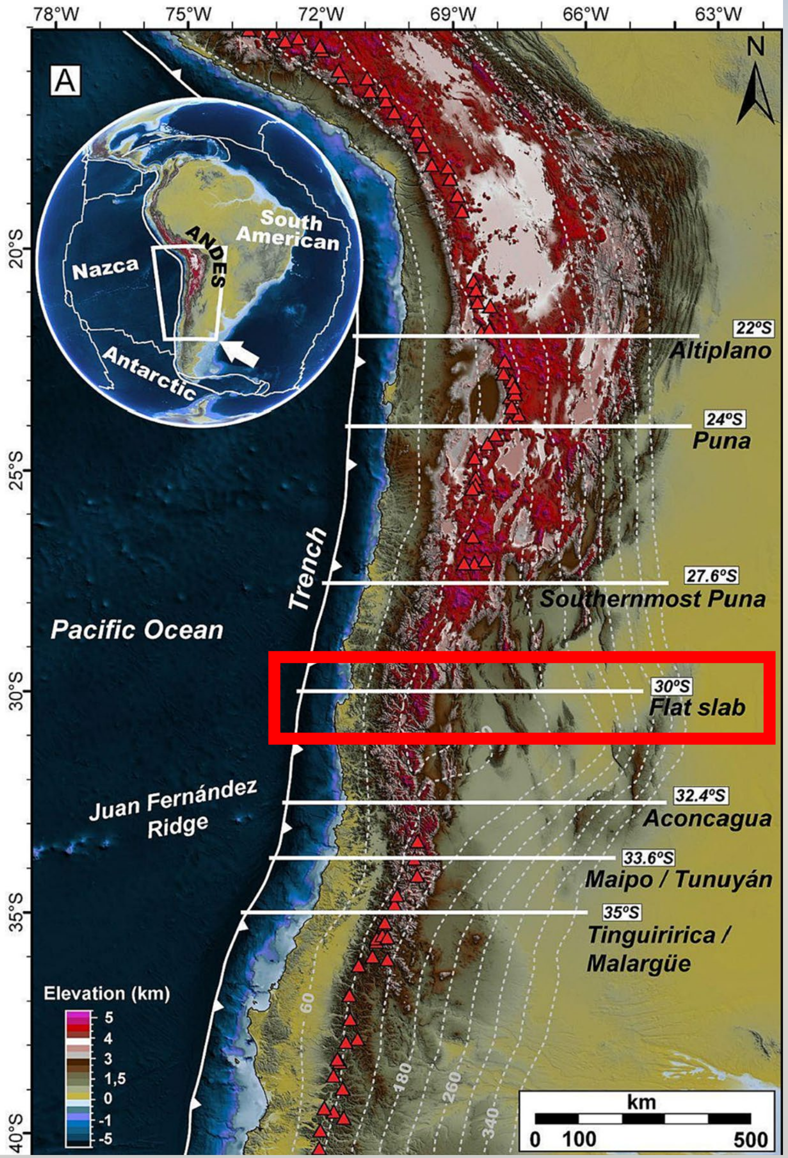
Archetype of subduction-related orogenic system

- Linked processes between thrust-belt thickening, surface uplift, basin subsidence, and arc magmatism
  - ➢ Orogenic cyclicity *DeCelles et al., 2009; 2015*
  - ➢ Evolutionary stages of wedge growth *Giambiagi et al., 2022*

➢ Paleogene orogenic history remains contentious

- ➢ Tectonic stasis/quiescence? *Horton and Fuentes, 2016; Horton et al., 2018*
- ➢ Recent recognition of Paleogene retroarc strata *Fosdick et al., 2017; Suriano et al., 2023; Ronemus et al., 2024*
- ➢ New structural and thermochronology of hinterland deformation *Lossada et al., 2017; Rodriguez et al., 2018; and Mackaman-Lofland et al., 2024*

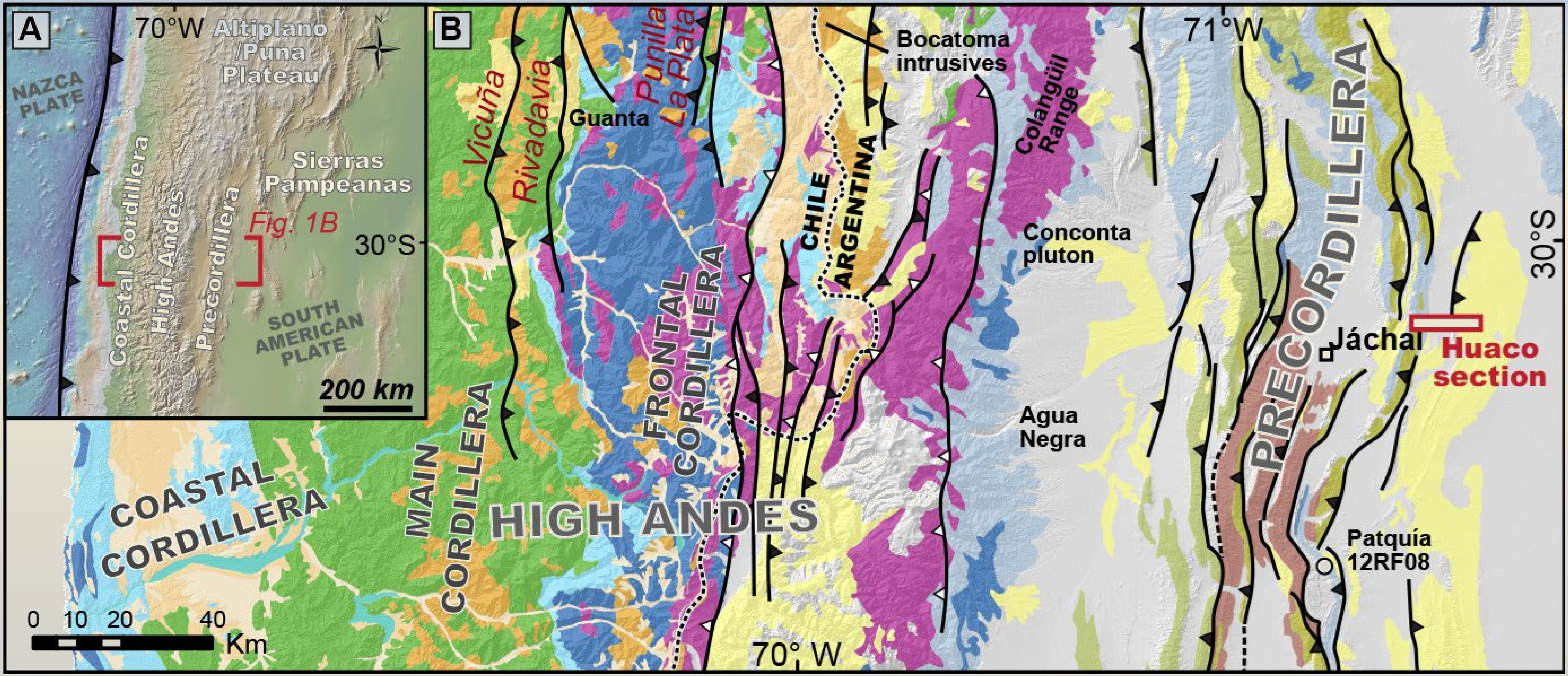
We revisit the detrital signature of Paleogene – Neogene strata to test whether there is evidence of hinterland exhumation and source-basin sediment routing



Giambiagi et al. (2022)

Southern Central Andes 30°S

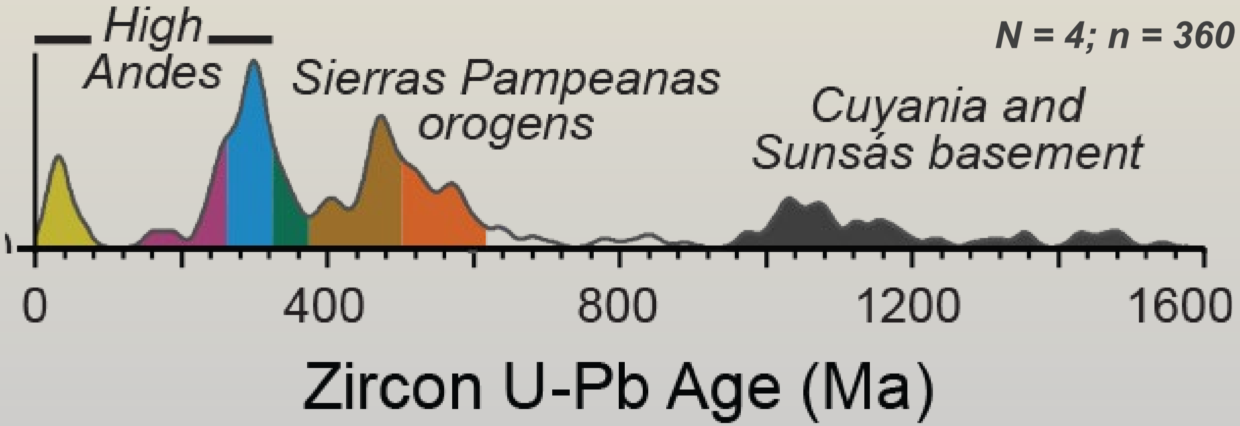
Pampean flat-slab segment



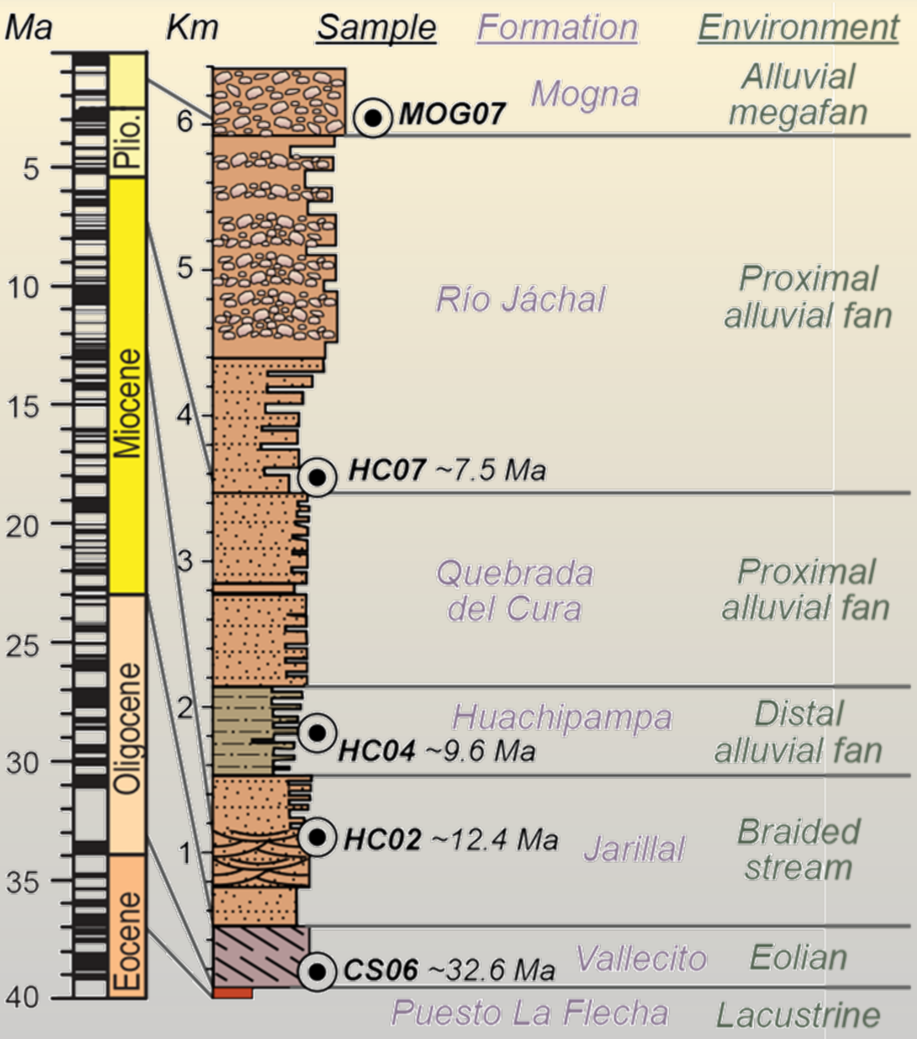
- Neogene sedimentary and volcanic rocks
- Paleogene sedimentary and volcanic rocks
- Palegene intrusive rocks
- Cretaceous sedimentary and igneous rocks
- Jurassic sedimentary and igneous rocks
- Perm-Triassic Choiyoi Group
- Devonian-Permian clastics
- Upper Paleozoic intrusions
- Silurian-Devonian clastics
- C-Ordovician carbonates

Fosdick et al. (2024) Geology

Bermejo – Vinchina foreland basin



Huaco Composite Section



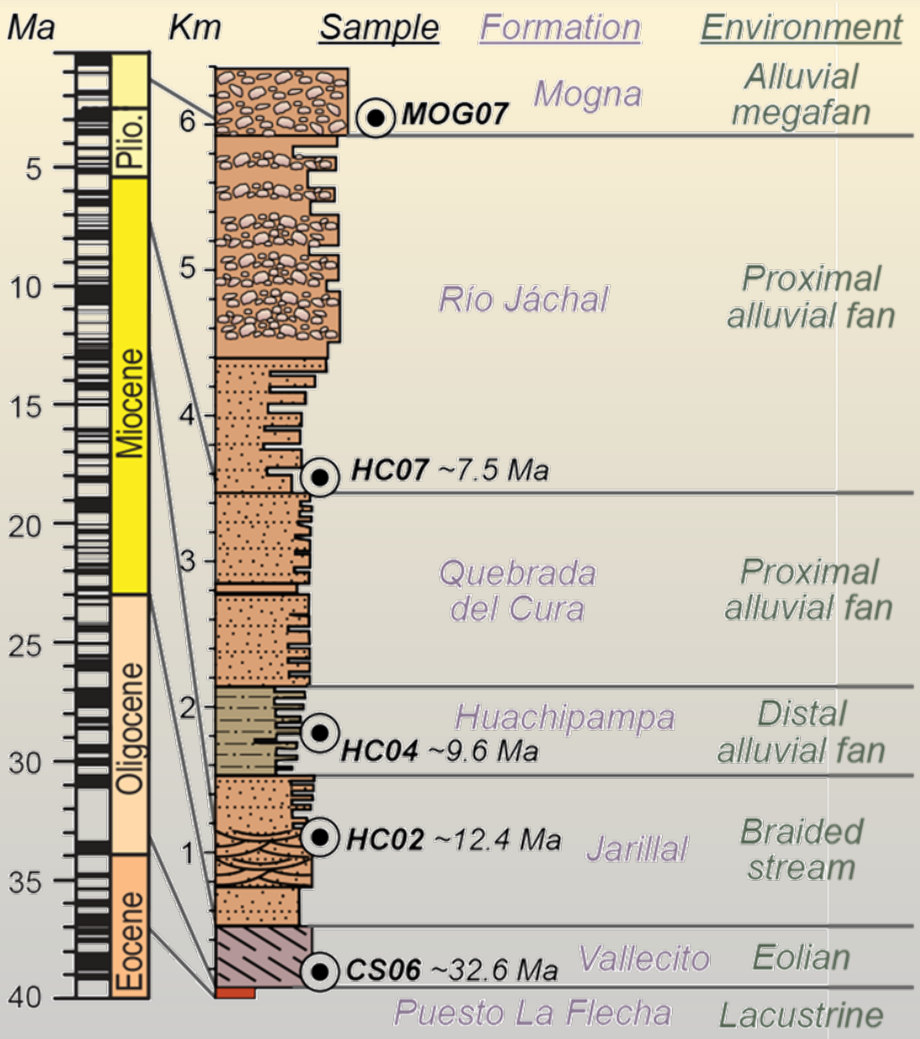
Bermejo – Vinchina foreland basin

Vallecito Fm. **(lower Oligocene to lower Miocene)**
Eolian and fluvial deposits

Puesto de la Flecha Fm. **(upper Eocene)**
Distal lacustrine siltstone, sandstone, and evaporite deposits

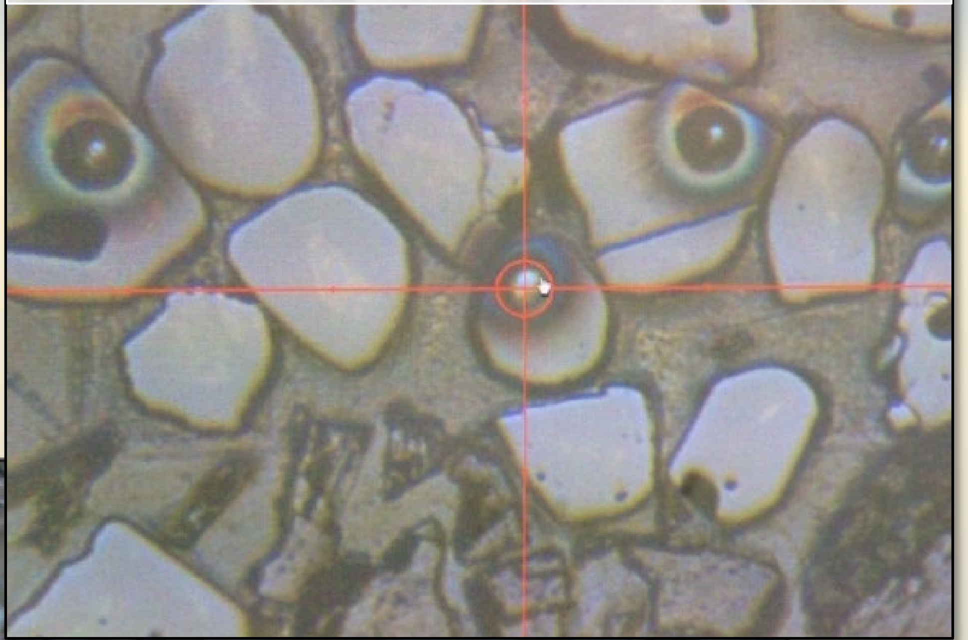
Fosdick et al. (2024)

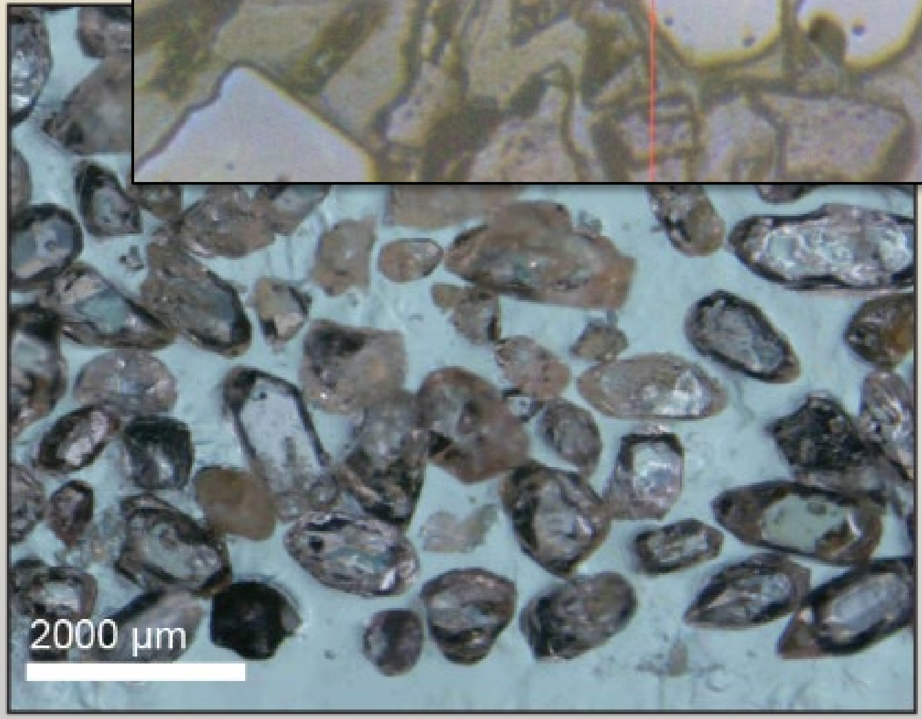
Huaco Composite Section



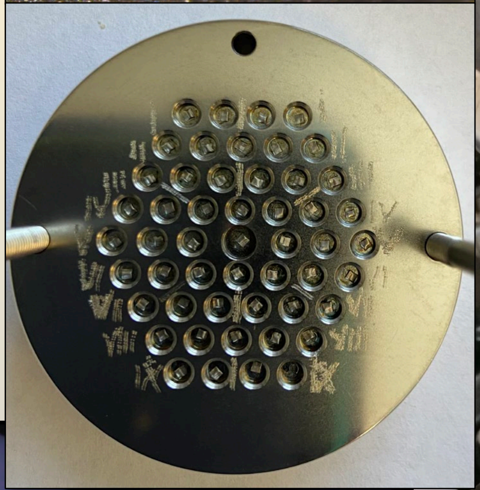
Paired Detrital U-Pb and (U-Th)/He Thermochronology

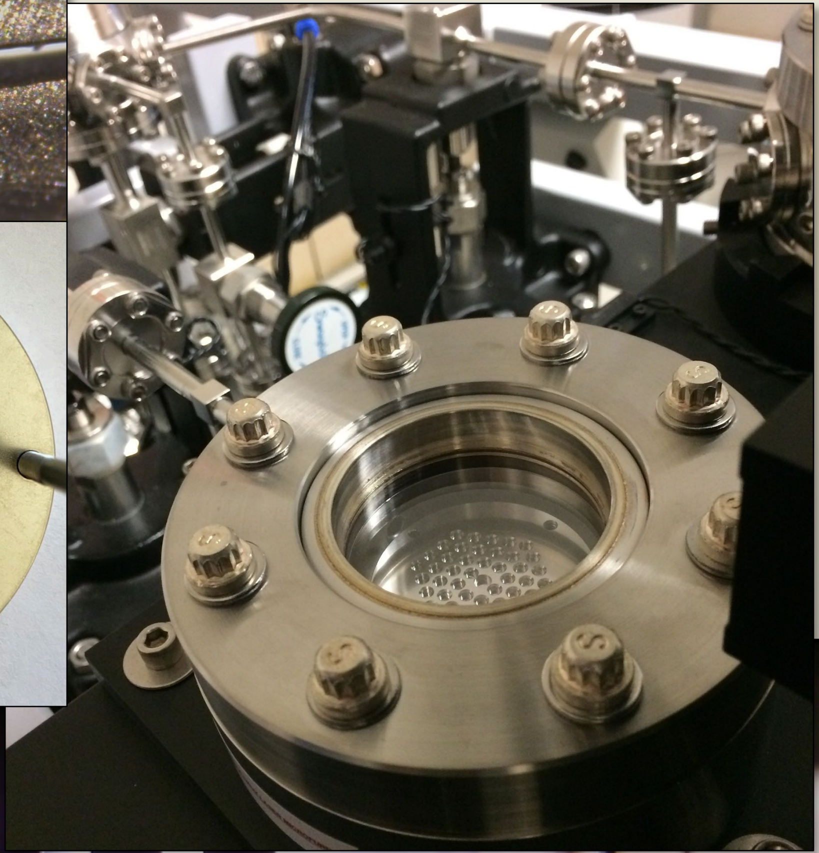
LA-ICPMS U-Pb analysis

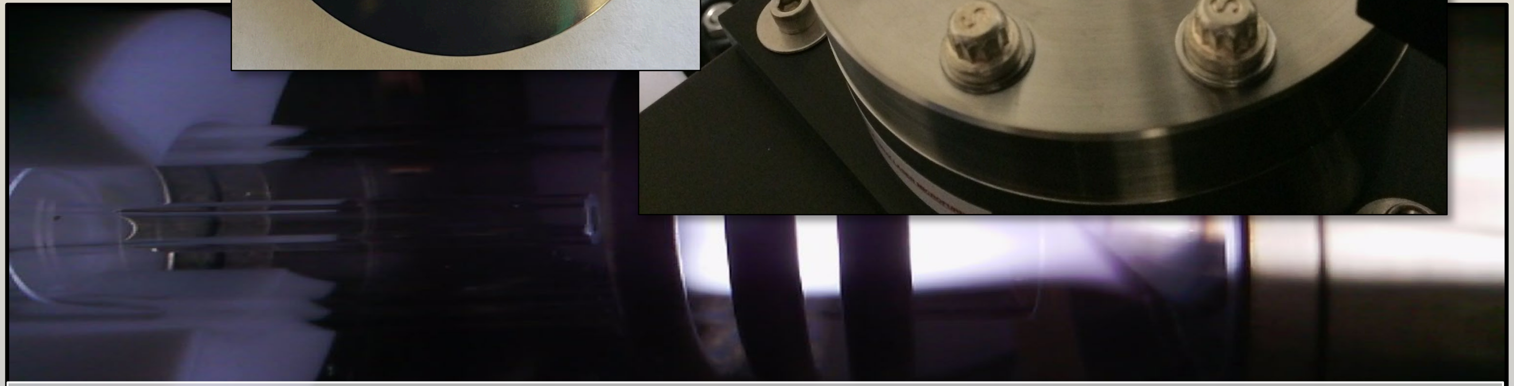




Radiogenic He degassing and measurement

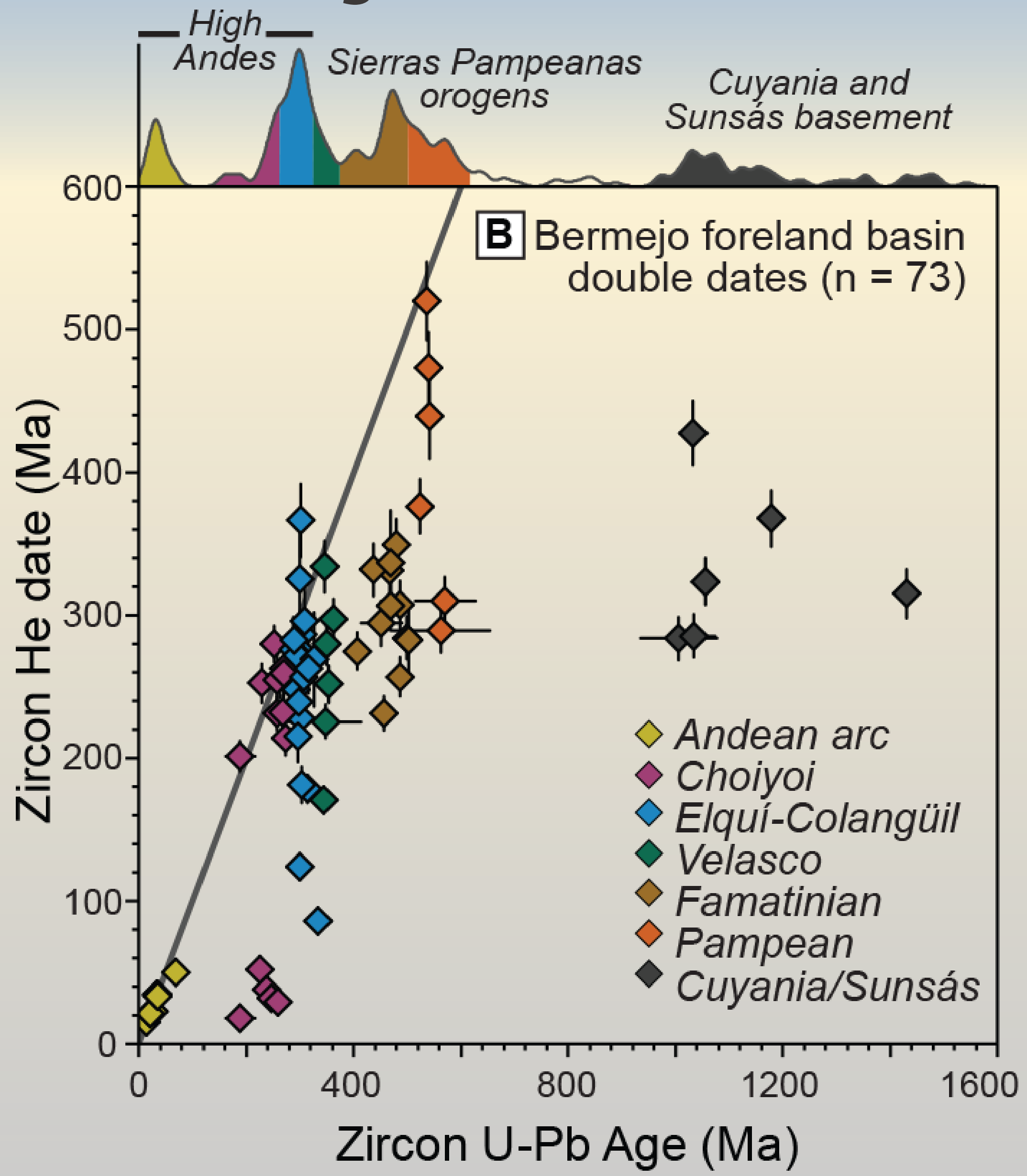


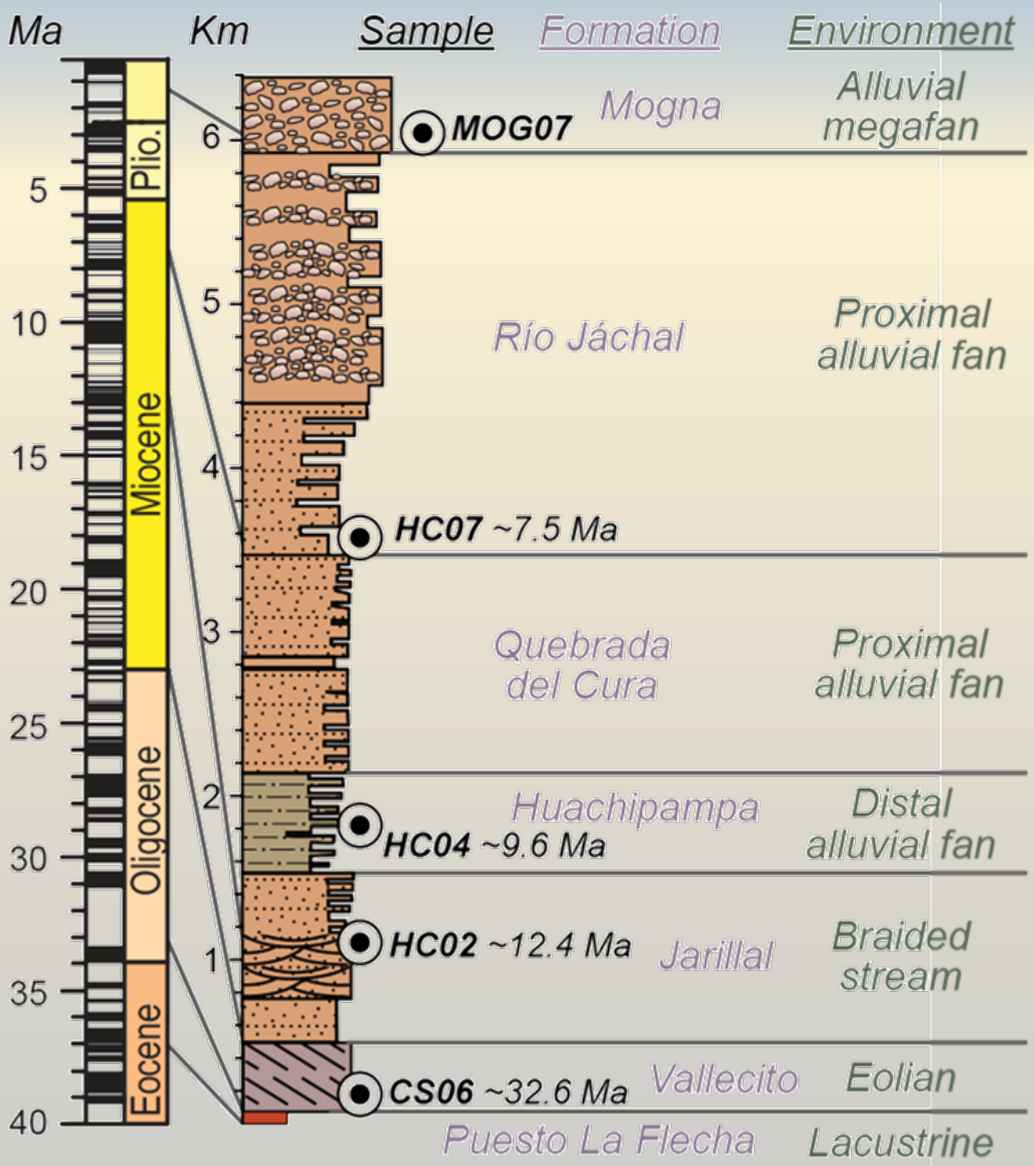




Dissolution and parent U-Th chemistry

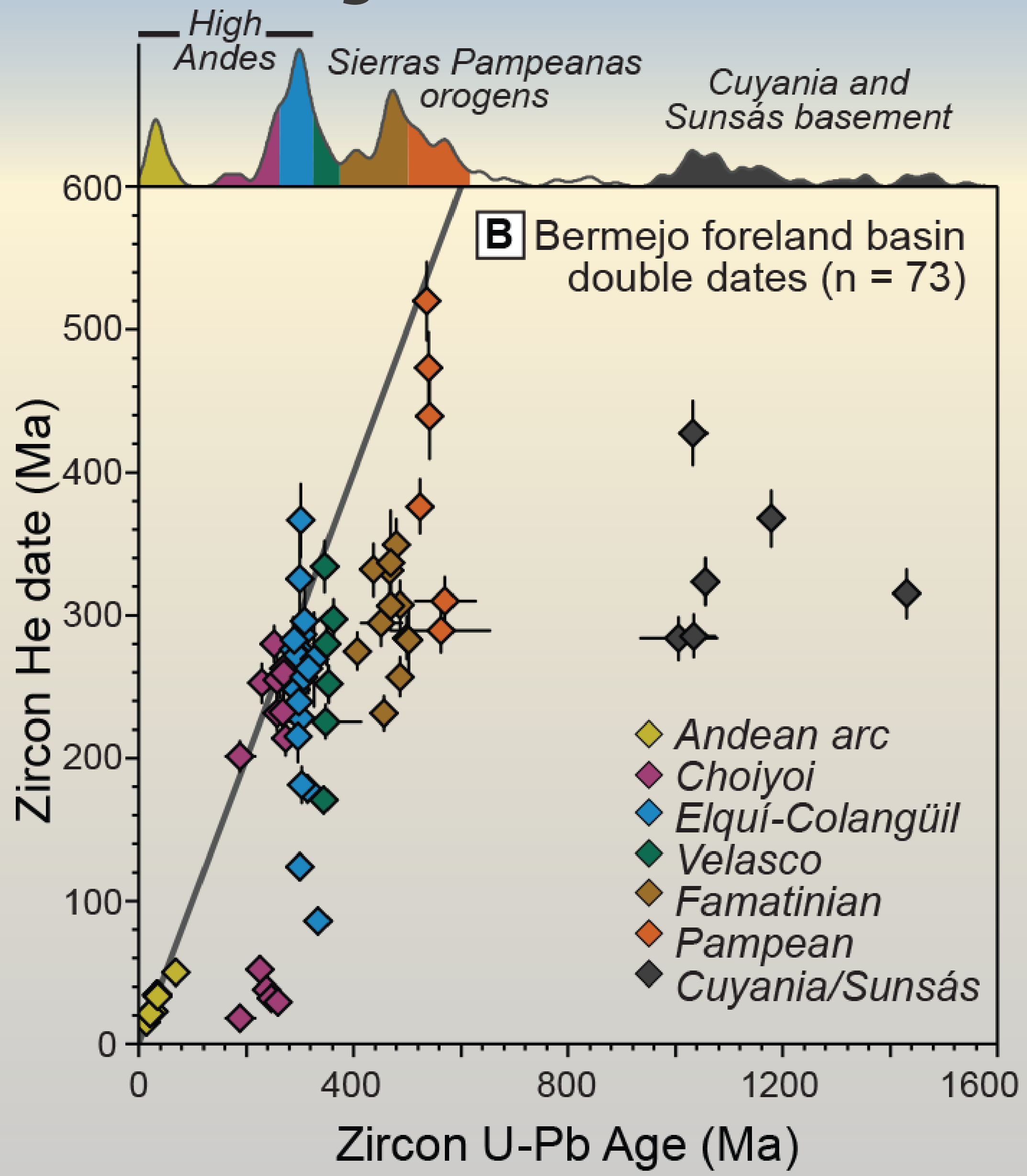
Bermejo Basin: detrital double-dating thermochronology





Fosdick et al. (2024)

Bermejo Basin: detrital double-dating thermochronology



Challenges with interpreting detrital thermochronology data

1) Missing geologic context available for in-situ samples (bedrock/outcrop/core)

2) Potential source areas have insufficient t-T history characterization
   → Precludes useful MDS or unmixing models

3) How to assess effects of post-depositional heating and diffusive He loss

Fosdick et al. (2024)

Thermal history modeling of detrital U-Pb-DZHe Data

HeFTy software (v 2.0 *Ketcham, 2024*)

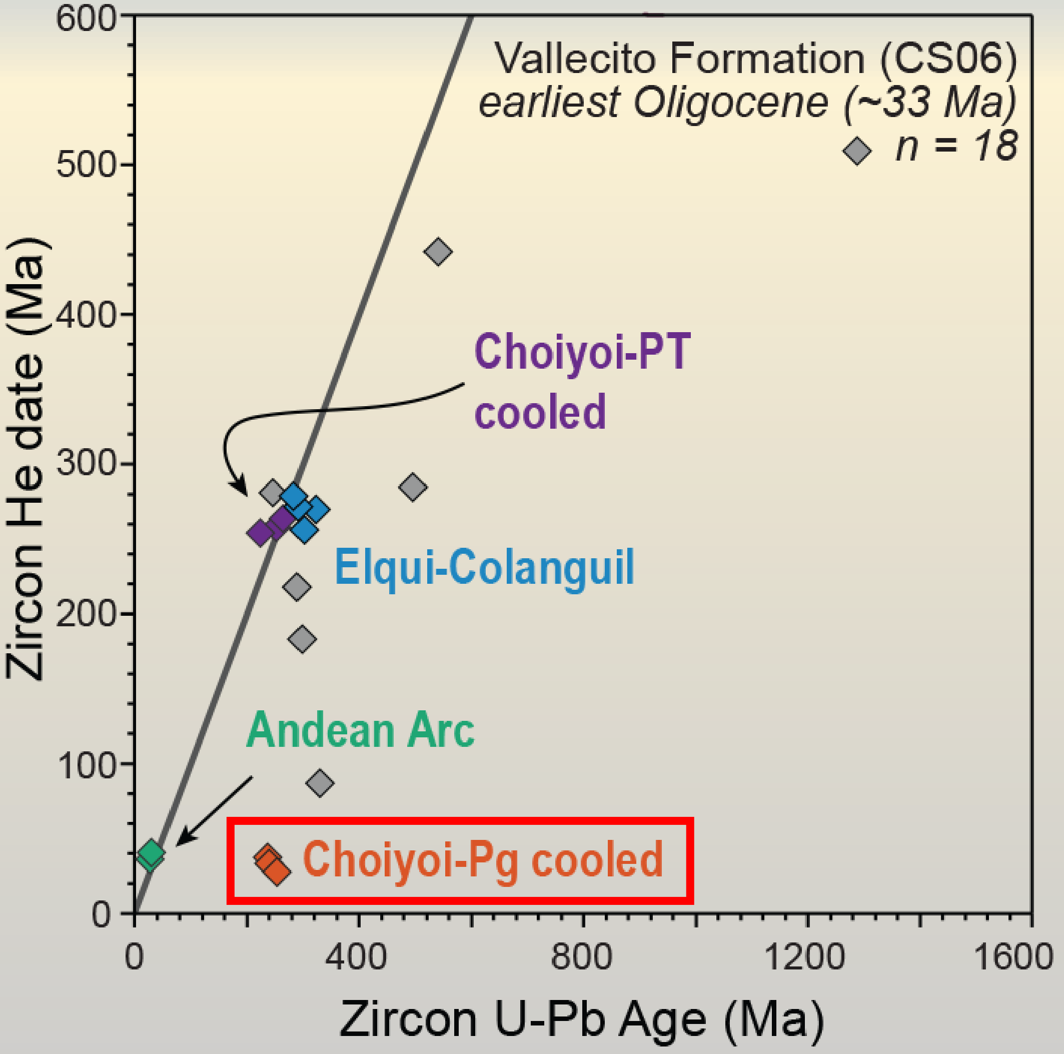
1. Identify define distinct **U-Pb-DZHe modes**

2. Construct inverse model to **test a specific hypothesis** or t-T scenario, constrained by other geologic information,
   e.g., U-Pb crystallization age, uniformities, burial histories

3. Invert (U-Th)/He data to resolve possible t-T histories permitted by data and diffusion kinetics

4. Leverage shared basin t-T history and other DZHe modes for whole sample to refine model and evaluate results

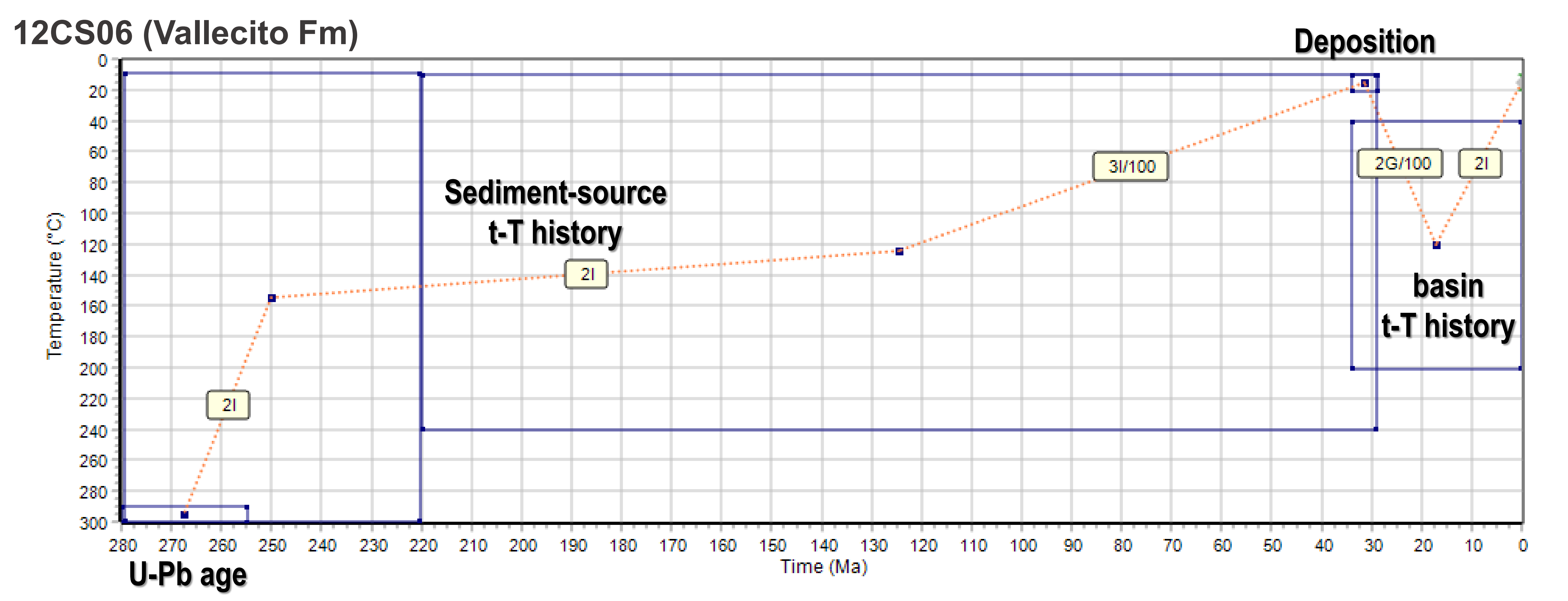
Detrital zircon U-Pb-ZHe modes



Fosdick et al. (2024)

Model 1: undefined burial t-T history

Choiyoi II



Data: Choiyoi II ZHe (n=4)
Sample AHe data (n=2)

Kinetics: RDAMM (Flowers et al., 2009)
ZDAMM (Guenthner et al., 2015)

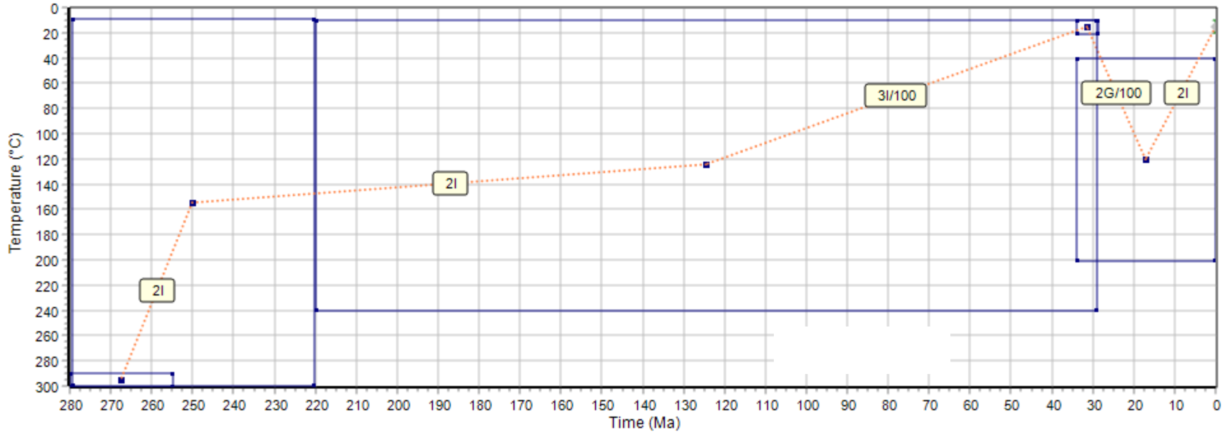
Constraints:
Box 1: DZ U-Pb age @ 300 °C
Box 2: Cooling
Box 3: Surface or reheating
Box 4: Sample deposition
Box 5: Burial reheating (80-200 °C, 34-0 Ma)
Surface conditions 15 ± 5 °C

HeFTy 2.0 (Ketcham 2024)

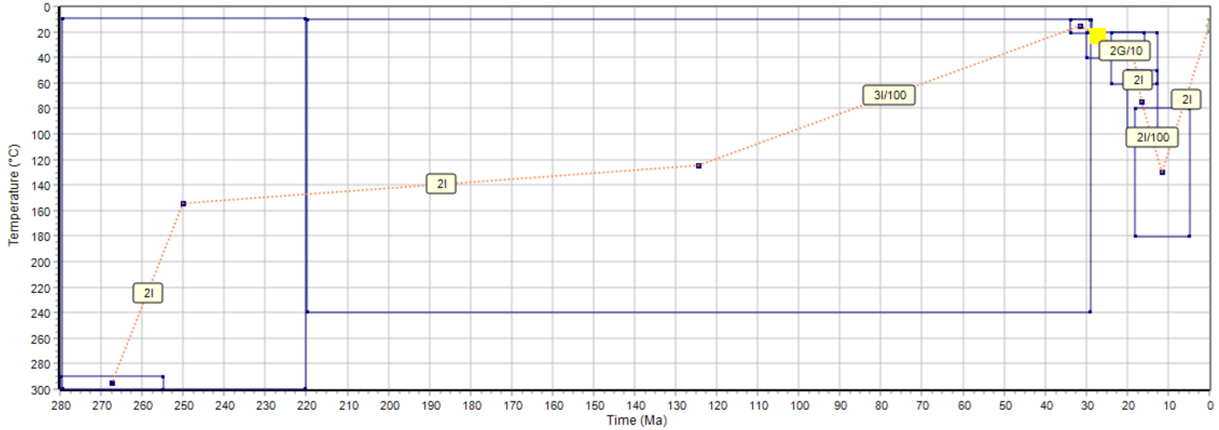
Model 2: constrained by basin subsidence record

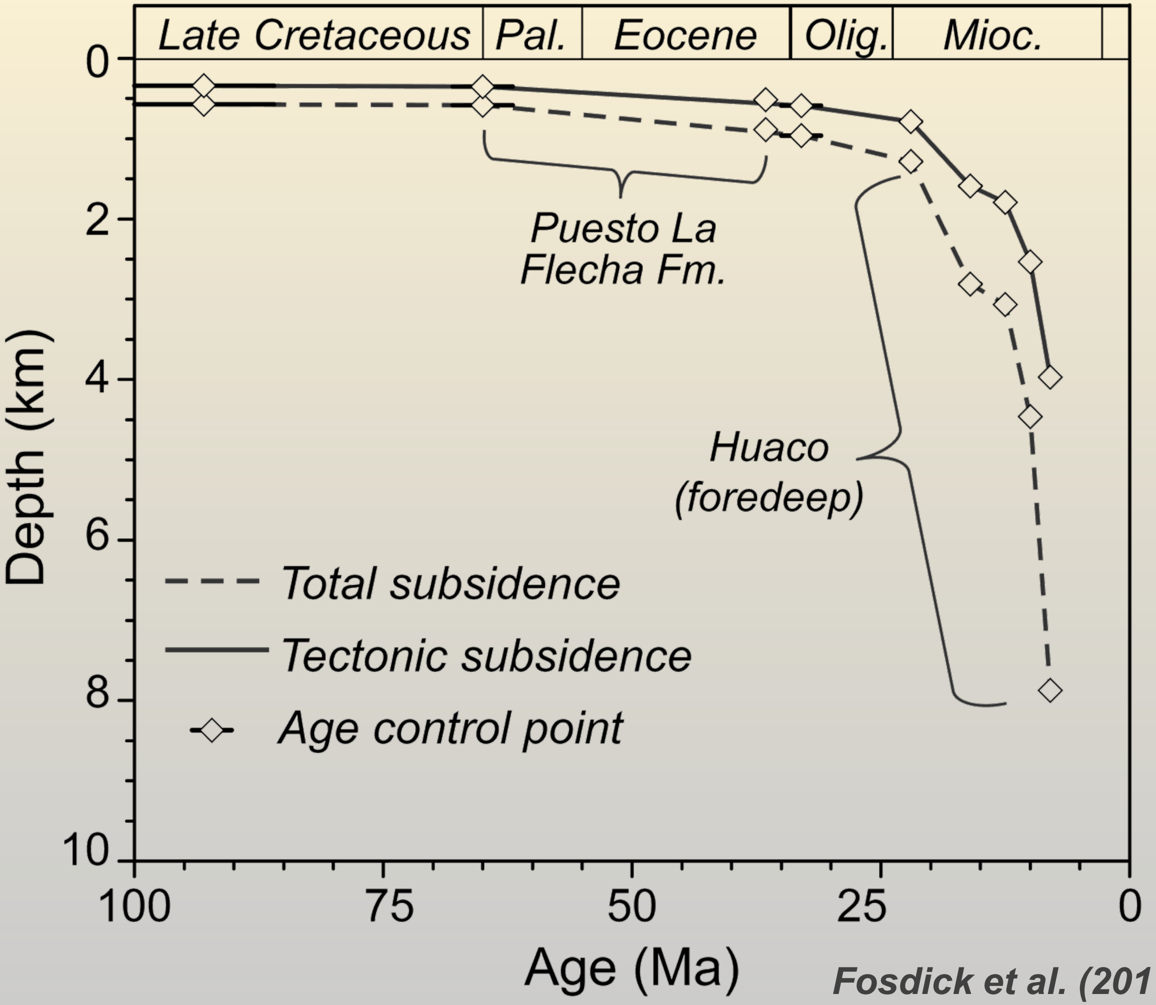
The most complete geologically constrained model

Model 1: undefined basin t-T history



Model 2: constrained by basin subsidence





Fosdick et al. (2017)

Model 2: constrained by basin subsidence record

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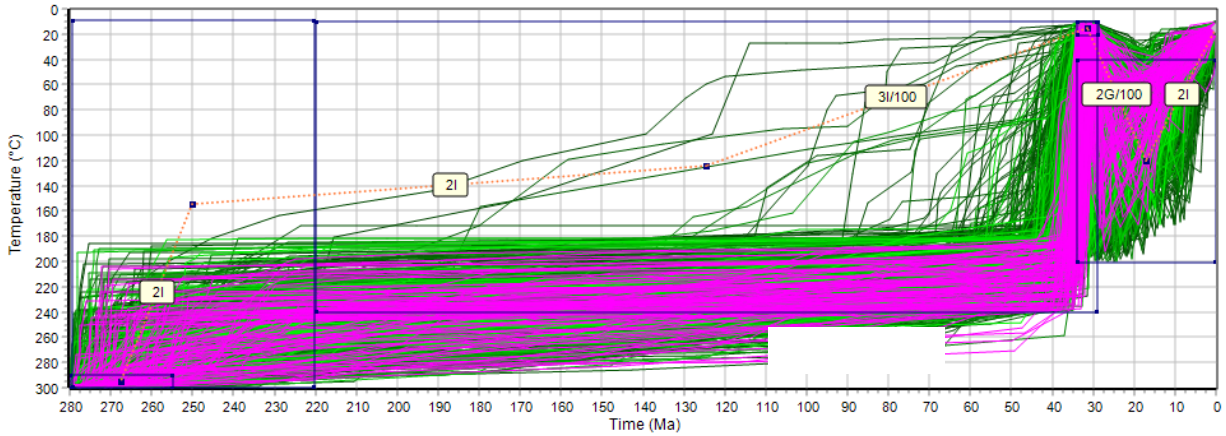
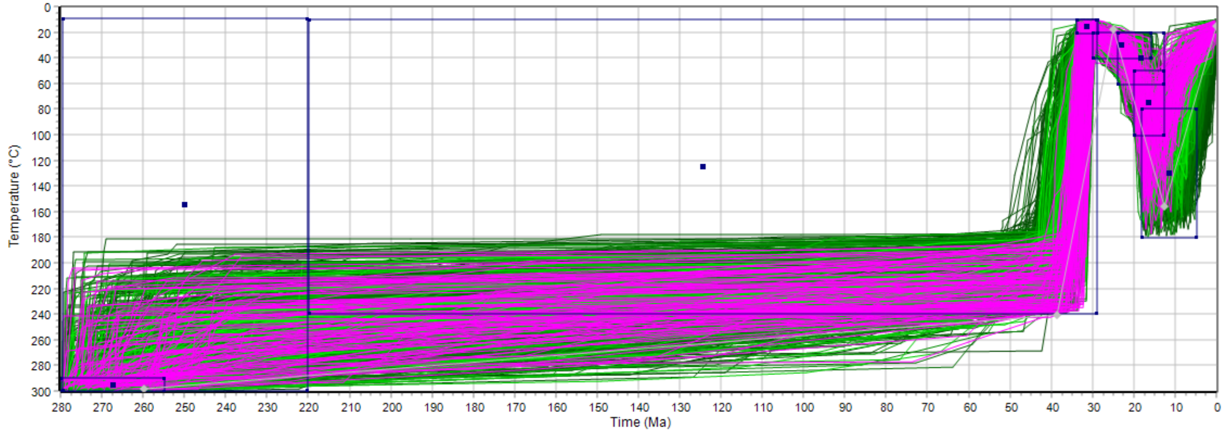
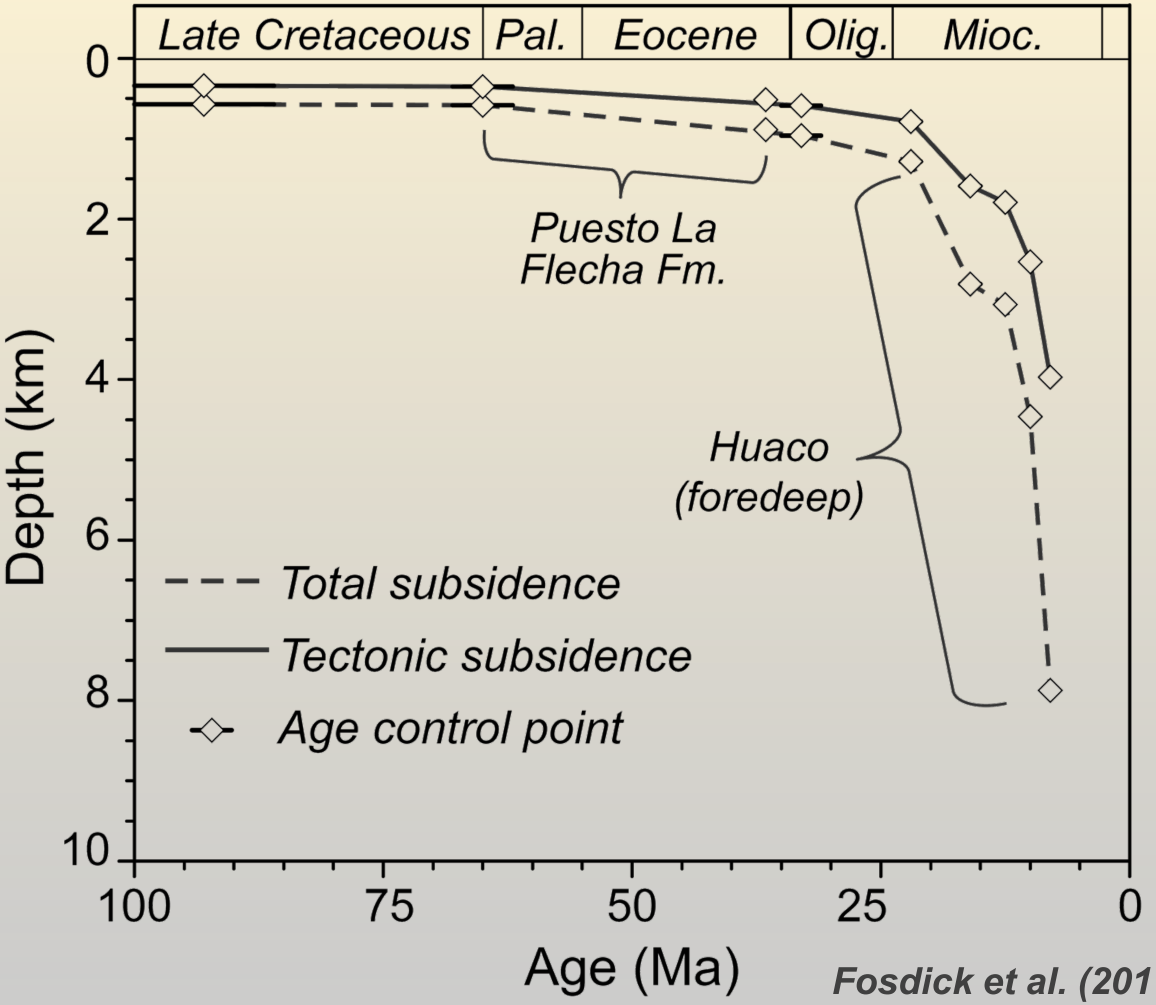
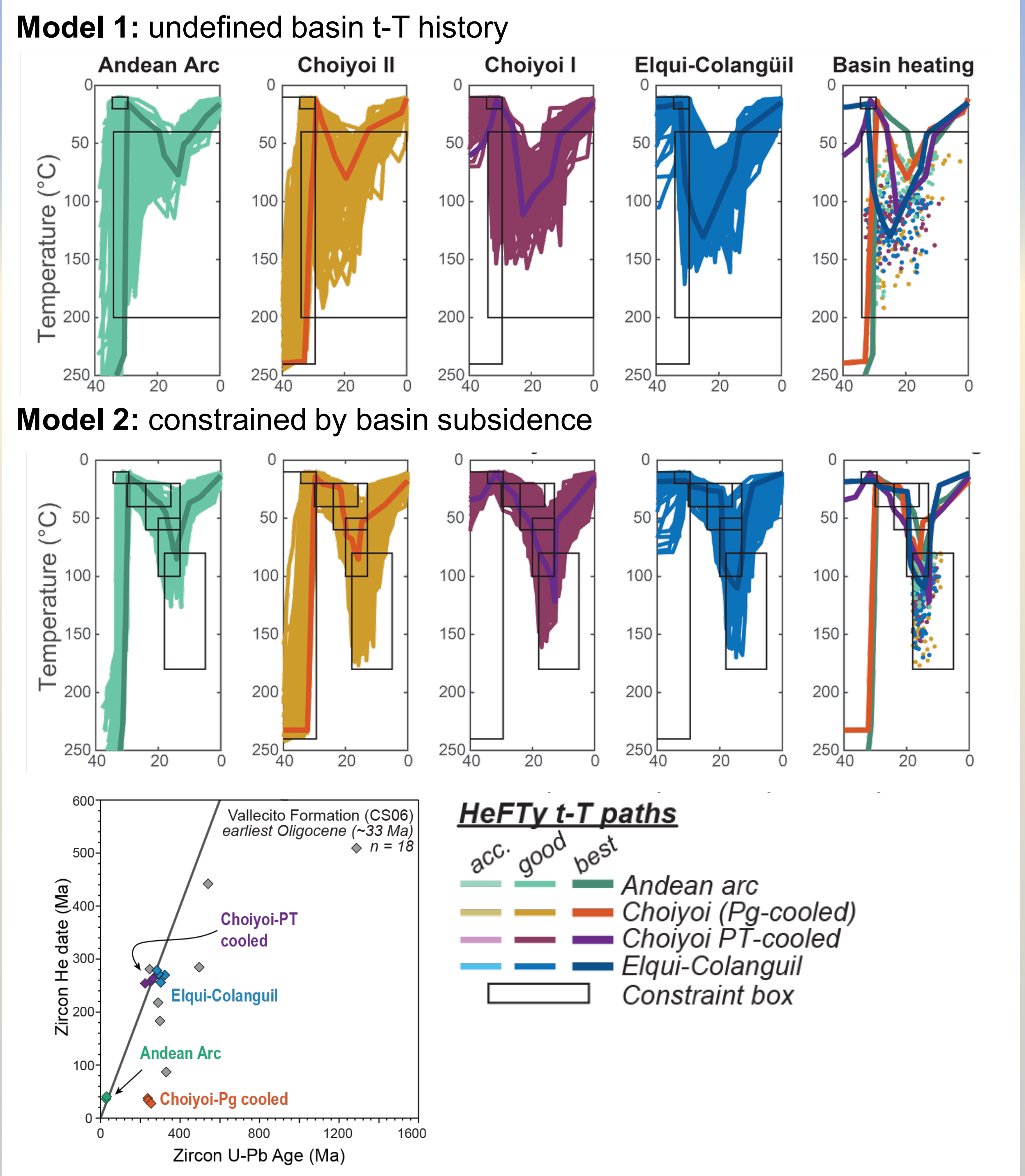


Model 2: constrained by basin subsidence



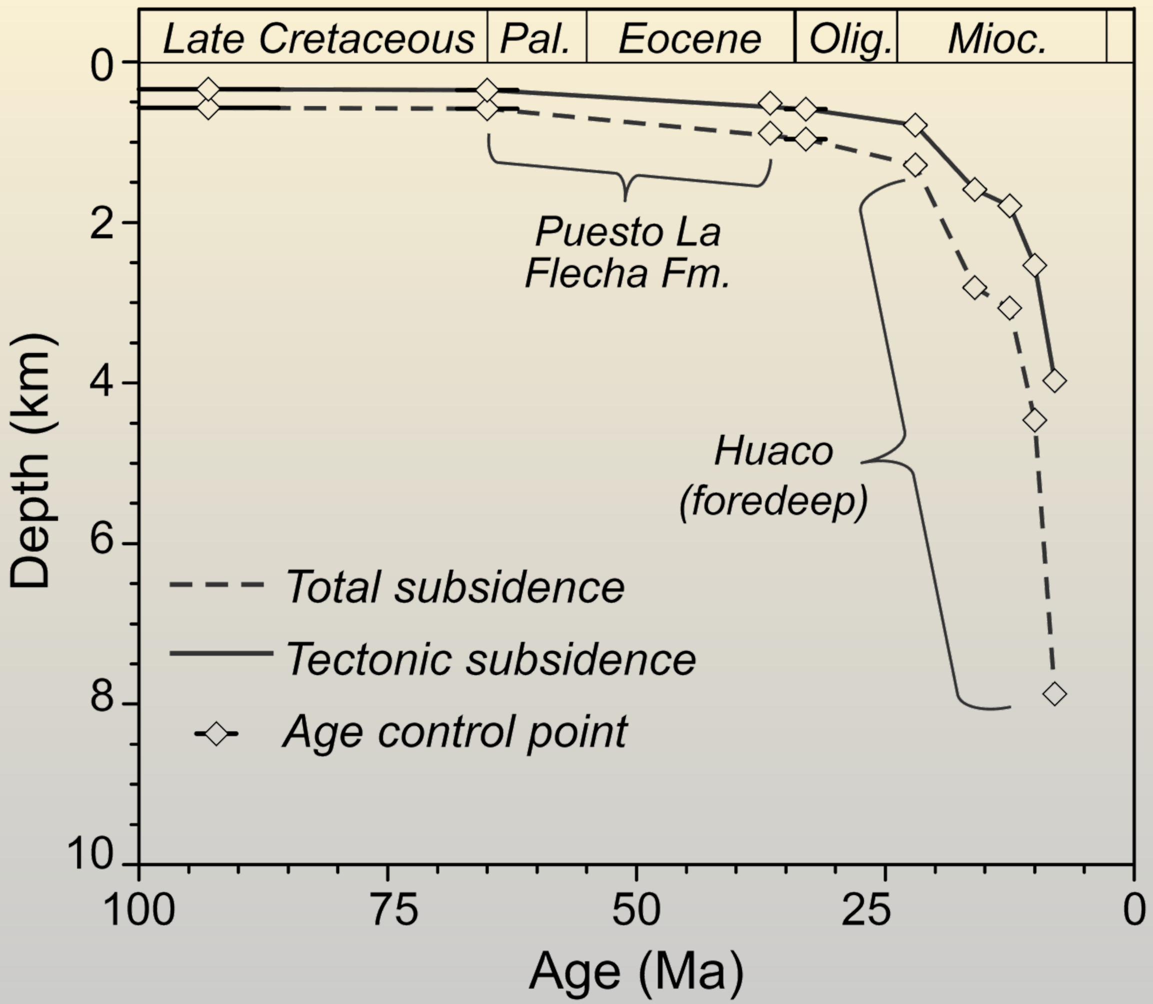


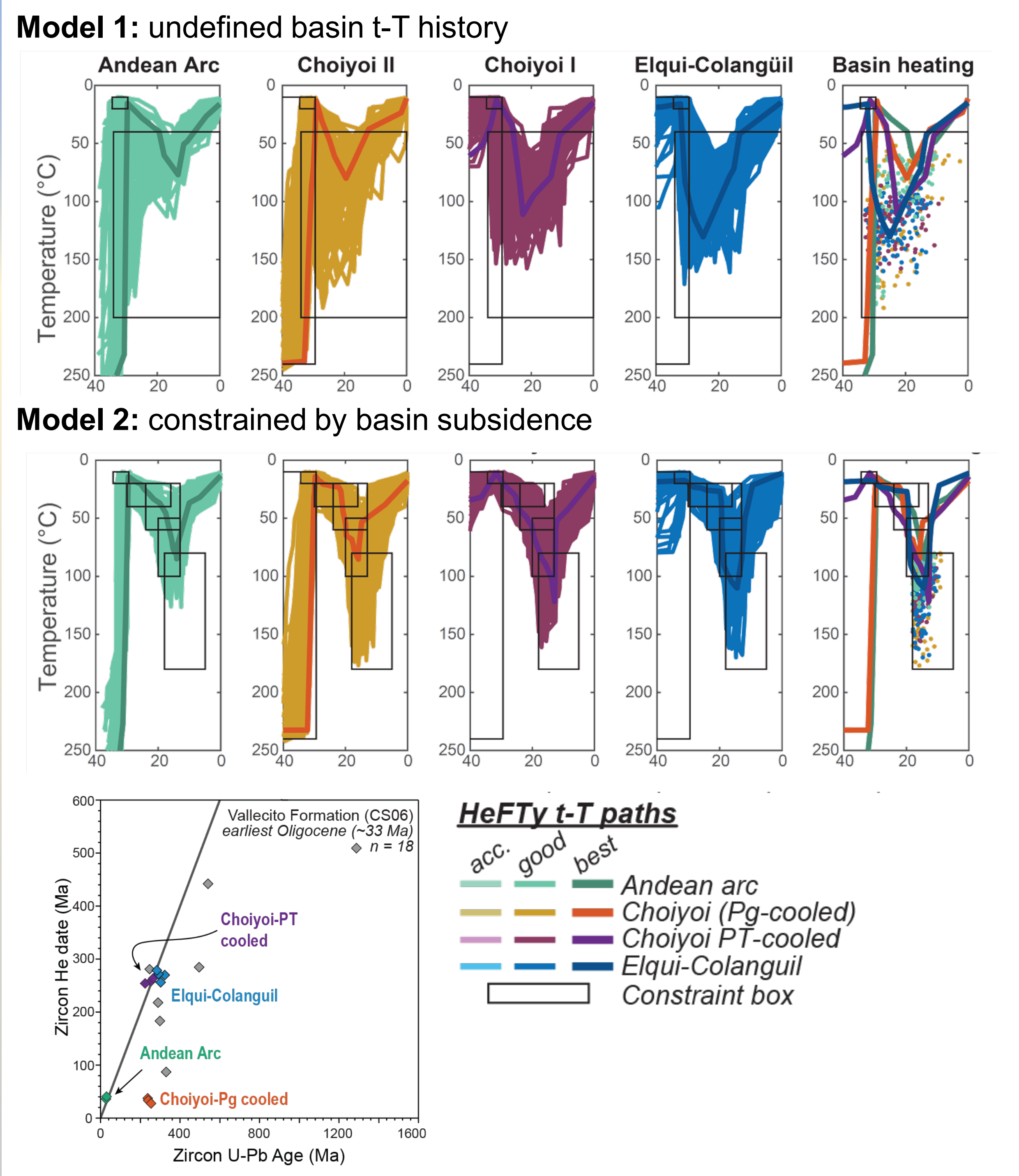
Fosdick et al. (2017)



Model 2: constrained by basin subsidence record

The most complete geologically constrained model



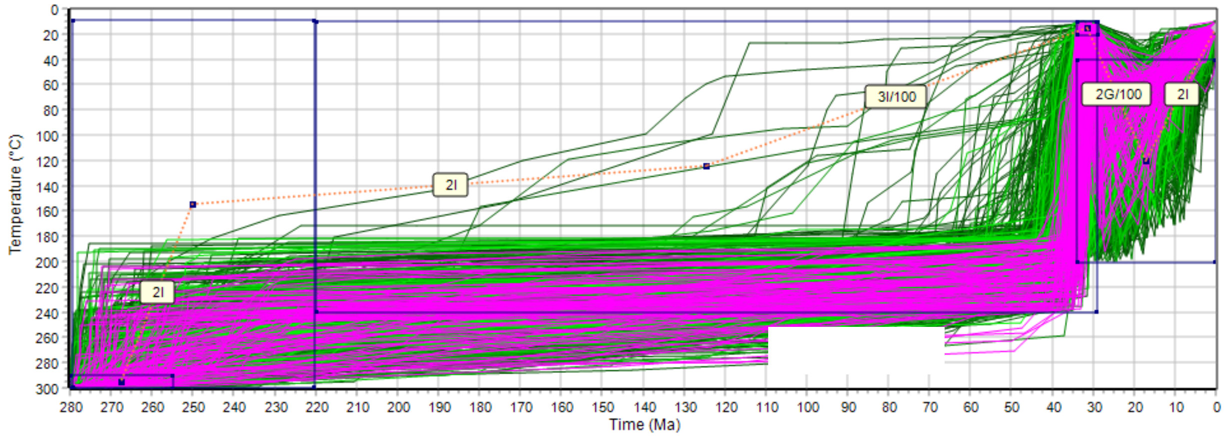


Model 3: constrained by basin subsidence record *and* requires compatible basin t-T history that satisfies all DZHe modes

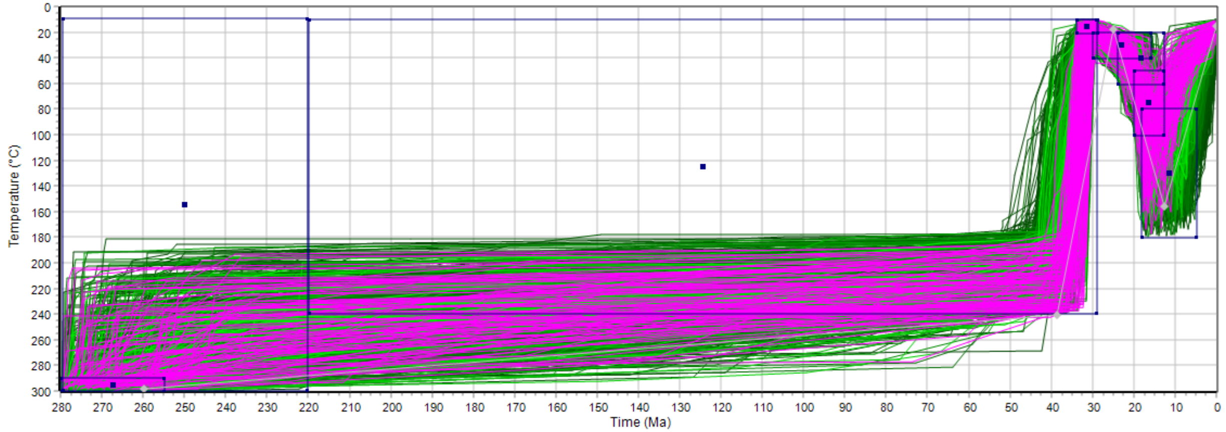
1. Evaluate overlapping basin t-T histories from Model 2

2. Refine basin t-T constraints to satisfy all modes
   → most retentive grains?
   → Younger DZHe mode(s)?
   → Depositional age important

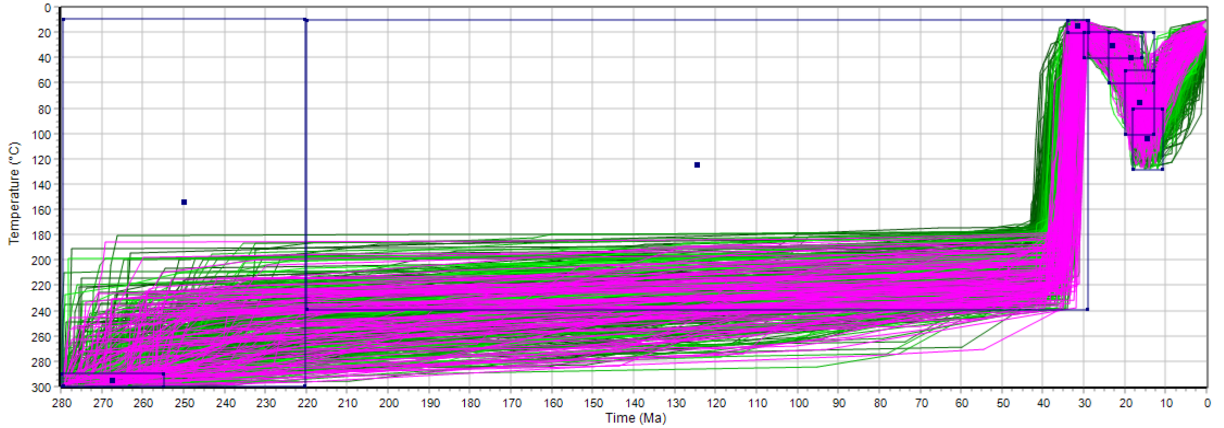
Model 1: undefined basin t-T history



Model 2: constrained by basin subsidence



Model 3: refined by overlapping DZHe modes



Model 3: constrained by basin subsidence record *and* requires compatible basin t-T history that satisfies all DZHe modes

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2. Refine basin t-T constraints to satisfy all modes
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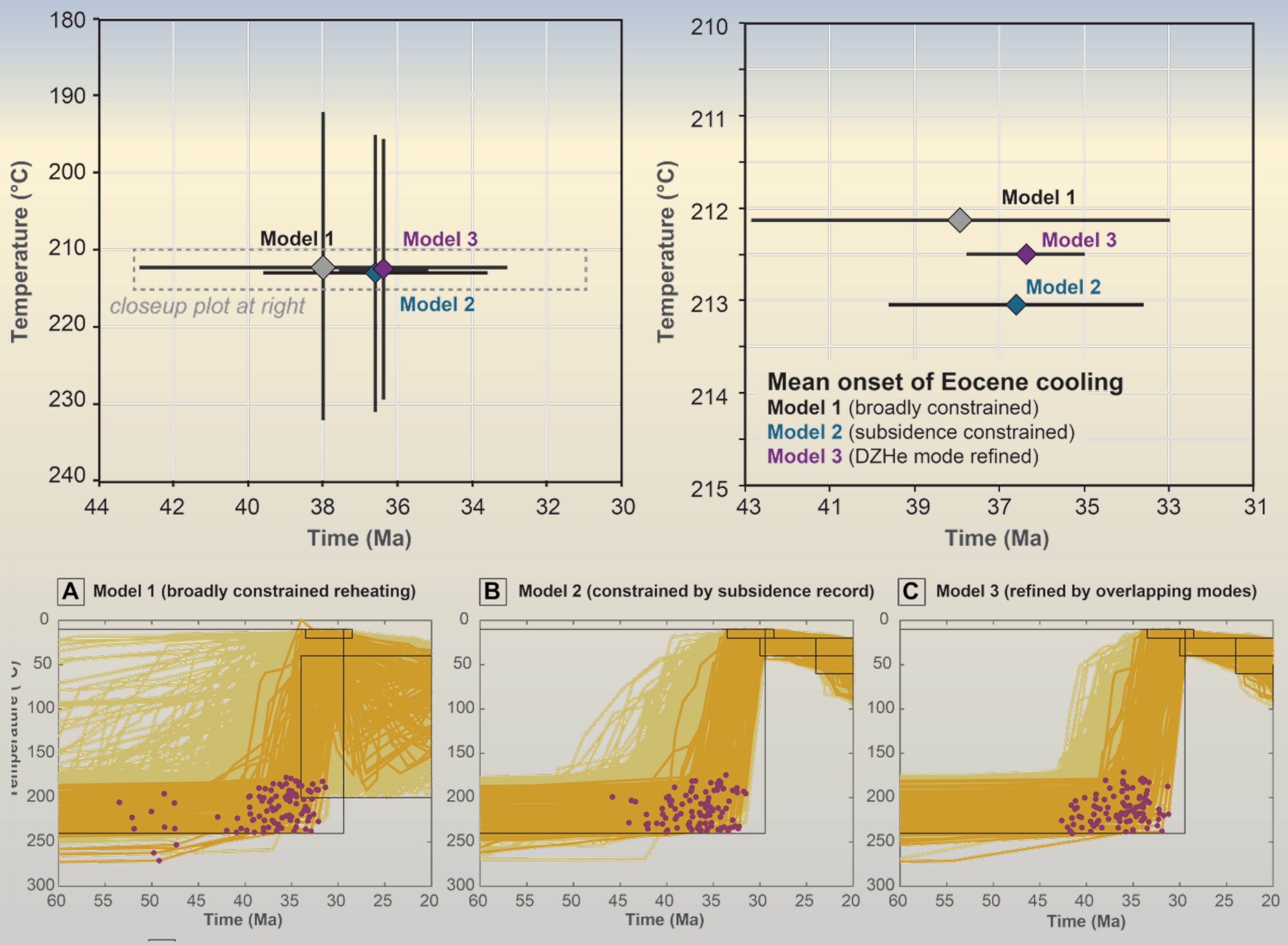
Model comparison and sensitivity evaluation

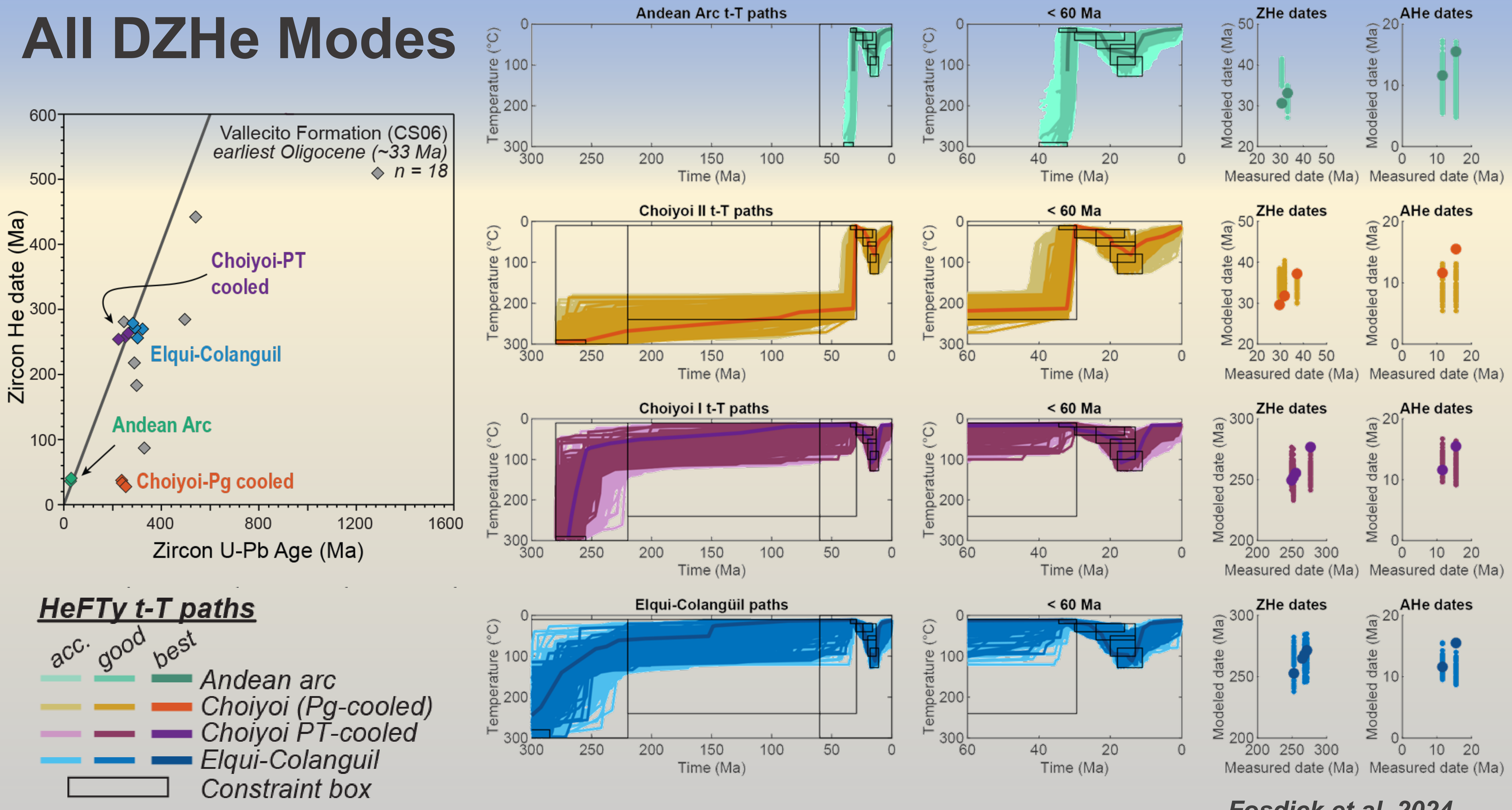


Models that leverage shared basin t-T history and satisfy all DZHe modes refine estimates in **onset of cooling** and maximum post-depositional **burial heating**

For Choiyoi II DZHe mode, lag time (tc – td) is refined from up to 10 Myr (Model 1) versus 2-5 My (Model 3)

Reheating 100-120°C at 23 Ma (Model 1) versus 90-110°C at 15 Ma (Model 3) prior to cooling and inferred basin inversion

All DZHe Modes



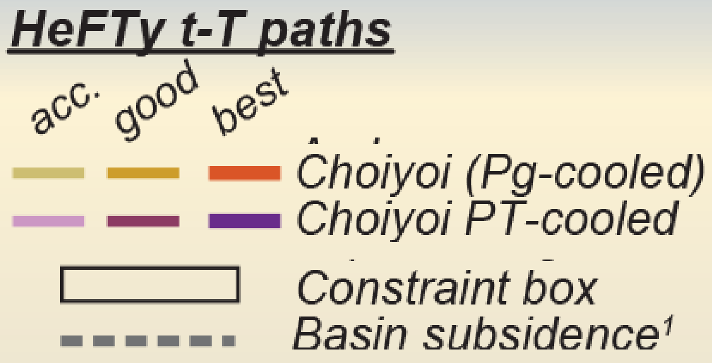
Fosdick et al. 2024

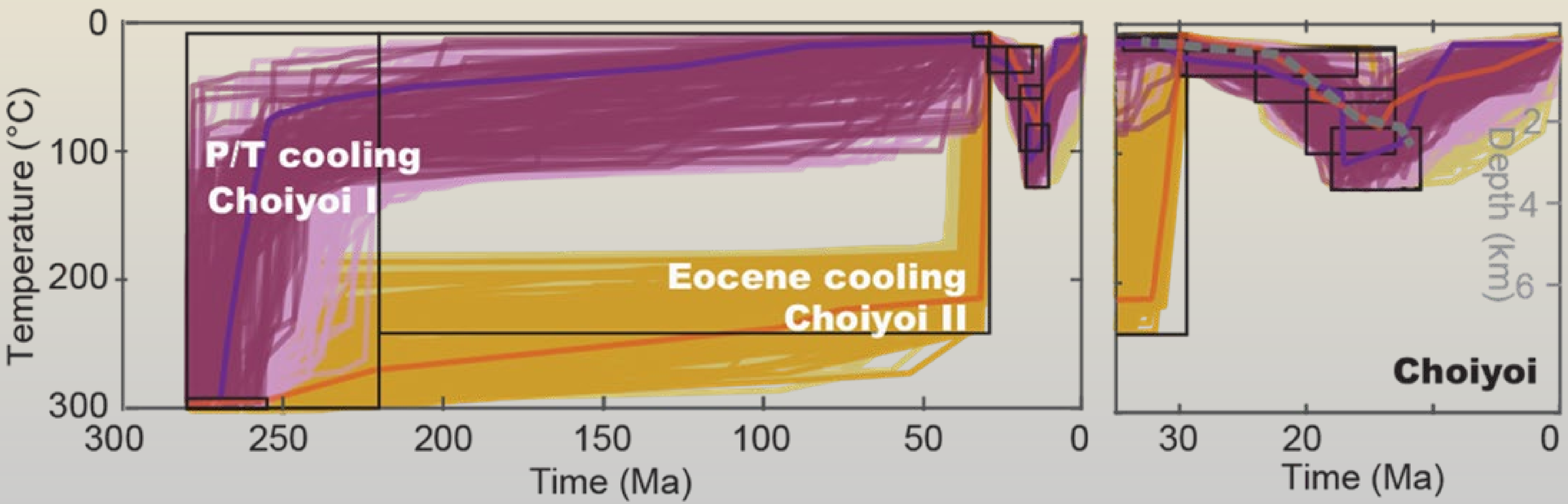
Implications for Eocene hinterland unroofing

Two distinct t-T histories of Choiyoi-derived detritus requires multiple sources:

- *pre-orogenic* signature (Choiyoi I)
- *synorogenic* unroofing signature (Choiyoi II)

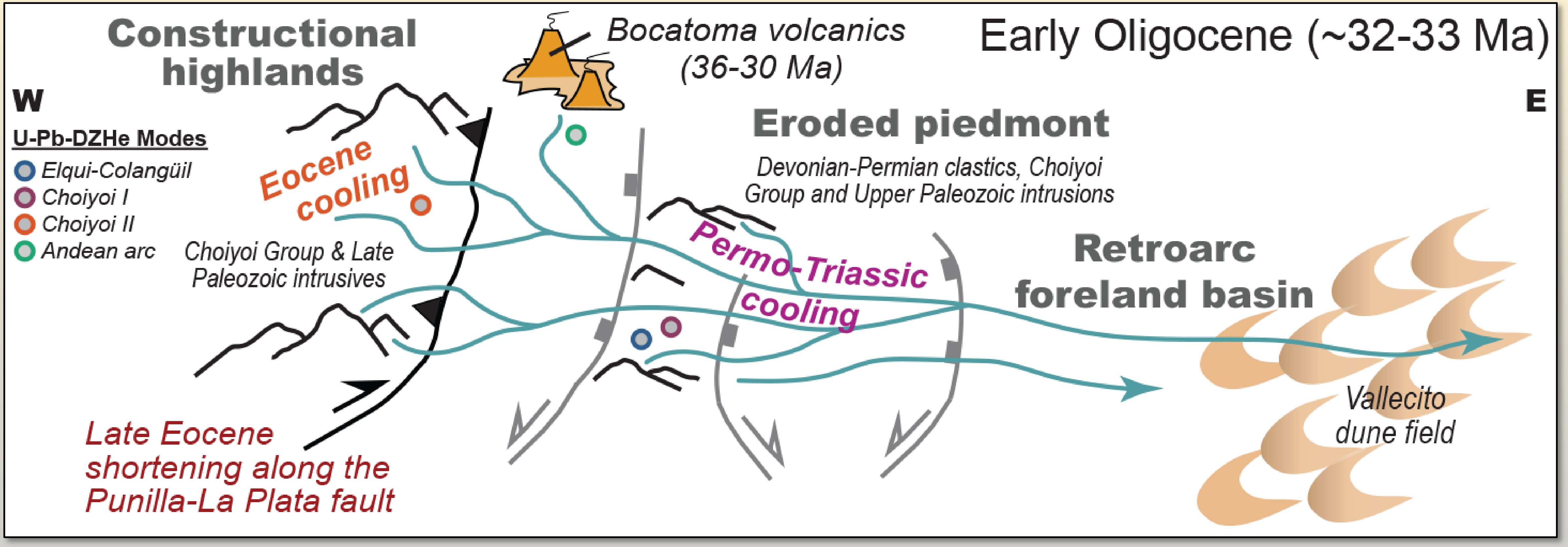
Onset of cooling ~38–35 Ma; 2-5 Myr lag time between cooling and deposition





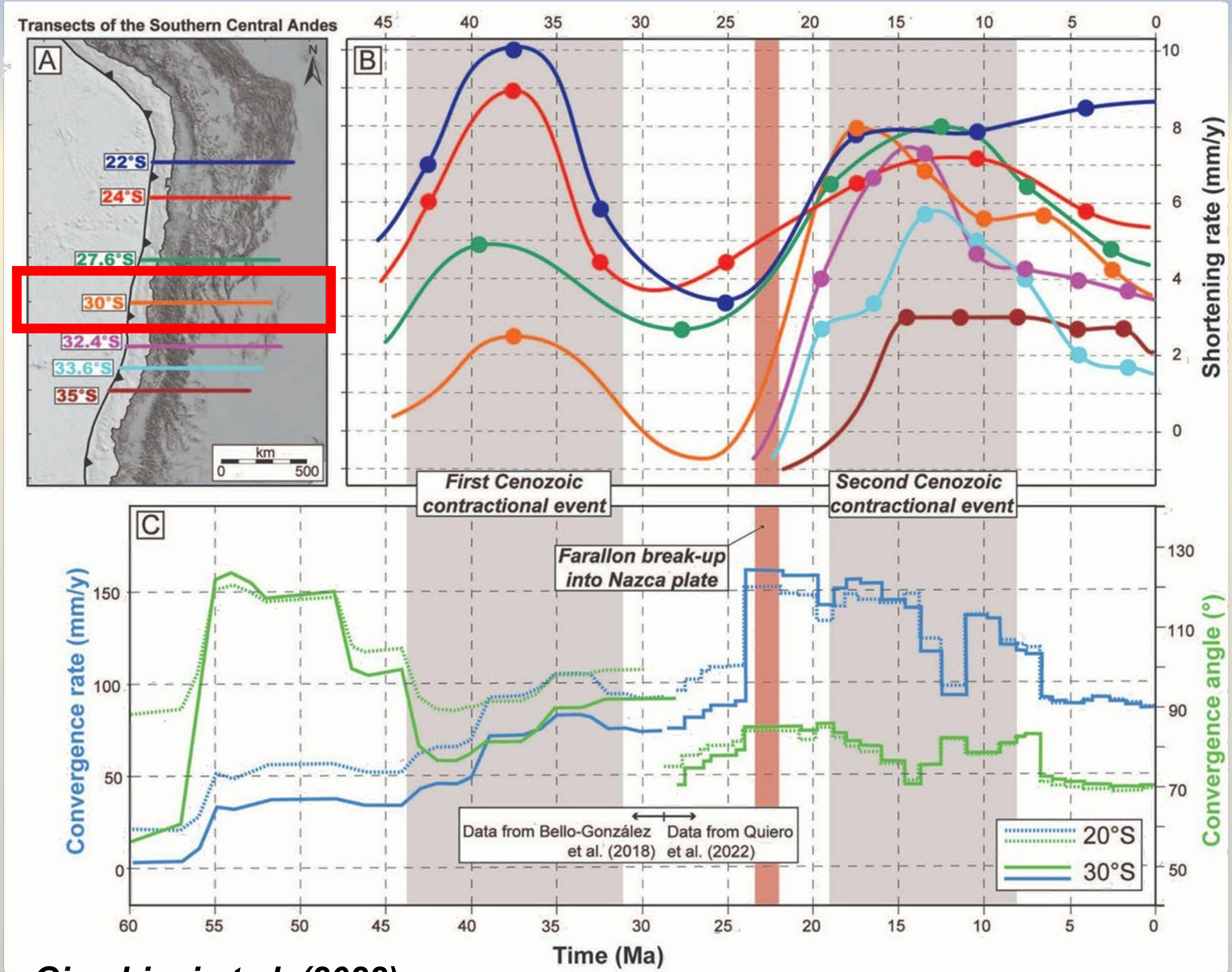
Implications for Eocene hinterland unroofing

Rejuvenated phase of **shortening**, **exhumation**, and **sediment routing** to the distal foreland at 30°S in late Eocene–early Oligocene time



Fosdick et al. 2024

Implications for Eocene hinterland unroofing



Giambiagi et al. (2022)

Along-strike development of Andean shortening

Two major phases of Cenozoic orogenesis across the Central Andes

Integrated foreland basin system across changes in tectonic subduction mode, basement structures, and climate gradients

Southward decrease in Eocene shortening rate → define the southernmost extent of this contractional phase?

Concluding points and take-aways

- Detrital U-Pb-ZHe thermochronology **differentiates ambiguous** hinterland sediment sources with unique t-T histories

- **Modeling approach for discrete detrital U-Pb-ZHe modes** can be powerful tool to resolve source-to-basin t-T histories

  → opportunities for interpreting detrital datasets as double-dating thermochronology capabilities expand (e.g., LADD)
  → test specific hypotheses for a given sediment source
  → refine lag time and peak reheating estimates

- In the southern Central Andes ~30°S, **rapid latest Eocene hinterland cooling** and inferred exhumation

  → Difficult to reconcile with neutral-state stress model for the Paleogene Andes → **rejuvenated phase** of shortening, exhumation, and sediment routing to distal foreland

Thank you!!