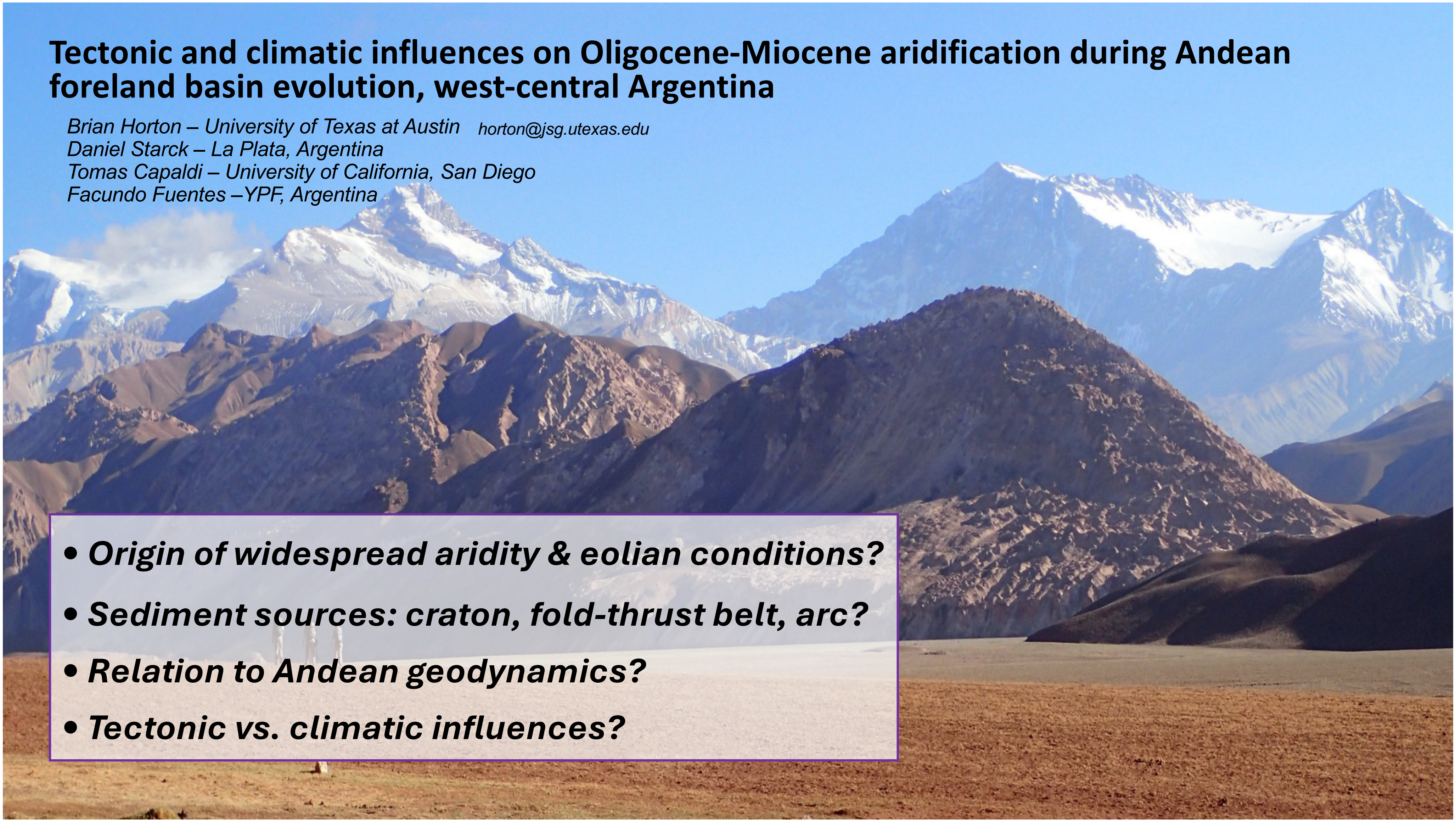
# Tectonic and climatic influences on Oligocene-Miocene aridification during Andean foreland basin evolution, west-central Argentina


*Brian Horton – University of Texas at Austin* *horton@jsg.utexas.edu*
*Daniel Starck – La Plata, Argentina*
*Tomas Capaldi – University of California, San Diego*
*Facundo Fuentes –YPF, Argentina*

- ***Origin of widespread aridity & eolian conditions?***
- ***Sediment sources: craton, fold-thrust belt, arc?***
- ***Relation to Andean geodynamics?***
- ***Tectonic vs. climatic influences?***

## MOTIVATION

- ***Origin of widespread aridity & eolian conditions?***
- ***Sediment sources: craton, fold-thrust belt, magmatic arc?***
- ***Relation to Andean geodynamics?***
- ***Tectonic vs. climatic influences?***

Tectonic and climatic significance of Oligocene-Miocene eolian sandstones in the Andean foreland basin of Argentina

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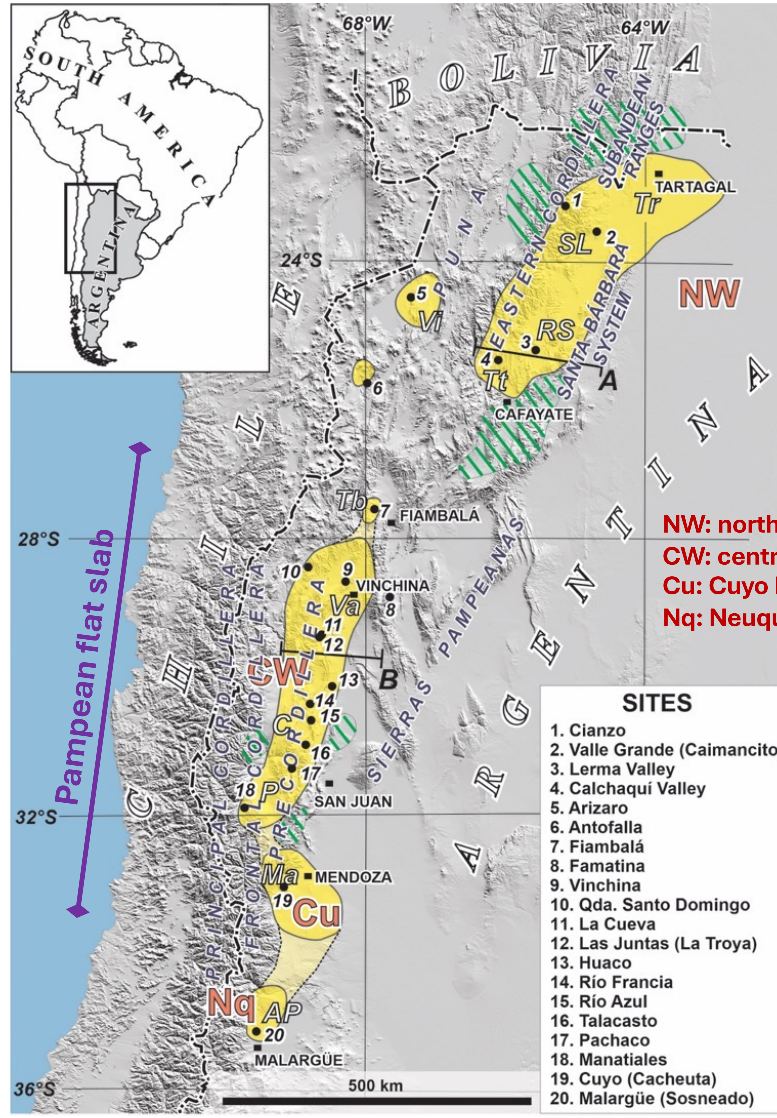
# GEOLOGIC FRAMEWORK

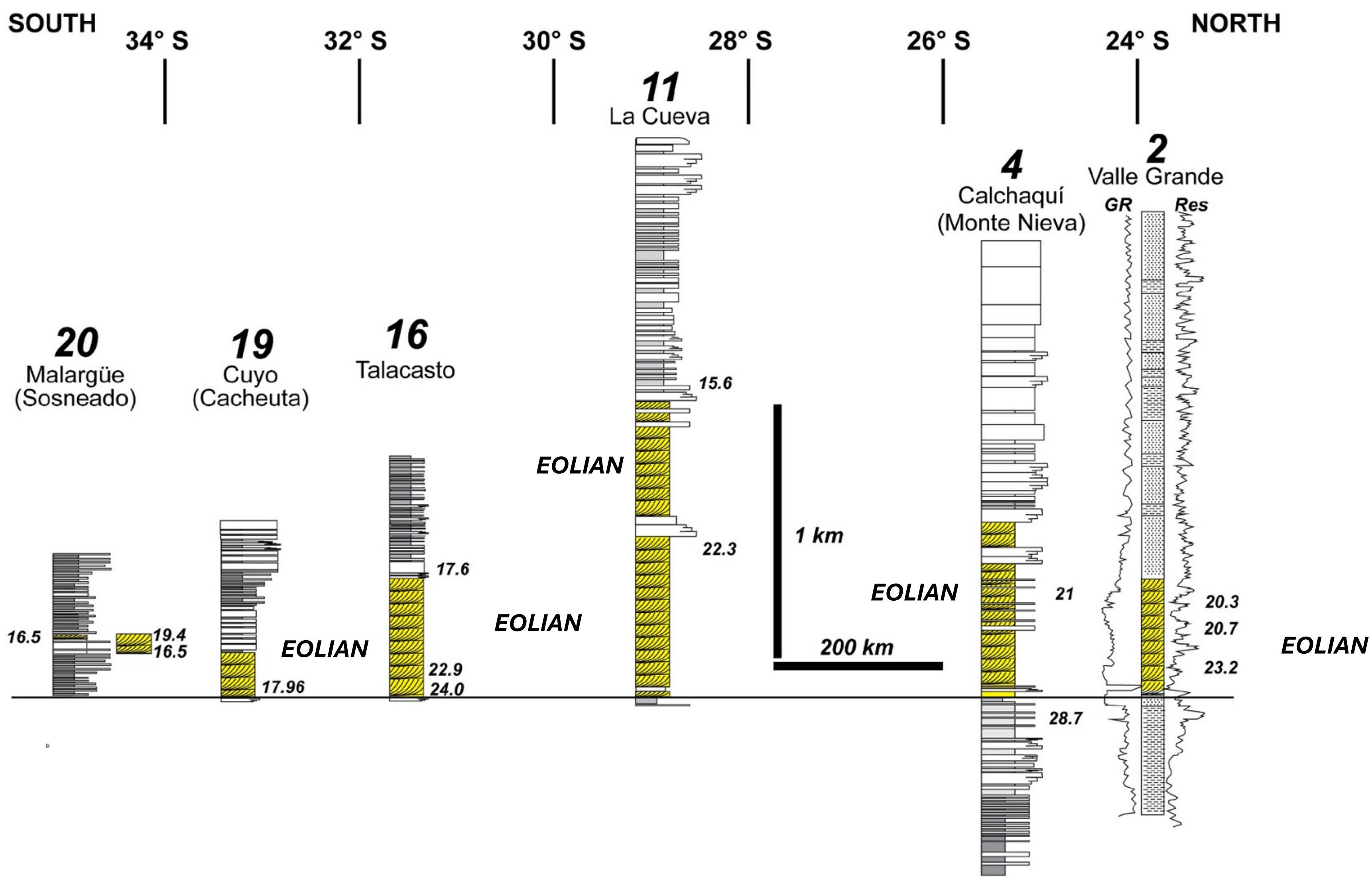
**Eolian spatial extent:**

- 22-36°S (>1500 km along strike)
- Andean retroarc foreland basin

**= *20 localities***

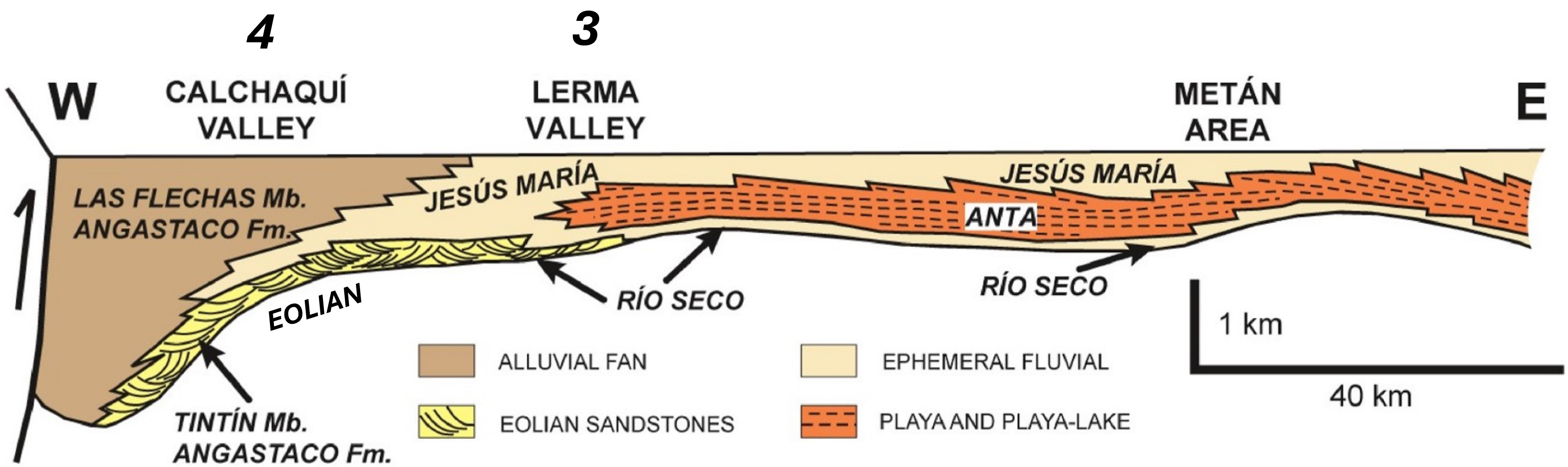



NW: northwest
CW: central west
Cu: Cuyo Basin
Nq: Neuquen Basin

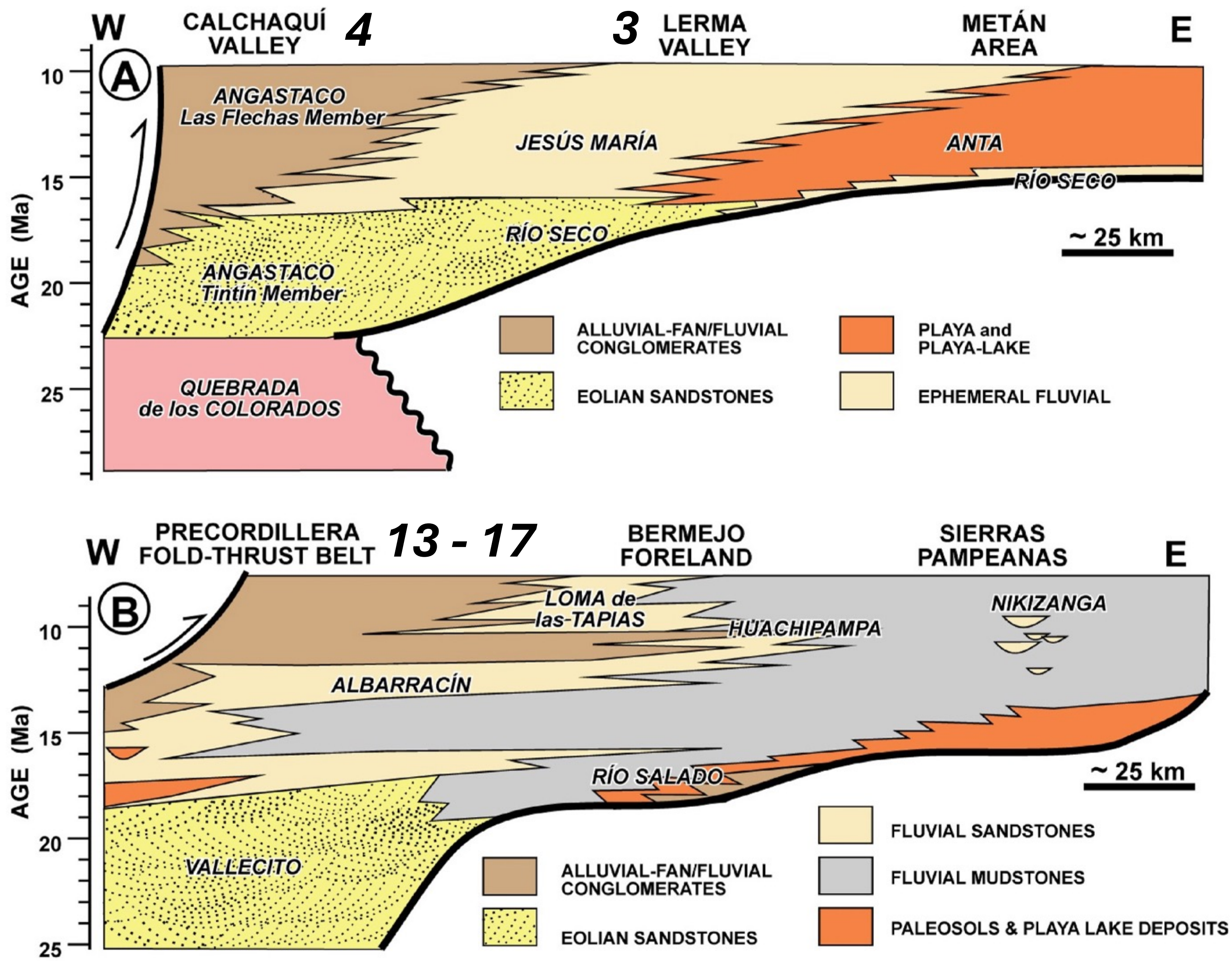


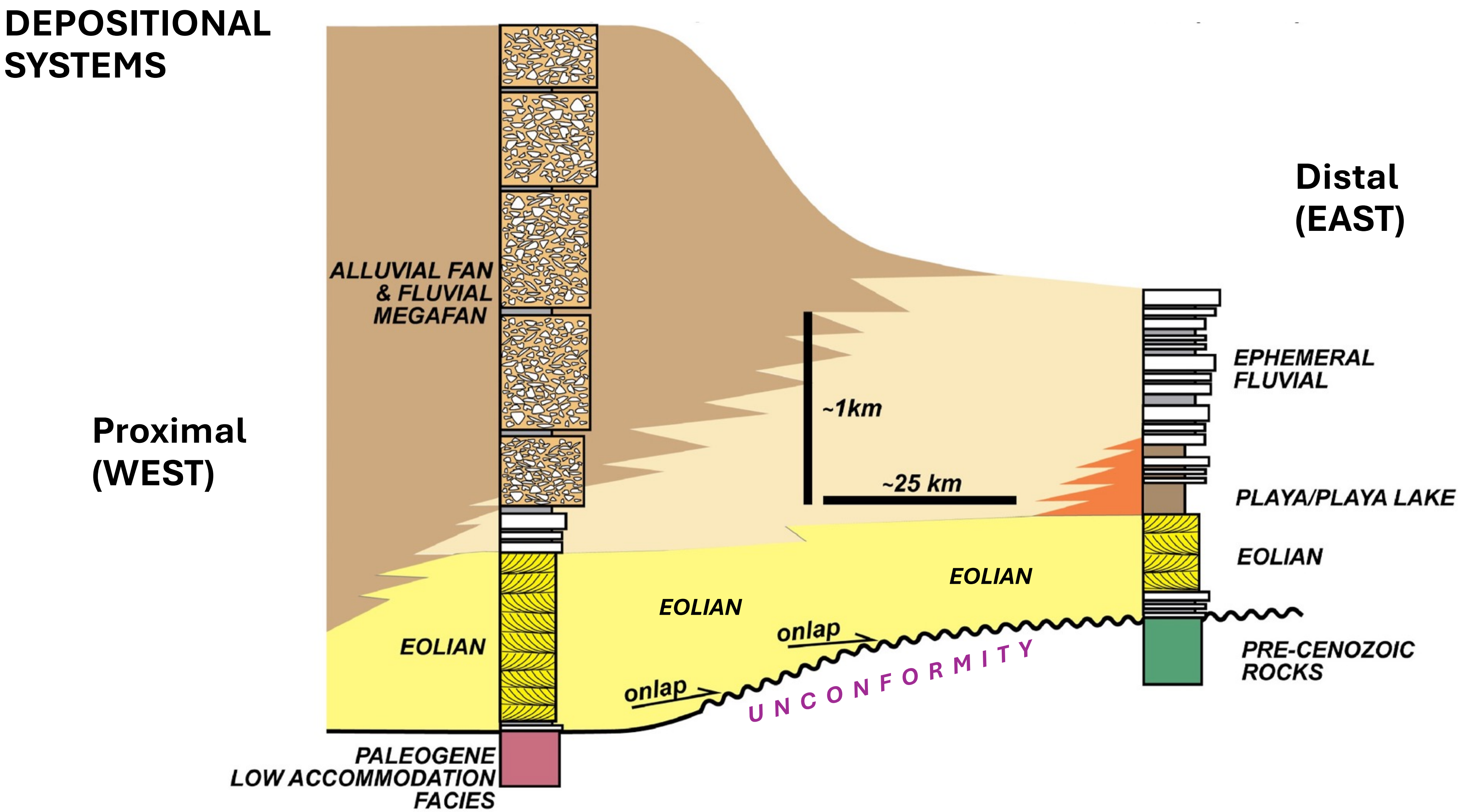
SOUTH
NORTH
34° S
32° S
30° S
28° S
26° S
24° S
11
La Cueva
4
Calchaquí
(Monte Nieva)
2
Valle Grande
GR
Res
20
Malargüe
(Sosneado)
19
Cuyo
(Cacheuta)
16
Talacasto
15.6
EOLIAN
1 km
200 km
22.3
17.6
21
20.3
20.7
23.2
16.5
19.4
16.5
17.96
22.9
24.0
28.7

# DEPOSITIONAL SYSTEMS



# DEPOSITIONAL SYSTEMS




DEPOSITIONAL
SYSTEMS
Distal
(EAST)
Proximal
(WEST)
ALLUVIAL FAN
& FLUVIAL
MEGAFAN
~1km
~25 km
EPHEMERAL
FLUVIAL
PLAYA/PLAYA LAKE
EOLIAN
EOLIAN
EOLIAN
EOLIAN
onlap
onlap
UNCONFORMITY
PRE-CENOZOIC
ROCKS
PALEOGENE
LOW ACCOMMODATION
FACIES

# STRATIGRAPHIC FRAMEWORK

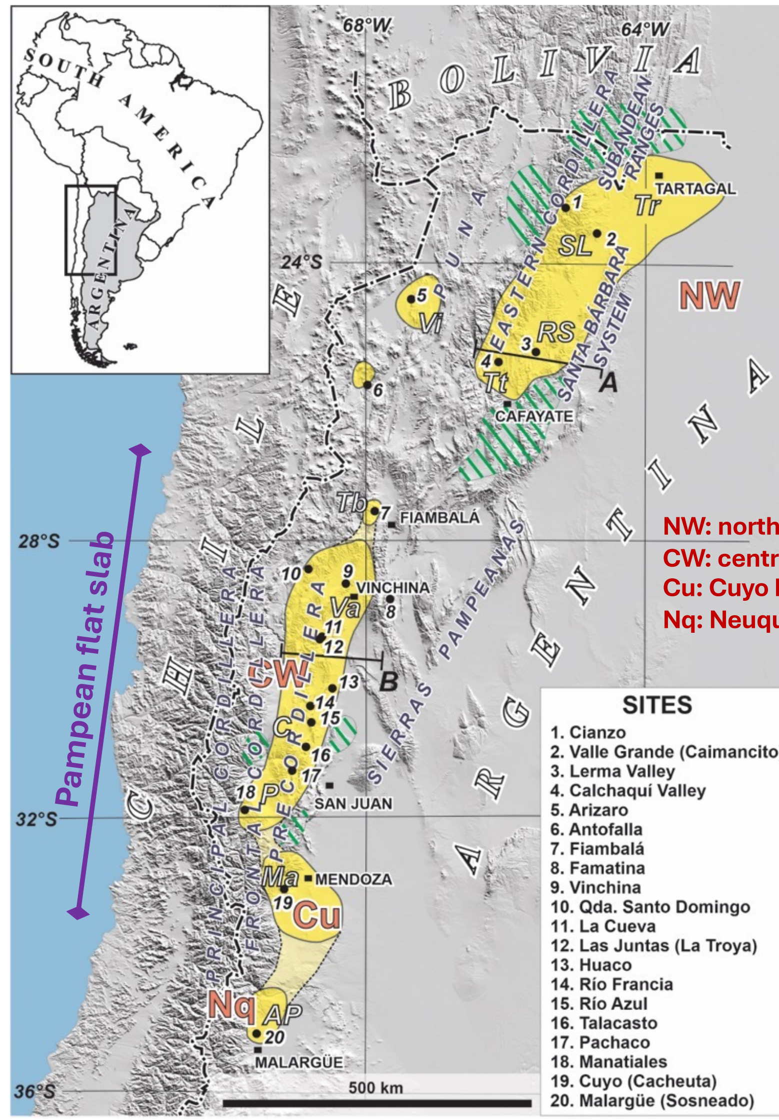
**Eolian spatial extent:**

- 22-36°S (>1500 km along strike)
- Andean retroarc foreland basin

= ***20 localities***

**Eolian chronology**

- U-Pb detrital zircon ages of sandstones
- Selected interbedded ashfall tuffs
  U-Pb, $^{40}Ar/^{39}Ar$, fission track ages
- Eolian duration = 24 to 16 Ma
  locally, pre-24 Ma
  locally, post-16 Ma

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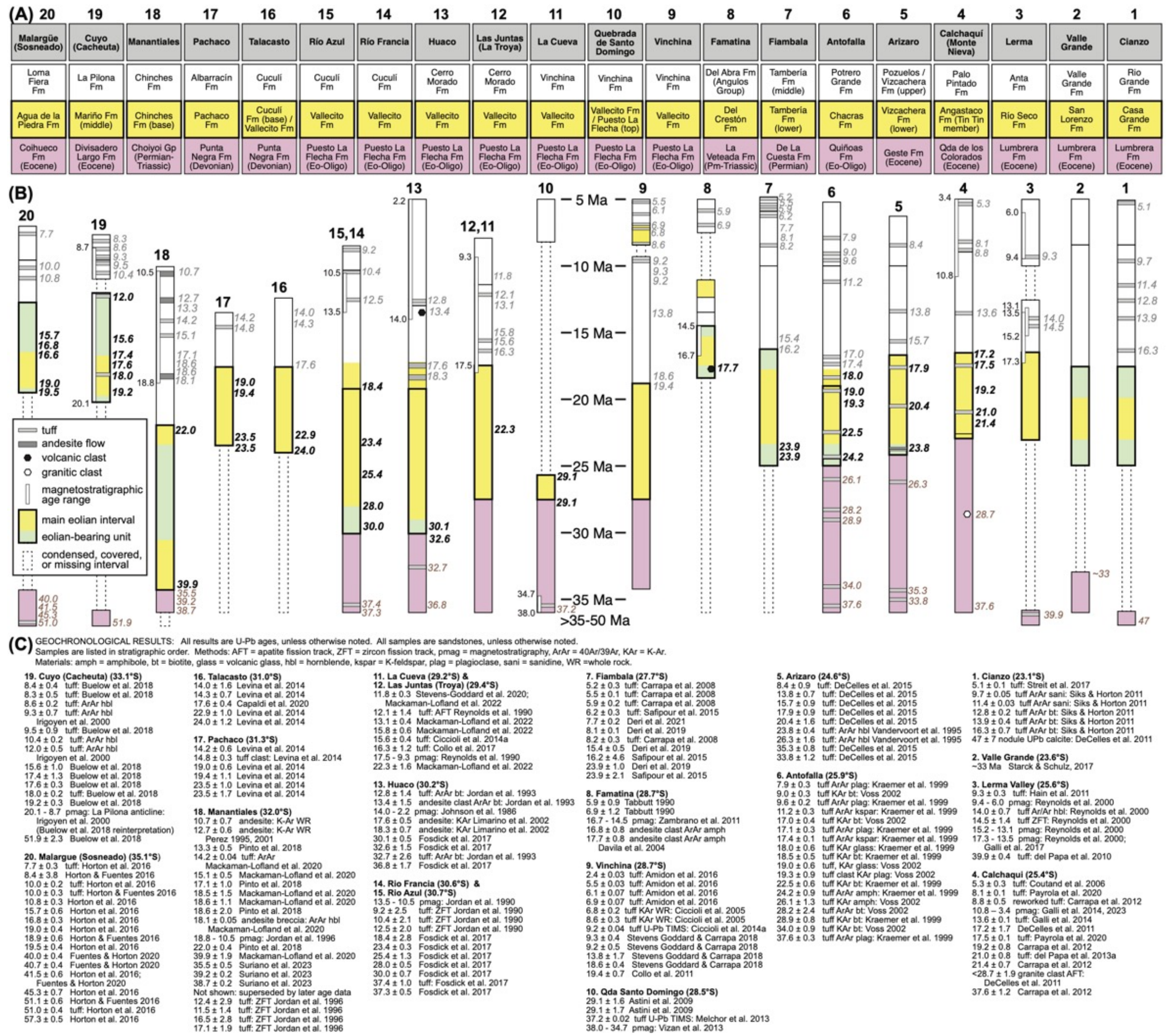
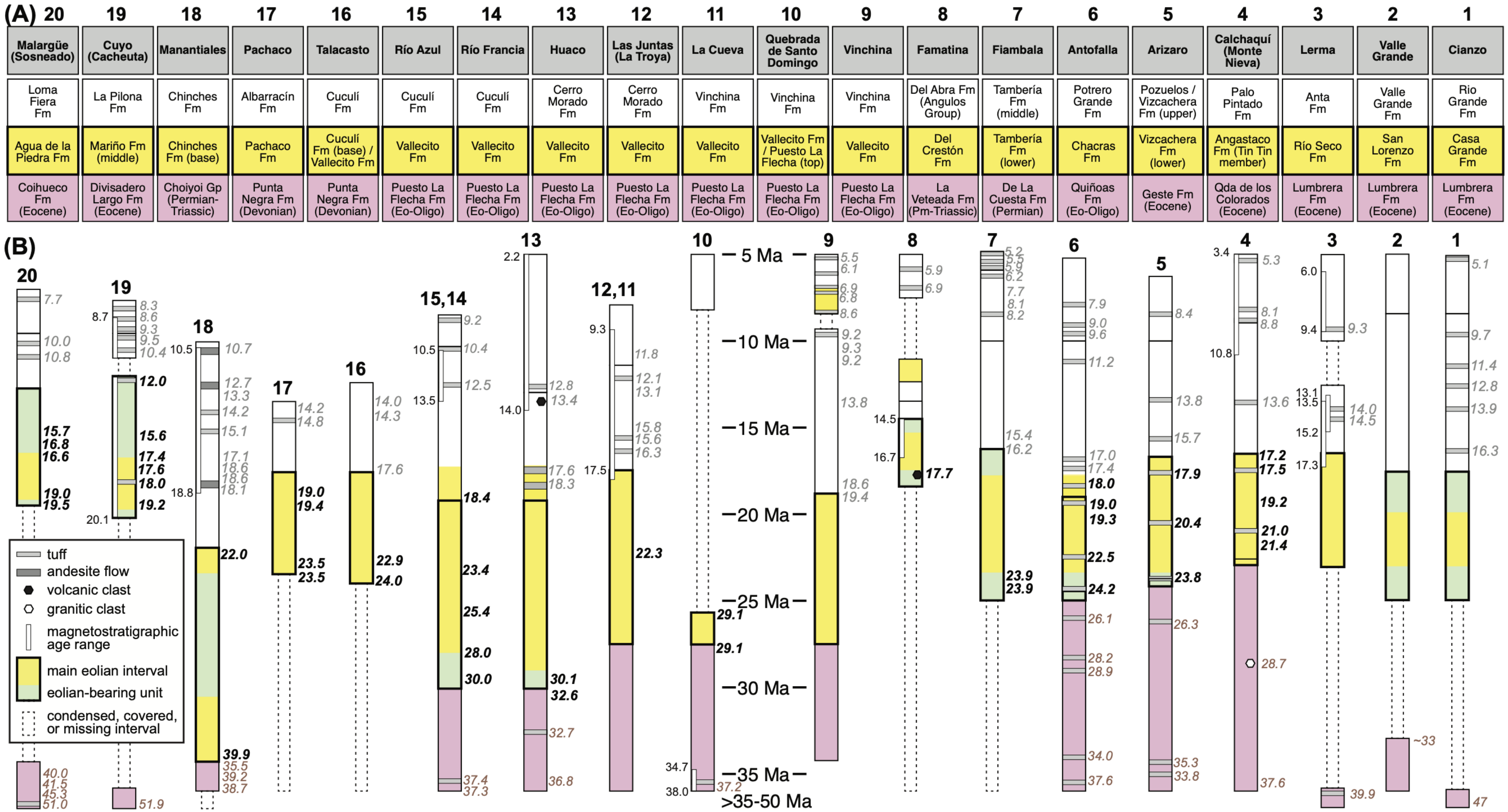




(A)
20 Malargüe (Sosneado) — Loma Fiera Fm — Agua de la Piedra Fm — Coihueco Fm (Eocene)
19 Cuyo (Cacheuta) — La Pilona Fm — Mariño Fm (middle) — Divisadero Largo Fm (Eocene)
18 Manantiales — Chinches Fm — Chinches Fm (base) — Choiyoi Gp (Permian-Triassic)
17 Pachaco — Albarracín Fm — Pachaco Fm — Punta Negra Fm (Devonian)
16 Talacasto — Cuculí Fm — Cuculí Fm (base) / Vallecito Fm — Punta Negra Fm (Devonian)
15 Río Azul — Cuculí Fm — Vallecito Fm — Puesto La Flecha Fm (Eo-Oligo)
14 Río Francia — Cuculí Fm — Vallecito Fm — Puesto La Flecha Fm (Eo-Oligo)
13 Huaco — Cerro Morado Fm — Vallecito Fm — Puesto La Flecha Fm (Eo-Oligo)
12 Las Juntas (La Troya) — Cerro Morado Fm — Vallecito Fm — Puesto La Flecha Fm (Eo-Oligo)
11 La Cueva — Vinchina Fm — Vallecito Fm — Puesto La Flecha Fm (Eo-Oligo)
10 Quebrada de Santo Domingo — Vinchina Fm — Vallecito Fm / Puesto La Flecha (top) — Puesto La Flecha Fm (Eo-Oligo)
9 Vinchina — Vinchina Fm — Vallecito Fm — Puesto La Flecha Fm (Eo-Oligo)
8 Famatina — Del Abra Fm (Angulos Group) — Del Crestón Fm — La Veteada Fm (Pm-Triassic)
7 Fiambala — Tambería Fm (middle) — Tambería Fm (lower) — De La Cuesta Fm (Permian)
6 Antofalla — Potrero Grande Fm — Chacras Fm — Quiñoas Fm (Eo-Oligo)
5 Arizaro — Pozuelos / Vizcachera Fm (upper) — Vizcachera Fm (lower) — Geste Fm (Eocene)
4 Calchaquí (Monte Nieva) — Palo Pintado Fm — Angastaco Fm (Tin Tin member) — Qda de los Colorados (Eocene)
3 Lerma — Anta Fm — Río Seco Fm — Lumbrera Fm (Eocene)
2 Valle Grande — Valle Grande Fm — San Lorenzo Fm — Lumbrera Fm (Eocene)
1 Cianzo — Rio Grande Fm — Casa Grande Fm — Lumbrera Fm (Eocene)
(B)
20 19 18 17 16 15,14 13 12,11 10 9 8 7 6 5 4 3 2 1
5 Ma
10 Ma
15 Ma
20 Ma
25 Ma
30 Ma
35 Ma
>35-50 Ma
tuff
andesite flow
volcanic clast
granitic clast
magnetostratigraphic age range
main eolian interval
eolian-bearing unit
condensed, covered, or missing interval

# STRATIGRAPHIC FRAMEWORK

**(C)** GEOCHRONOLOGICAL RESULTS: All results are U-Pb ages, unless otherwise noted. All samples are sandstones, unless otherwise noted.
Samples are listed in stratigraphic order. Methods: AFT = apatite fission track, ZFT = zircon fission track, pmag = magnetostratigraphy, ArAr = 40Ar/39Ar, KAr = K-Ar.
Materials: amph = amphibole, bt = biotite, glass = volcanic glass, hbl = hornblende, kspar = K-feldspar, plag = plagioclase, sani = sanidine, WR =whole rock.

**19. Cuyo (Cacheuta) (33.1°S)**
8.4 ± 0.4 tuff: Buelow et al. 2018
8.3 ± 0.5 tuff: Buelow et al. 2018
8.6 ± 0.2 tuff: ArAr hbl
9.3 ± 0.7 tuff: ArAr hbl
Irigoyen et al. 2000
9.5 ± 0.9 tuff: Buelow et al. 2018
10.4 ± 0.2 tuff: ArAr hbl
12.0 ± 0.5 tuff: ArAr hbl
Irigoyen et al. 2000
15.6 ± 1.0 Buelow et al. 2018
17.4 ± 1.3 Buelow et al. 2018
17.6 ± 0.3 Buelow et al. 2018
18.0 ± 0.2 tuff: Buelow et al. 2018
19.2 ± 0.3 Buelow et al. 2018
20.1 - 8.7 pmag: La Pilona anticline:
Irigoyen et al. 2000
(Buelow et al. 2018 reinterpretation)
51.9 ± 2.3 Buelow et al. 2018

**20. Malargue (Sosneado) (35.1°S)**
7.7 ± 0.3 tuff: Horton et al. 2016
8.4 ± 3.8 Horton & Fuentes 2016
10.0 ± 0.2 tuff: Horton et al. 2016
10.0 ± 0.3 tuff: Horton & Fuentes 2016
10.8 ± 0.3 Horton et al. 2016
15.7 ± 0.6 Horton et al. 2016
16.8 ± 0.3 Horton et al. 2016
19.0 ± 0.4 Horton et al. 2016
18.9 ± 0.6 Horton & Fuentes 2016
19.5 ± 0.4 Horton et al. 2016
40.0 ± 0.4 Fuentes & Horton 2020
40.7 ± 0.4 Fuentes & Horton 2020
41.5 ± 0.6 Horton et al. 2016;
Fuentes & Horton 2020
45.3 ± 0.7 Horton et al. 2016
51.1 ± 0.6 Horton & Fuentes 2016
51.0 ± 0.4 tuff: Horton et al. 2016
57.3 ± 0.5 Horton et al. 2016

**16. Talacasto (31.0°S)**
14.0 ± 1.6 Levina et al. 2014
14.3 ± 0.7 Levina et al. 2014
17.6 ± 0.4 Capaldi et al. 2020
22.9 ± 1.0 Levina et al. 2014
24.0 ± 1.2 Levina et al. 2014

**17. Pachaco (31.3°S)**
14.2 ± 0.6 Levina et al. 2014
14.8 ± 0.3 tuff clast: Levina et al. 2014
19.0 ± 0.6 Levina et al. 2014
19.4 ± 1.1 Levina et al. 2014
23.5 ± 1.0 Levina et al. 2014
23.5 ± 1.7 Levina et al. 2014

**18. Manantiales (32.0°S)**
10.7 ± 0.7 andesite: K-Ar WR
12.7 ± 0.6 andesite: K-Ar WR
Perez 1995, 2001
13.3 ± 0.5 Pinto et al. 2018
14.2 ± 0.04 tuff: ArAr
Mackaman-Lofland et al. 2020
15.1 ± 0.5 Mackaman-Lofland et al. 2020
17.1 ± 1.0 Pinto et al. 2018
18.5 ± 1.5 Mackaman-Lofland et al. 2020
18.6 ± 1.1 Mackaman-Lofland et al. 2020
18.6 ± 2.0 Pinto et al. 2018
18.1 ± 0.05 andesite breccia: ArAr hbl
Mackaman-Lofland et al. 2020
18.8 - 10.5 pmag: Jordan et al. 1996
22.0 ± 0.4 Pinto et al. 2018
39.9 ± 1.9 Mackaman-Lofland et al. 2020
35.5 ± 0.5 Suriano et al. 2023
39.2 ± 0.2 Suriano et al. 2023
38.7 ± 0.2 Suriano et al. 2023
Not shown: superseded by later age data
12.4 ± 2.9 tuff: ZFT Jordan et al. 1996
11.5 ± 1.4 tuff: ZFT Jordan et al. 1996
16.5 ± 2.8 tuff: ZFT Jordan et al. 1996
17.1 ± 1.9 tuff: ZFT Jordan et al. 1996

**11. La Cueva (29.2°S) &**
**12. Las Juntas (Troya) (29.4°S)**
11.8 ± 0.3 Stevens-Goddard et al. 2020;
Mackaman-Lofland et al. 2022
12.1 ± 1.4 tuff: AFT Reynolds et al. 1990
13.1 ± 0.4 Mackaman-Lofland et al. 2022
15.8 ± 0.6 Mackaman-Lofland et al. 2022
15.6 ± 0.4 tuff: Ciccioli et al. 2014a
16.3 ± 1.2 tuff: Collo et al. 2017
17.5 - 9.3 pmag: Reynolds et al. 1990
22.3 ± 1.6 Mackaman-Lofland et al. 2022

**13. Huaco (30.2°S)**
12.8 ± 1.4 tuff: ArAr bt: Jordan et al. 1993
13.4 ± 1.5 andesite clast ArAr bt: Jordan et al. 1993
14.0 - 2.2 pmag: Johnson et al. 1986
17.6 ± 0.5 andesite: KAr Limarino et al. 2002
18.3 ± 0.7 andesite: KAr Limarino et al. 2002
30.1 ± 0.5 Fosdick et al. 2017
32.6 ± 1.5 Fosdick et al. 2017
32.7 ± 2.6 tuff: ArAr bt: Jordan et al. 1993
36.8 ± 1.7 Fosdick et al. 2017

**14. Rio Francia (30.6°S) &**
**15. Rio Azul (30.7°S)**
13.5 - 10.5 pmag: Jordan et al. 1990
9.2 ± 2.5 tuff: ZFT Jordan et al. 1990
10.4 ± 2.1 tuff: ZFT Jordan et al. 1990
12.5 ± 2.0 tuff: ZFT Jordan et al. 1990
18.4 ± 2.8 Fosdick et al. 2017
23.4 ± 0.3 Fosdick et al. 2017
25.4 ± 1.3 Fosdick et al. 2017
28.0 ± 0.5 Fosdick et al. 2017
30.0 ± 0.7 Fosdick et al. 2017
37.4 ± 1.0 tuff: Fosdick et al. 2017
37.3 ± 0.5 Fosdick et al. 2017

**7. Fiambala (27.7°S)**
5.2 ± 0.3 tuff: Carrapa et al. 2008
5.5 ± 0.1 tuff: Carrapa et al. 2008
5.9 ± 0.2 tuff: Carrapa et al. 2008
6.2 ± 0.3 tuff: Safipour et al. 2015
7.7 ± 0.2 Deri et al. 2021
8.1 ± 0.1 Deri et al. 2019
8.2 ± 0.3 tuff: Carrapa et al. 2008
15.4 ± 0.5 Deri et al. 2019
16.2 ± 4.6 Safipour et al. 2015
23.9 ± 1.0 Deri et al. 2019
23.9 ± 2.1 Safipour et al. 2015

**8. Famatina (28.7°S)**
5.9 ± 0.9 Tabbutt 1990
6.9 ± 1.2 Tabbutt 1990
16.7 - 14.5 pmag: Zambrano et al. 2011
16.8 ± 0.8 andesite clast ArAr amph
17.7 ± 0.8 andesite clast ArAr amph
Davila et al. 2004

**9. Vinchina (28.7°S)**
2.4 ± 0.03 tuff: Amidon et al. 2016
5.5 ± 0.03 tuff: Amidon et al. 2016
6.1 ± 0.07 tuff: Amidon et al. 2016
6.9 ± 0.07 tuff: Amidon et al. 2016
6.8 ± 0.2 tuff KAr WR: Ciccioli et al. 2005
8.6 ± 0.3 tuff KAr WR: Ciccioli et al. 2005
9.2 ± 0.04 tuff U-Pb TIMS: Ciccioli et al. 2014a
9.3 ± 0.4 Stevens Goddard & Carrapa 2018
9.2 ± 0.5 Stevens Goddard & Carrapa 2018
13.8 ± 1.7 Stevens Goddard & Carrapa 2018
18.6 ± 0.4 Stevens Goddard & Carrapa 2018
19.4 ± 0.7 Collo et al. 2011

**10. Qda Santo Domingo (28.5°S)**
29.1 ± 1.6 Astini et al. 2009
29.1 ± 1.7 Astini et al. 2009
37.2 ± 0.02 tuff U-Pb TIMS: Melchor et al. 2013
38.0 - 34.7 pmag: Vizan et al. 2013

**5. Arizaro (24.6°S)**
8.4 ± 0.9 tuff: DeCelles et al. 2015
13.8 ± 0.7 tuff: DeCelles et al. 2015
15.7 ± 0.9 tuff: DeCelles et al. 2015
17.9 ± 0.9 tuff: DeCelles et al. 2015
20.4 ± 1.6 tuff: DeCelles et al. 2015
23.8 ± 0.4 tuff: ArAr hbl Vandervoort et al. 1995
26.3 ± 1.6 tuff: ArAr hbl Vandervoort et al. 1995
35.3 ± 0.8 tuff: DeCelles et al. 2015
33.8 ± 1.2 tuff: DeCelles et al. 2015

**6. Antofalla (25.9°S)**
7.9 ± 0.3 tuff ArAr plag: Kraemer et al. 1999
9.0 ± 0.3 tuff KAr bt: Voss 2002
9.6 ± 0.2 tuff ArAr plag: Kraemer et al. 1999
11.2 ± 0.3 tuff ArAr kspar: Kraemer et al. 1999
17.0 ± 0.4 tuff KAr bt: Voss 2002
17.1 ± 0.3 tuff ArAr plag: Kraemer et al. 1999
17.4 ± 0.1 tuff ArAr kspar: Kraemer et al. 1999
18.0 ± 0.6 tuff KAr glass: Kraemer et al. 1999
18.5 ± 0.5 tuff KAr bt: Kraemer et al. 1999
19.0 ± 0.6 tuff, KAr glass: Voss 2002
19.3 ± 0.9 tuff clast KAr plag: Voss 2002
22.5 ± 0.6 tuff KAr bt: Kraemer et al. 1999
24.2 ± 0.9 tuff ArAr amph: Kraemer et al. 1999
26.1 ± 1.3 tuff KAr amph: Voss 2002
28.2 ± 2.4 tuff ArAr bt: Voss 2002
28.9 ± 0.8 tuff KAr bt: Kraemer et al. 1999
34.0 ± 0.9 tuff KAr bt: Voss 2002
37.6 ± 0.3 tuff ArAr plag: Kraemer et al. 1999

**1. Cianzo (23.1°S)**
5.1 ± 0.1 tuff: Streit et al. 2017
9.7 ± 0.05 tuff ArAr sani: Siks & Horton 2011
11.4 ± 0.03 tuff ArAr sani: Siks & Horton 2011
12.8 ± 0.2 tuff ArAr bt: Siks & Horton 2011
13.9 ± 0.4 tuff ArAr bt: Siks & Horton 2011
16.3 ± 0.7 tuff ArAr bt: Siks & Horton 2011
47 ± 7 nodule UPb calcite: DeCelles et al. 2011

**2. Valle Grande (23.6°S)**
~33 Ma Starck & Schulz, 2017

**3. Lerma Valley (25.6°S)**
9.3 ± 0.3 tuff: Hain et al. 2011
9.4 - 6.0 pmag: Reynolds et al. 2000
14.0 ± 0.7 tuff Ar/Ar hbl: Reynolds et al. 2000
14.5 ± 1.4 tuff ZFT: Reynolds et al. 2000
15.2 - 13.1 pmag: Reynolds et al. 2000
17.3 - 13.5 pmag: Reynolds et al. 2000;
Galli et al. 2017
39.9 ± 0.4 tuff: del Papa et al. 2010

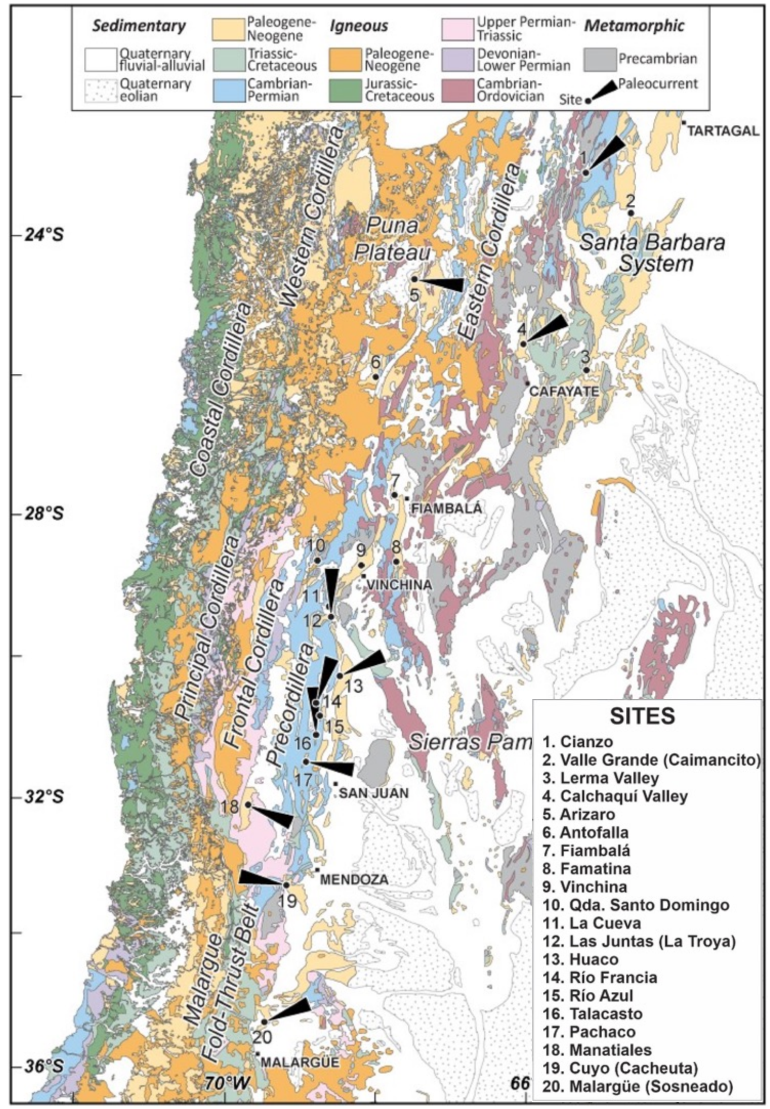
**4. Calchaqui (25.4°S)**
5.3 ± 0.3 tuff: Coutand et al. 2006
8.1 ± 0.1 tuff: Payrola et al. 2020
8.8 ± 0.5 reworked tuff: Carrapa et al. 2012
10.8 – 3.4 pmag: Galli et al. 2014, 2023
13.6 ± 0.1 tuff: Galli et al. 2014
17.2 ± 1.7 DeCelles et al. 2011
17.5 ± 0.1 tuff: Payrola et al. 2020
19.2 ± 0.8 Carrapa et al. 2012
21.0 ± 0.8 tuff: del Papa et al. 2013a
21.4 ± 0.7 Carrapa et al. 2012
<28.7 ± 1.9 granite clast AFT:
DeCelles et al. 2011
37.6 ± 1.2 Carrapa et al. 2012

# SEDIMENT DISPERSAL

### *Paleocurrents*

Large-scale trough cross stratification: eolian dunes

Transverse: → E
Axial: → N
Oblique: → NE



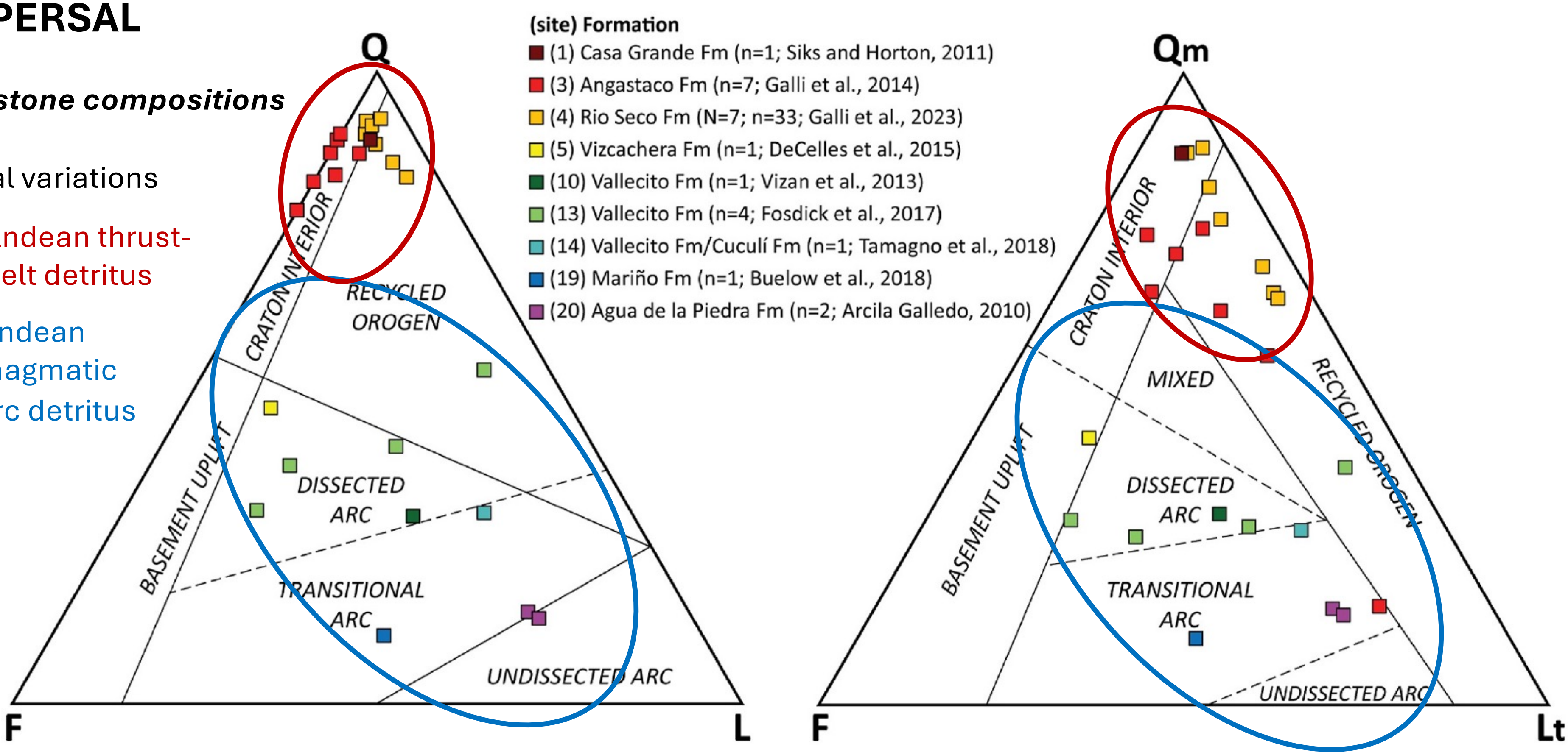
# SEDIMENT DISPERSAL

***Sandstone compositions***

Spatial variations

N: ↑ Andean thrust-belt detritus

S: ↑ Andean magmatic arc detritus

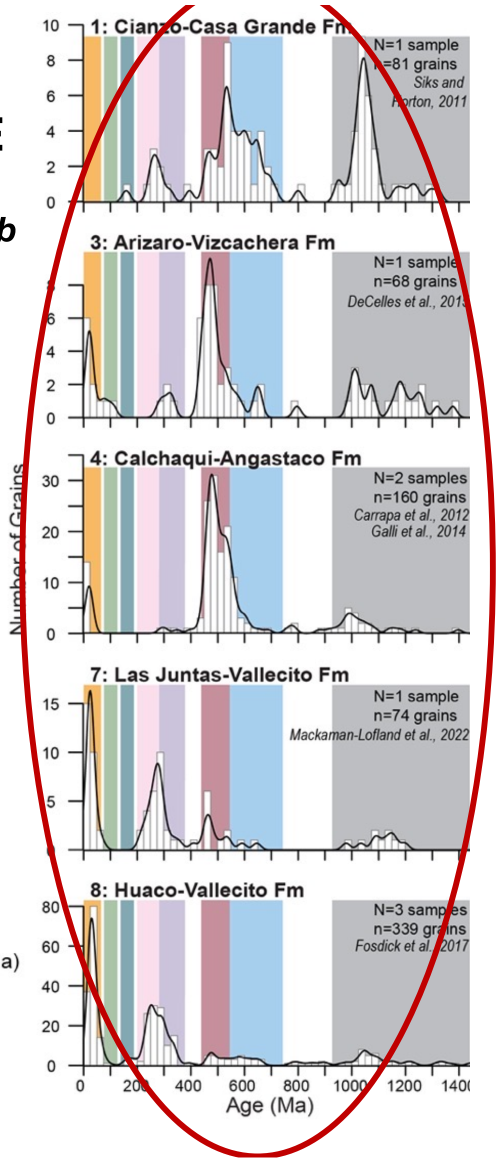


# SEDIMENT PROVENANCE

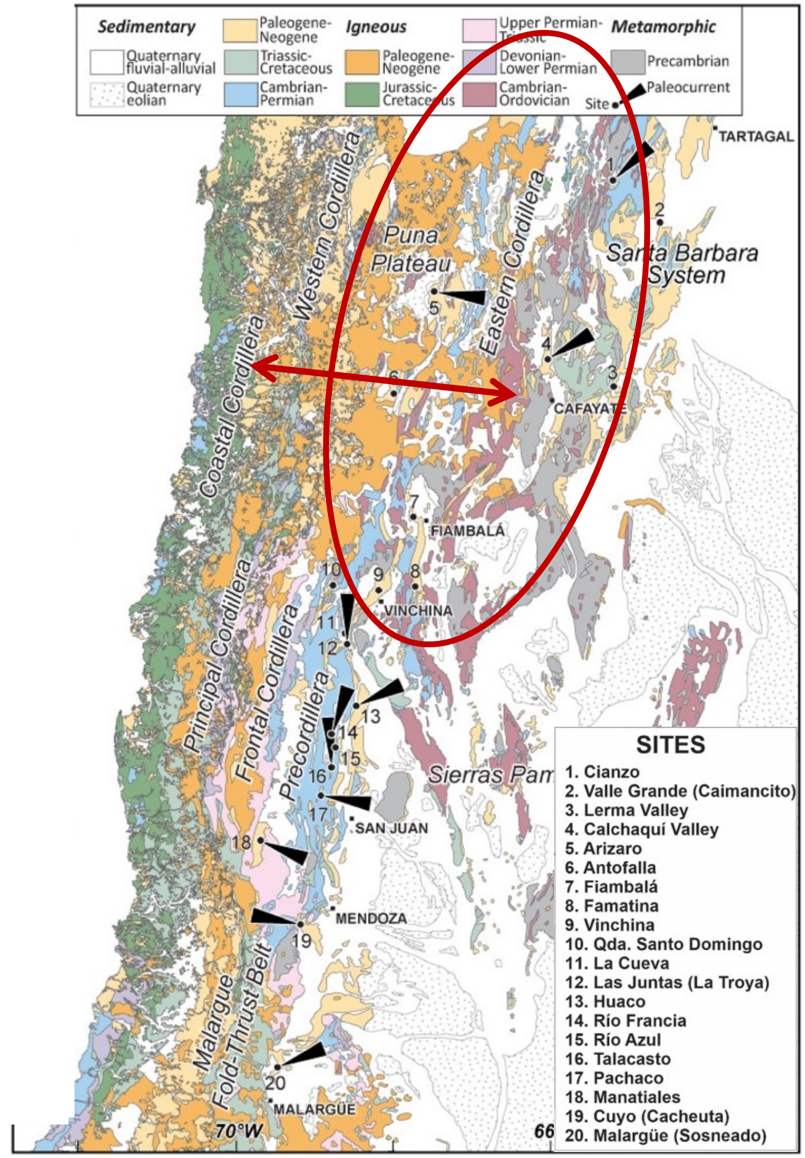
***Detrital zircon U-Pb geochronology***

Spatial variations

N: ↑ Andean thrust-belt detritus




- Paleogene-Neogene (0-60 Ma)
- Cretaceous (65-125 Ma)
- Jurassic (140-190 Ma)
- Permian-Triassic (200-280 Ma)
- Devonian-Permian (280-380 Ma)
- Cambrian-Ordovician (440-550 Ma)
- East Sierras Pampeanas (550-725 Ma)
- Sunsas (925-1450 Ma)



# SEDIMENT PROVENANCE

***Detrital zircon U-Pb geochronology***

Spatial variations

N: ↑ Andean thrust-belt detritus

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- Paleogene-Neogene (0-60 Ma)
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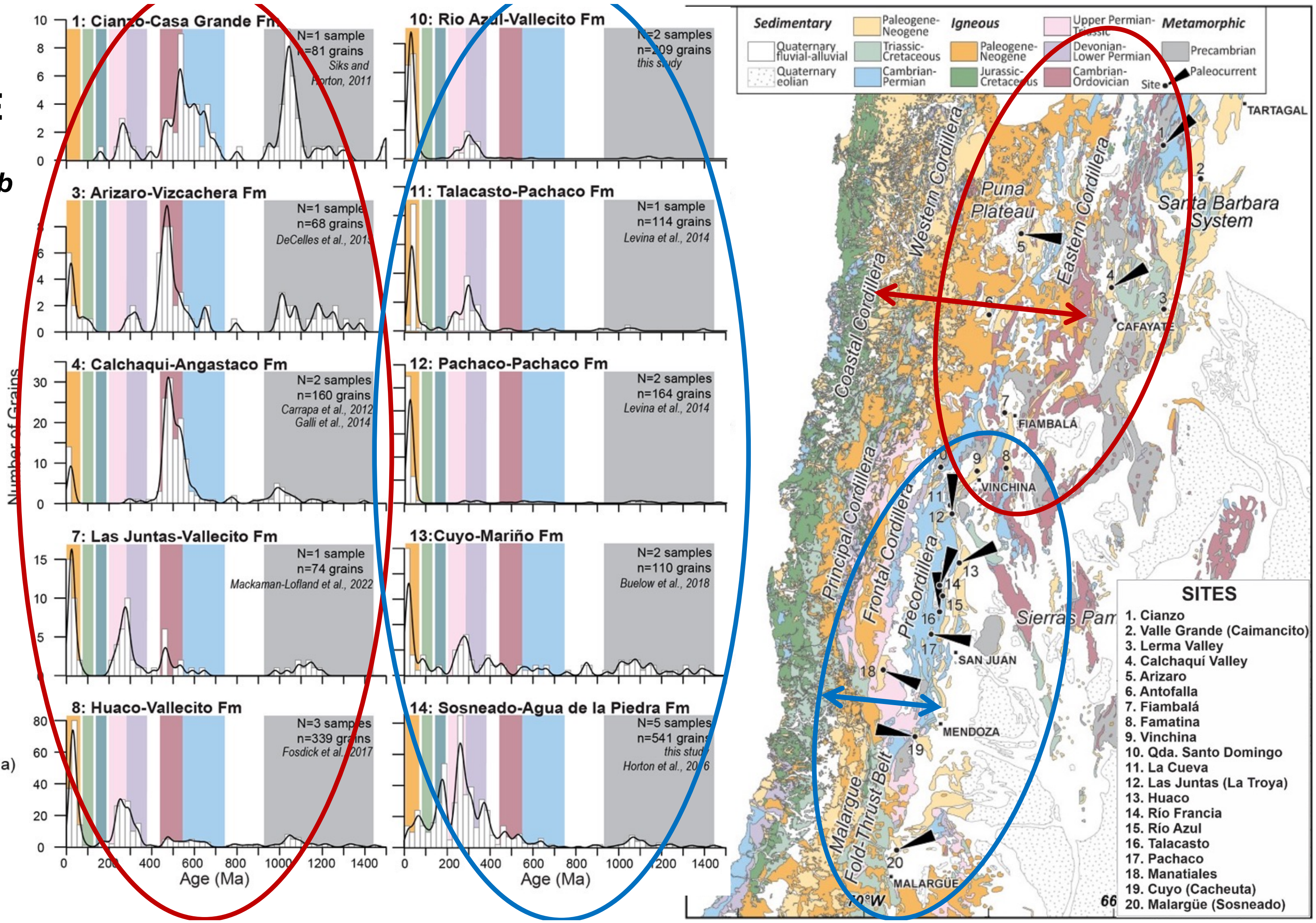
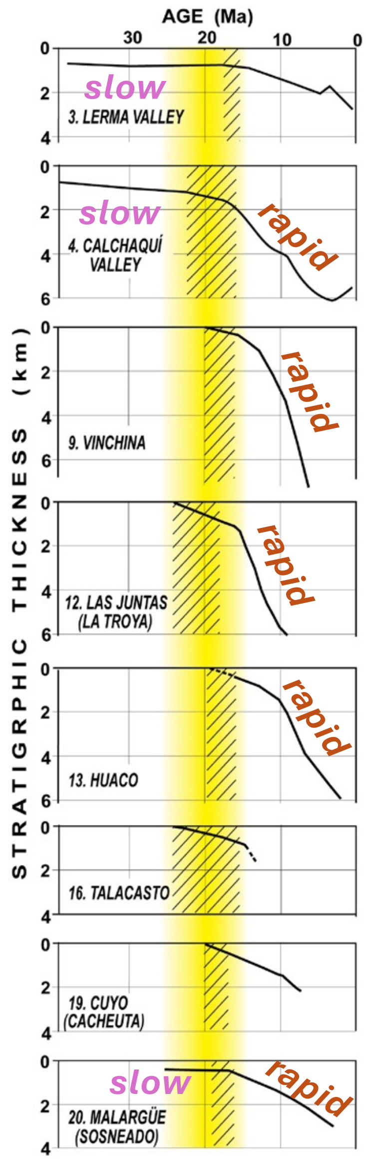


# SEDIMENT ACCOMMODATION

***Rates of sediment accumulation***

Onset of rapid accumulation
23-18 Ma

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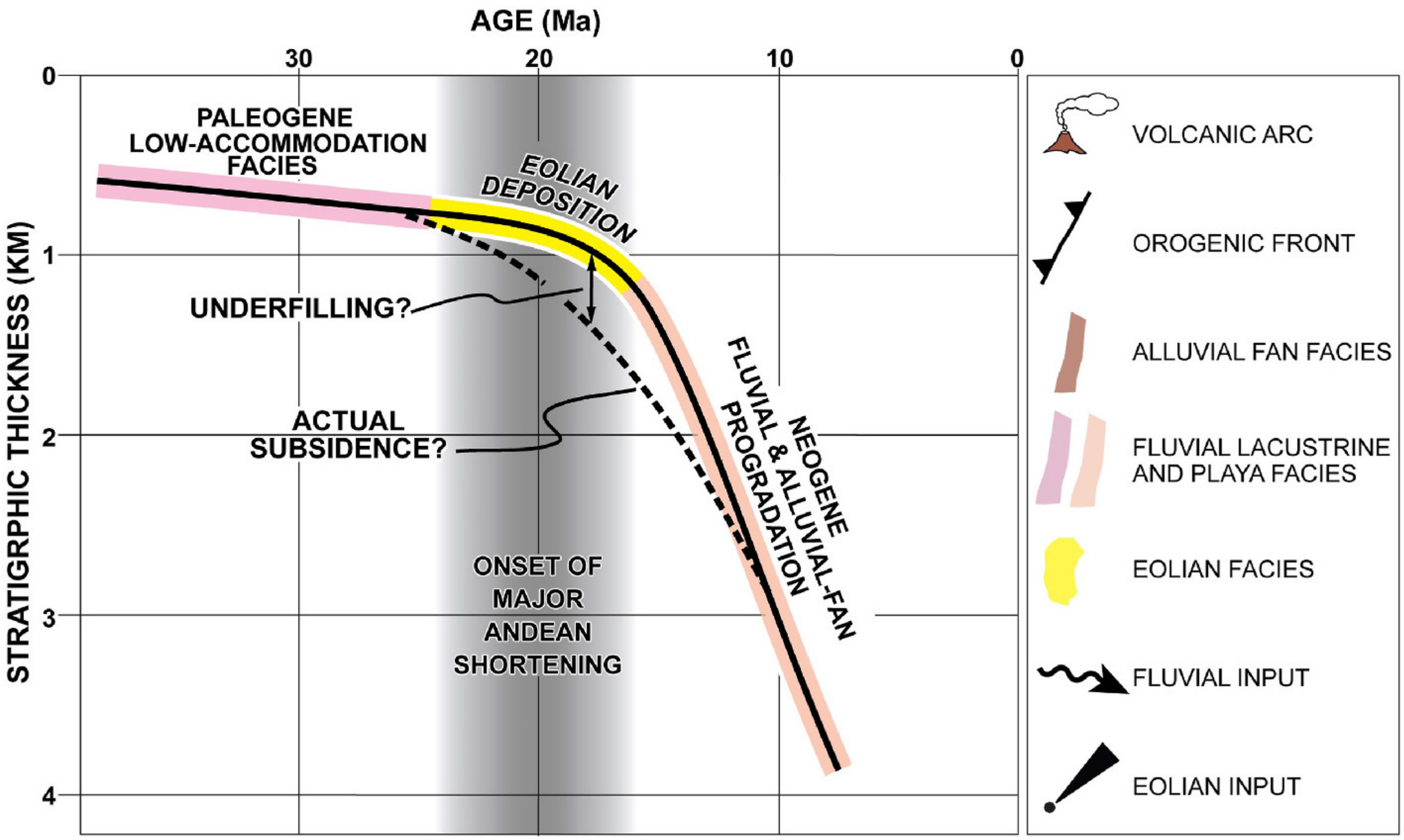
Onset of rapid accumulation
23-18 Ma



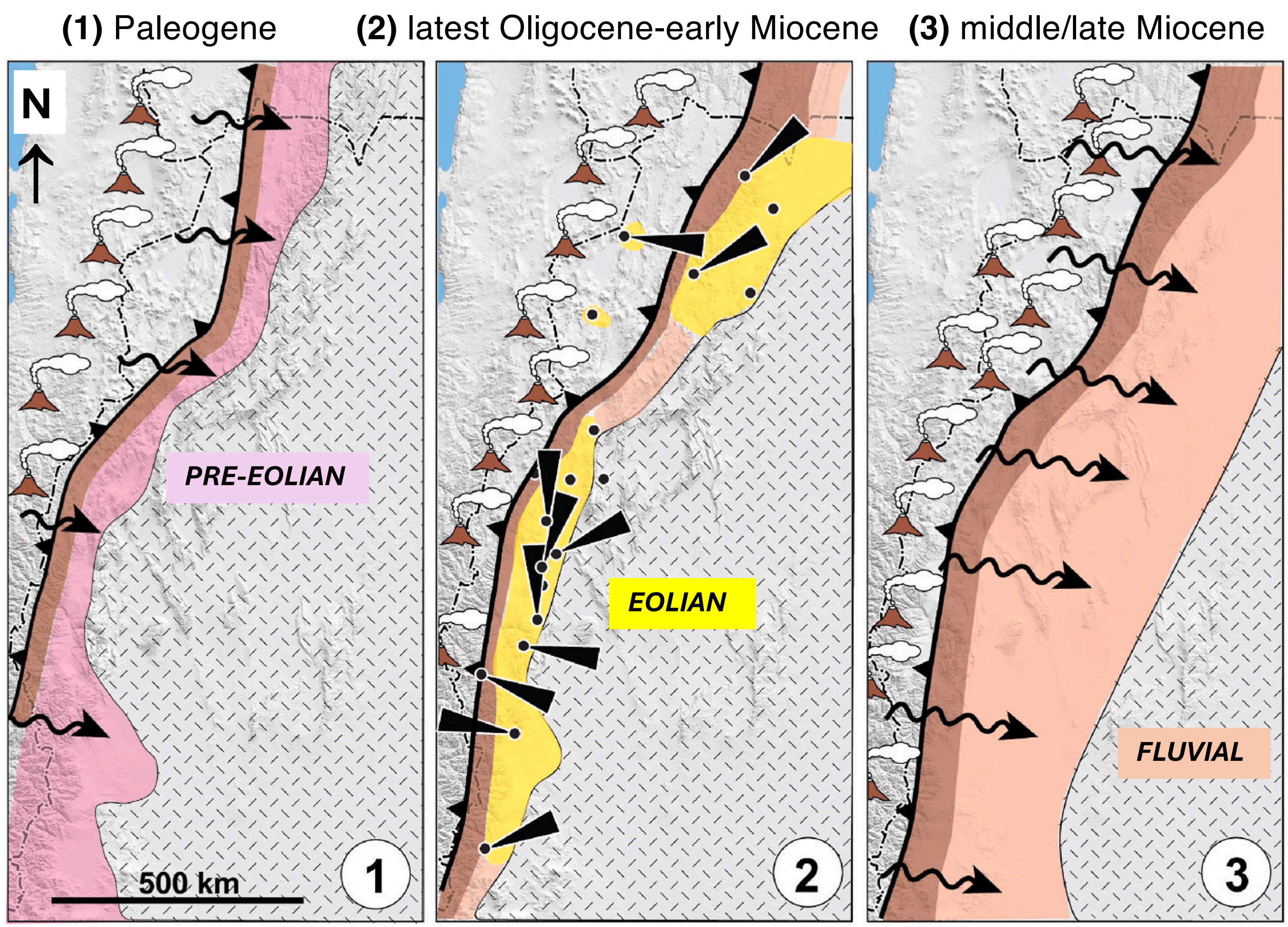
# DEPOSITIONAL RECONSTRUCTION

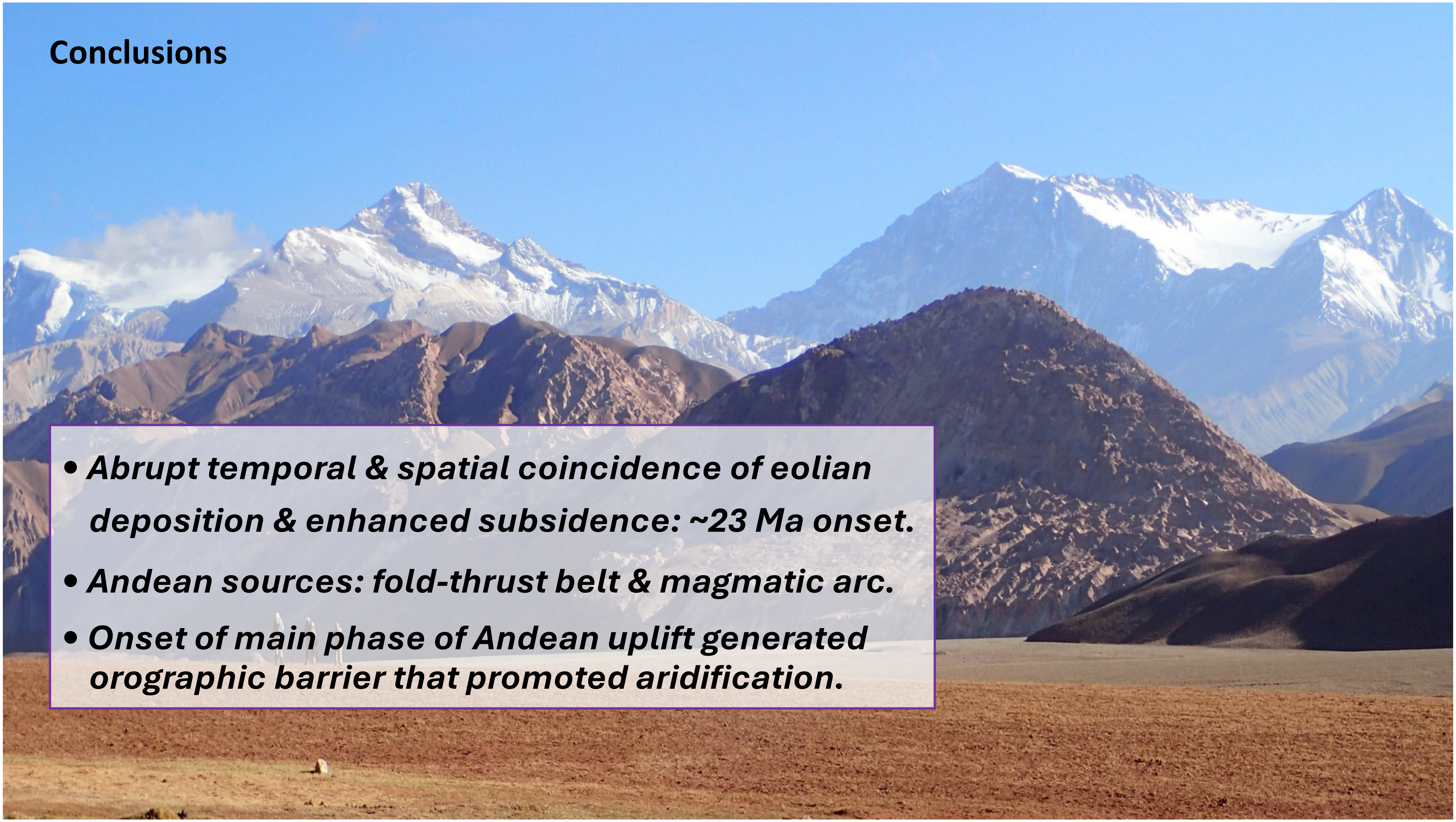
***Co-occurrence in time & space***

- Onset of eolian deposition
- Onset of rapid accumulation
- Onset of main phase of Andean shortening and flexural loading.

*We propose that establishment of topographic barrier promoted regional aridification.*

*Thus, Andean geodynamics = important influence on eolian conditions.*





## Conclusions

- ***Abrupt temporal & spatial coincidence of eolian deposition & enhanced subsidence: ~23 Ma onset.***
- ***Andean sources: fold-thrust belt & magmatic arc.***
- ***Onset of main phase of Andean uplift generated orographic barrier that promoted aridification.***