# Decoupled cooling and exhumation signals in subduction orogens: An example from the Argentinean Pampean Ranges

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November 26, 2022



## Abstract

Reconstructing thermal histories in thrust belts using thermochronometry is a widely used method to infer the age and rates of thrusting, a precondition to understanding the driving mechanisms of orogenesis. Along a thrust sheet, the time and temperature conditions at the switch between heating and cooling retrieved from thermal modeling are commonly interpreted as the onset of thrust-induced exhumation associated with thrustbelt development. In subduction orogens such as the Andes, this interpretation can be challenged by the intrinsic changes in basal heat flow imposed by changes in subduction regimes. We document a case in the northwestern Sierras Pampeanas in the Argentinean Central Andes in which independent constraints on the onset late Cenozoic thrusting derived from structural cross-cutting relationships allow us to explore alternative causes for Cenozoic cooling signals. Located at ~31°S Lat, the Villa Unión-Ischigualasto basin hosts a composite stratigraphic record associated with Triassic rifting developed onto the Paleozoic substratum of western Gondwana and the overlying Meso-Cenozoic foreland basin record. A multi-method approach including apatite fission-track, apatite and zircon (U-Th)/He analyses, vitrinite reflectance and clay mineralogy carried out along three stratigraphic profiles, and inverse thermal modeling reveals the thermal history patterns and allows inferring its triggering mechanisms. Despite an up to 5 km-thick Cenozoic overburden and unlike previously thought, the thermal peak in the basin is not due to Cenozoic burial but occurred in the Triassic, associated with an abnormally high heat flow of up to 90 mWm-2 and less than 2 km of burial, which heated the base of the Triassic strata to ~160°C. Following exhumation, attested by the development of an unconformity between the Triassic and Late-Cretaceous-Cenozoic sequences, Cenozoic re-burial increased the temperature to ~110°C at the base of the Triassic section and only ~50°C 4 km upsection, suggesting a dramatic decrease in the thermal gradient. The onset of Cenozoic cooling from those conditions occurred between ~10 and 8 Ma, approximately 5 My before the onset of thrusting that has been independently documented by exceptionally well preserved stratigraphic-cross-cutting relationships. We argue that the onset of cooling is associated with lithospheric refrigeration following a decrease in the angle of subduction of the Nazca slab, leading to the eastward displacement of the asthenospheric wedge beneath the South American plate. Our study places time and temperature constraints on an idea that has been previously discussed in the region and calls for a careful interpretation of exhumation signals in thrustbelts inferred from thermochronology only.

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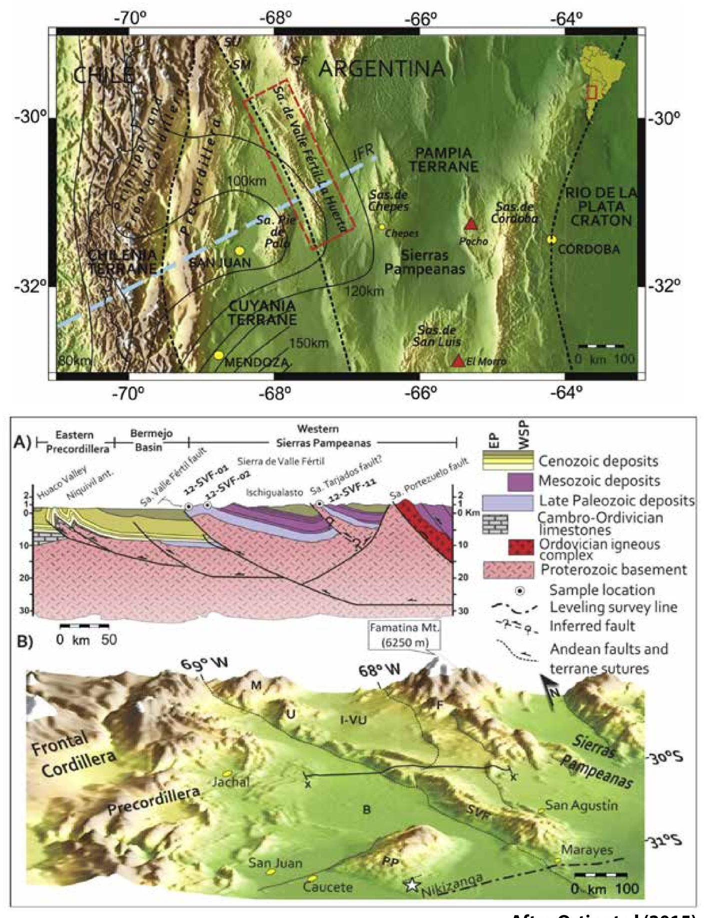
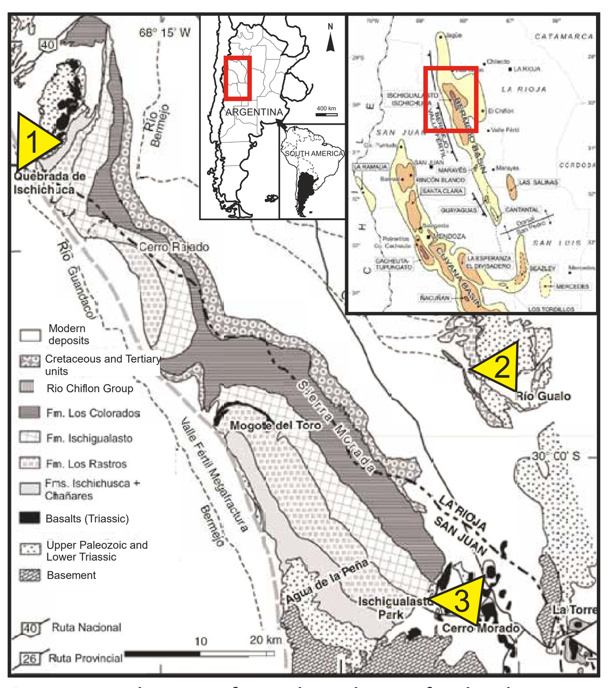
Thermo2020 Santa Fe, NM

## INTRODUCTION



After Ortiz et al (2015)

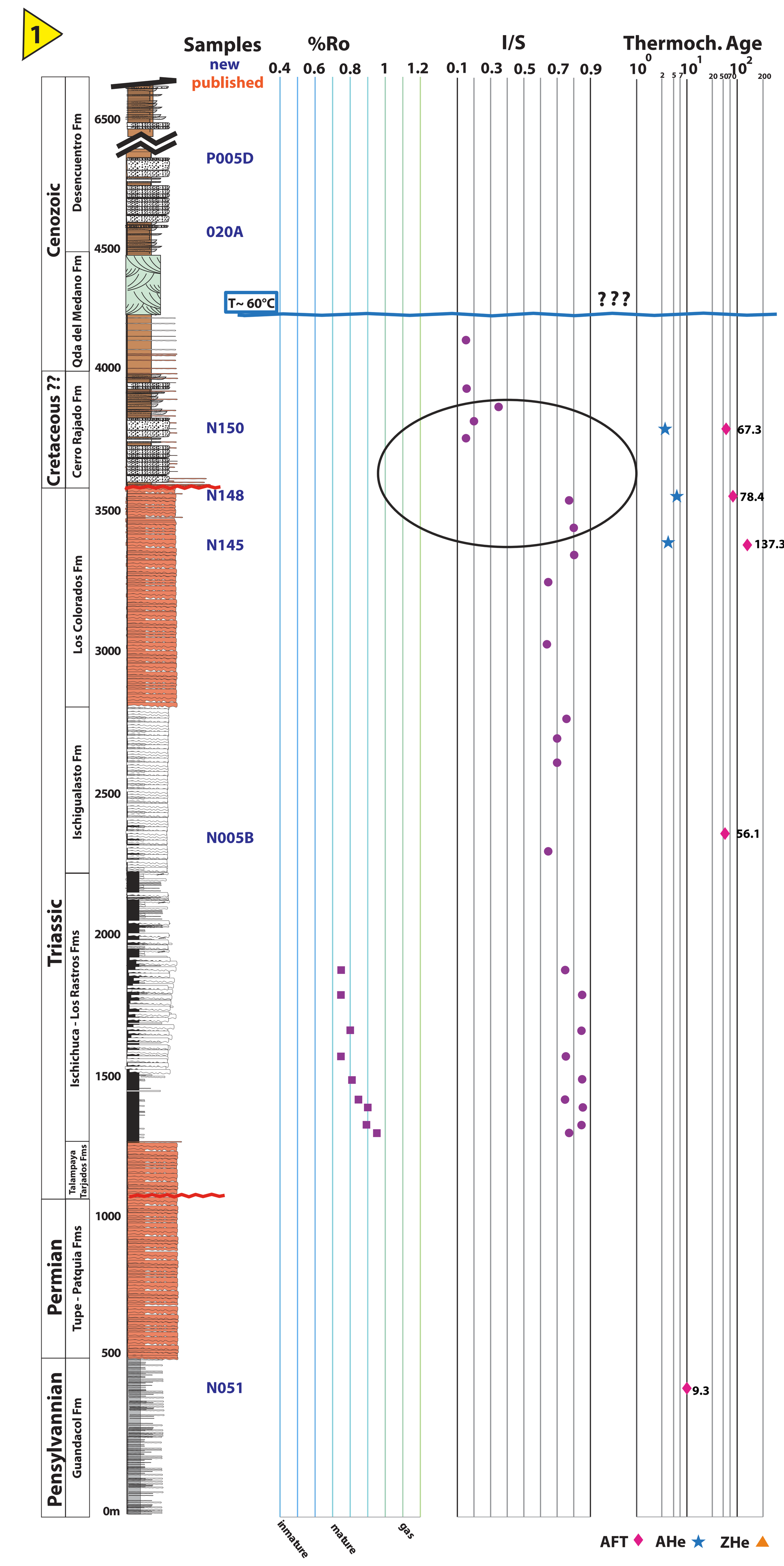


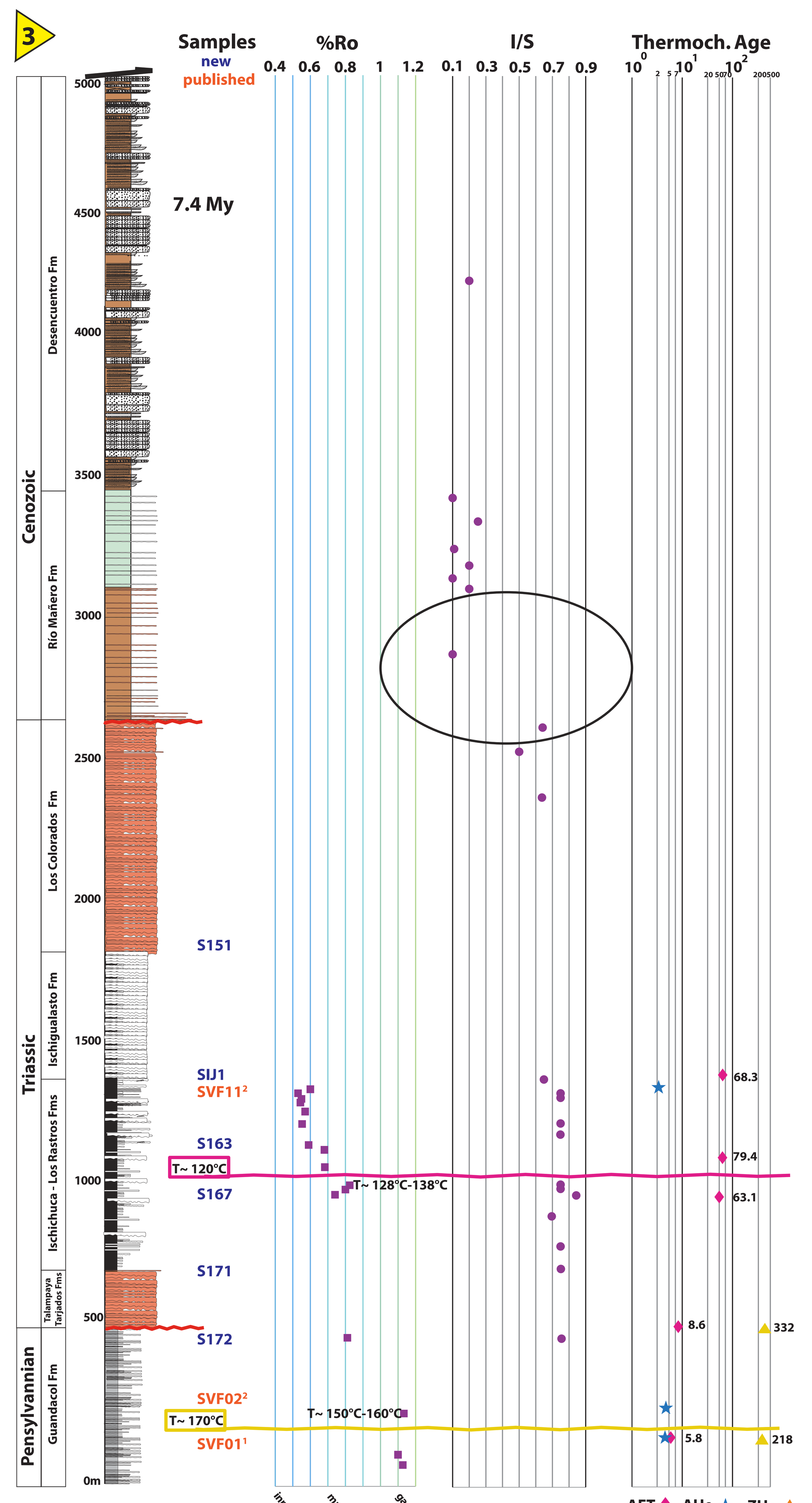
Driving mechanisms for rock cooling in foreland regions of subdction orogens:

- **Erosional exhumation induced by thrusting?**
- **Temporal variations in heat flow?**

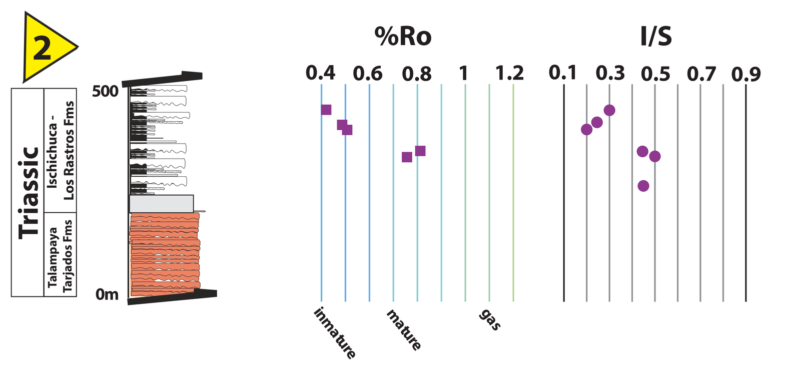
The Ischigualasto-Villa Unión Basin in the Pampean flat-slab region of the Central Andes in Argentina is a natural laboratory.

## 1. STRATIGRAPHY AND MULTI-METHOD PALEOTHERMOMETRY



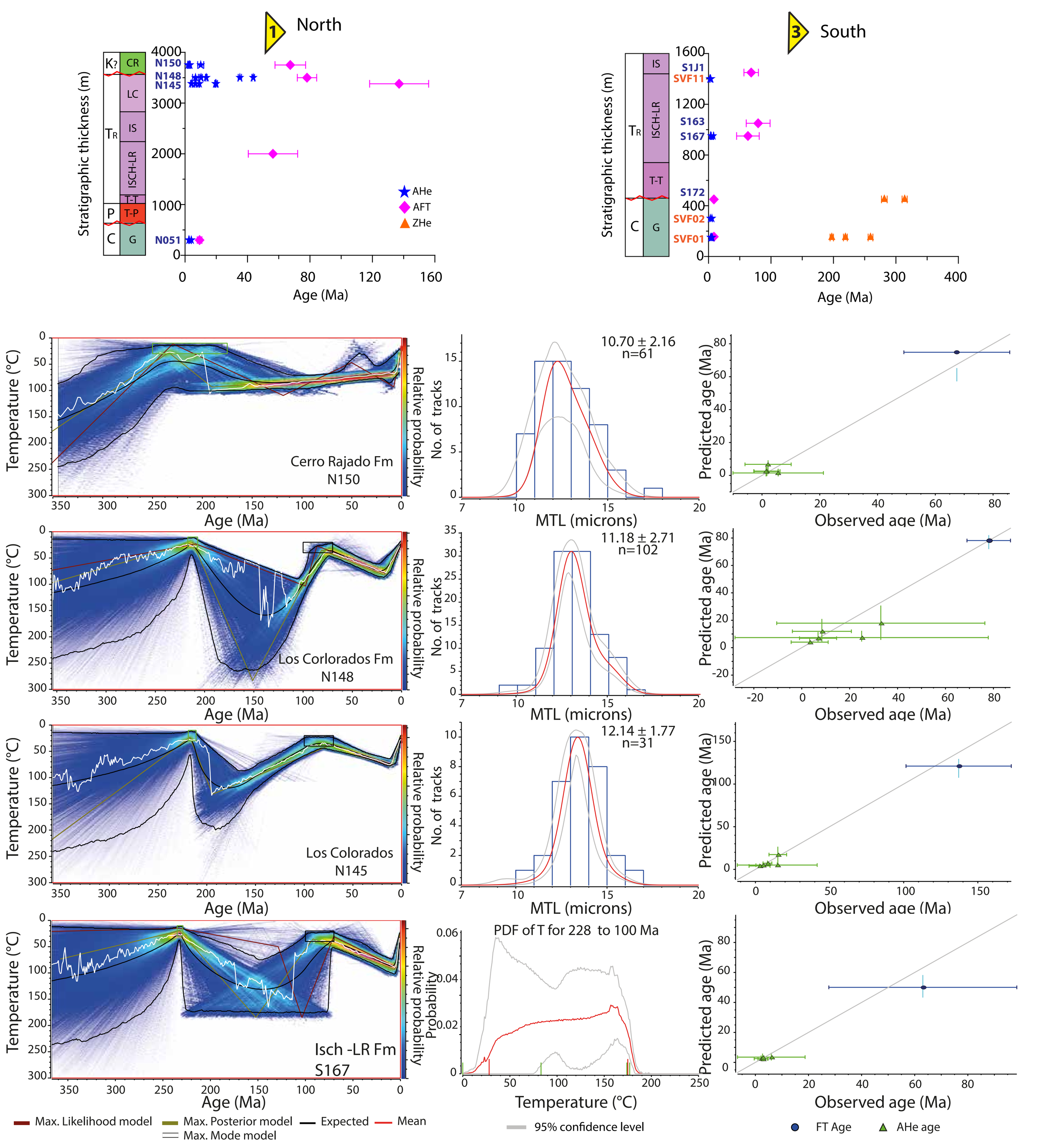


[1] Fosdick et al (2015)
[2] Ortiz et al (2015)



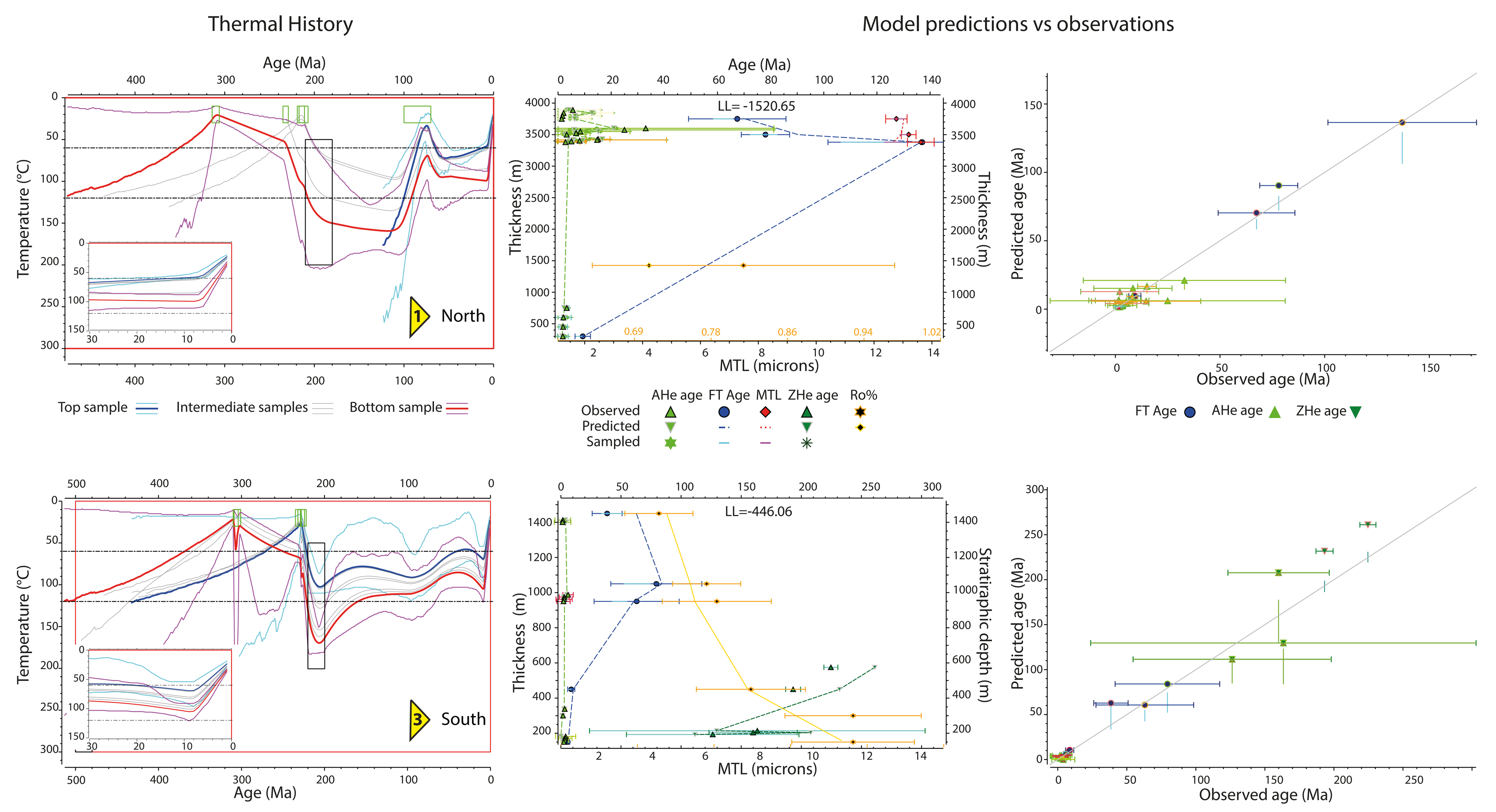
- Three stratigraphic sections covering up to 6.5 km of Carboniferous to Miocene strata.
- New vitrinite reflectance and clay crystallinity analyses, new and published AFT, AHe, and ZHe data
- Marked increase in maximum paleotemperatures across sub-Cretaceous unconformity (black circles)
- Cooling ages (see Section 2) allow defining limits of exhumed PRZs

## 2. THERMOCHRON AGES AND THERMAL MODELS



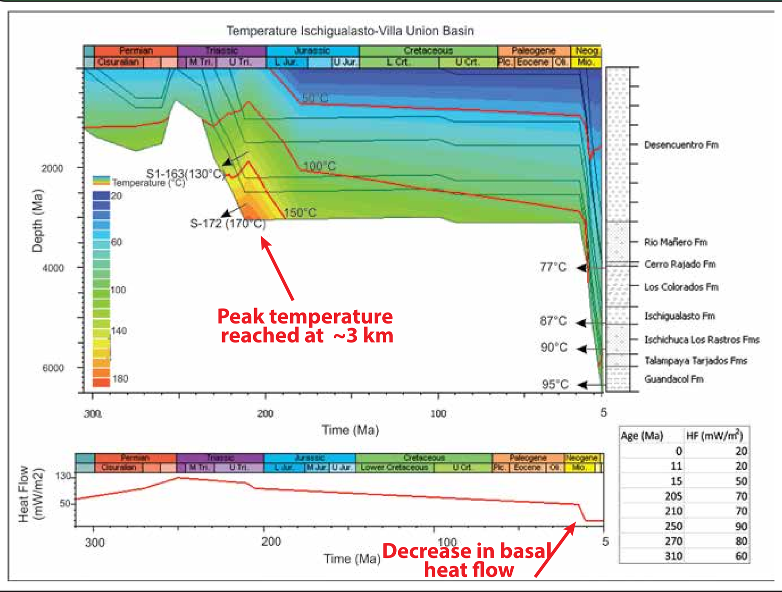
Peak temperatures reached in Mesozoic times, before Cenozoic peak burial

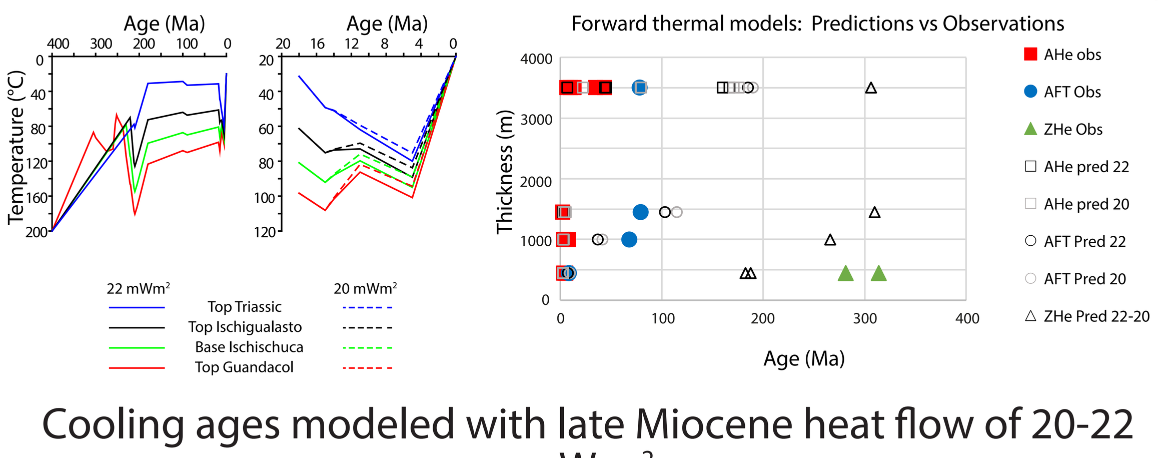
## 3. MULTI-SAMPLE THERMAL MODELING



- Triassic-Cretaceous unconformity provides important geological constraint to thermal modeling.
- Maximum temperatures reached during Triassic rifting (geological evidence)
- Limited Cenozoic reheating despite peak burial conditions

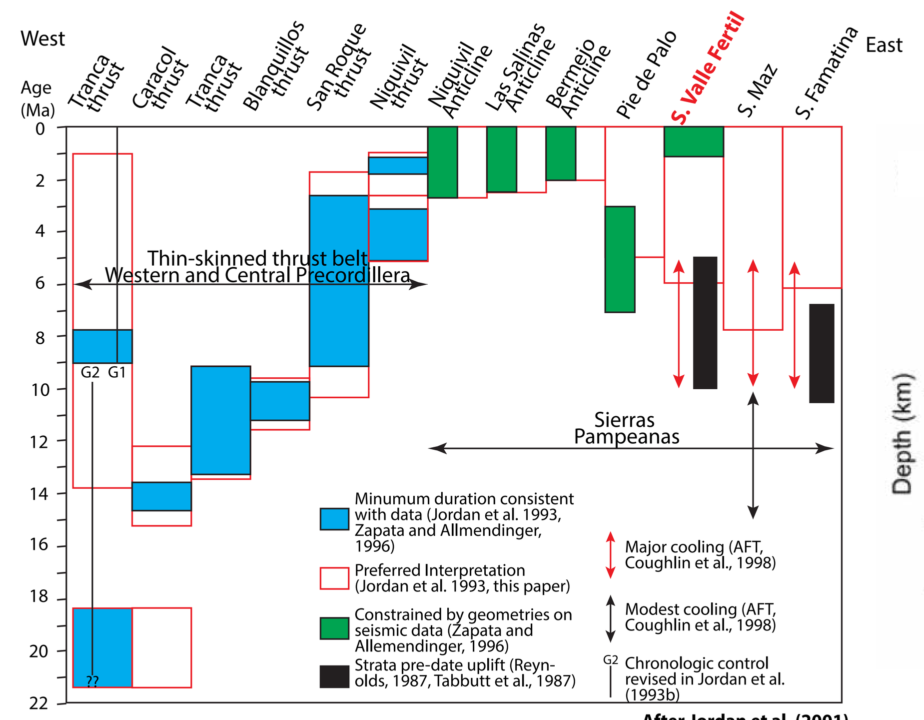
## 4. FORWARD THERMAL MODELING



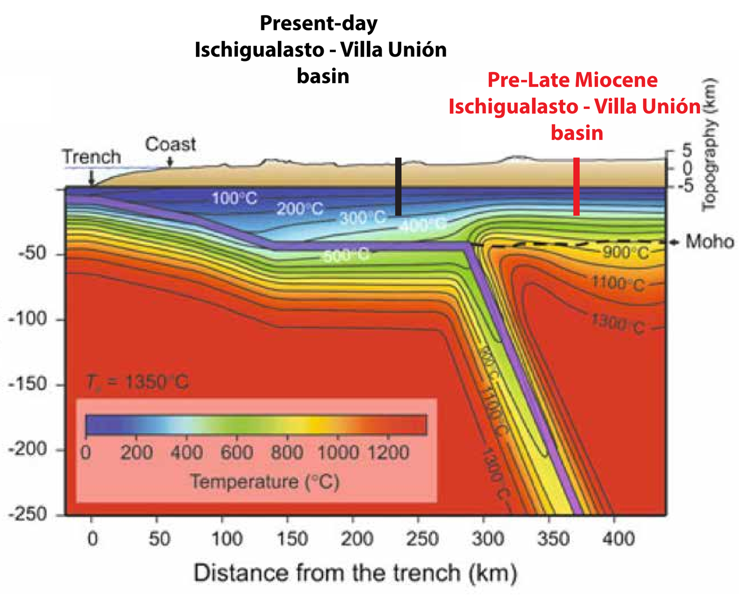


Cooling ages modeled with late Miocene heat flow of 20-22 mWm$^{-2}$

## 5.COOLING VS EXHUMATION SIGNALS



After Jordan et al. (2001)



- Maximum temperatures of ~170°C at the base of the section (Carboniferous strata) were achieved in the Triassic, with only about half of the (minimum) burial present in the Late Miocene. **High heat flow associated with rifting.**

- Cenozoic rehating to ~120°C at the base of the section despite up to 6 km of burial, and to < 100°C in Triassic strata. **Lower heat flow associated with flat-slab subduction.**

**Example of cooling and exhumation signal decoupled in subduction orogens, call for a rigurous interpretation of cooling paths in Andean fold-and-thrust belts.**

## ACKNOWLEDGEMENTS

Funding by the Sao Paulo Research Foundation (FAPESP, Brazil) and Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET, Argentina) binational project 2016/50441-1 *"Multi-method Paleothermometry in Sedimentary Basins"*.

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