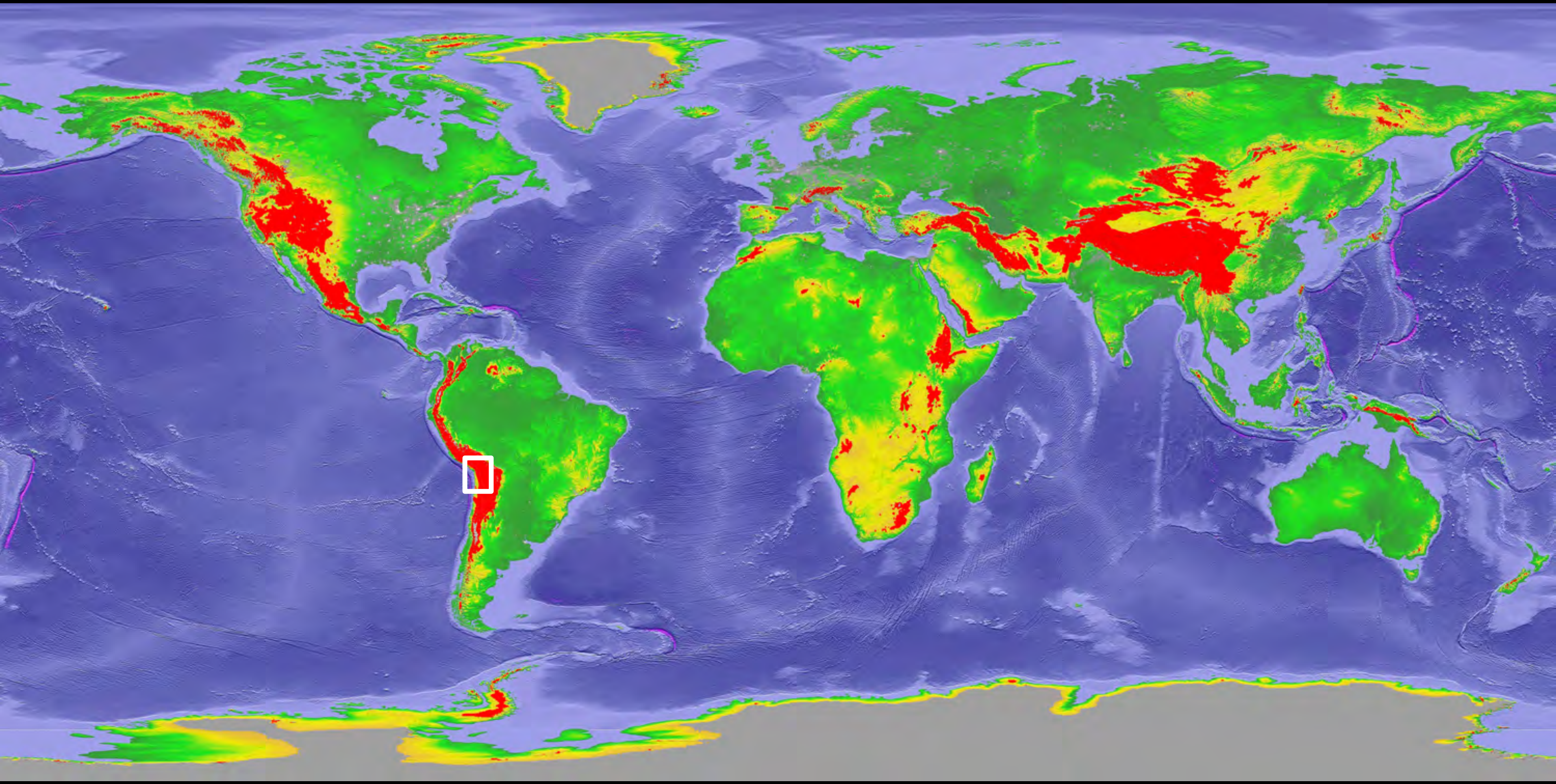
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

GZG Geowissenschaftliches Zentrum Göttingen

Ignimbrite flare-ups in the Central Andes: Crustal sources and processes of magma generation

Gerhard Wörner,
Elena Belousova, Simon Turner, Jelte Kemann,
Axel Schmitt, Axel Gerdes, Shan deSilva



Layout:

1. Geological setting (review, maybe skipped)
2. Ignimbrite compositions: AIDA data base: (review, maybe skipped)
   Ages, volume and composition through time and space
3. Evidence for large crustal contributions (review, maybe skipped)
4. Zircon U/Pb dating combined with O-isotope and Hf-isotope analyses (new data)

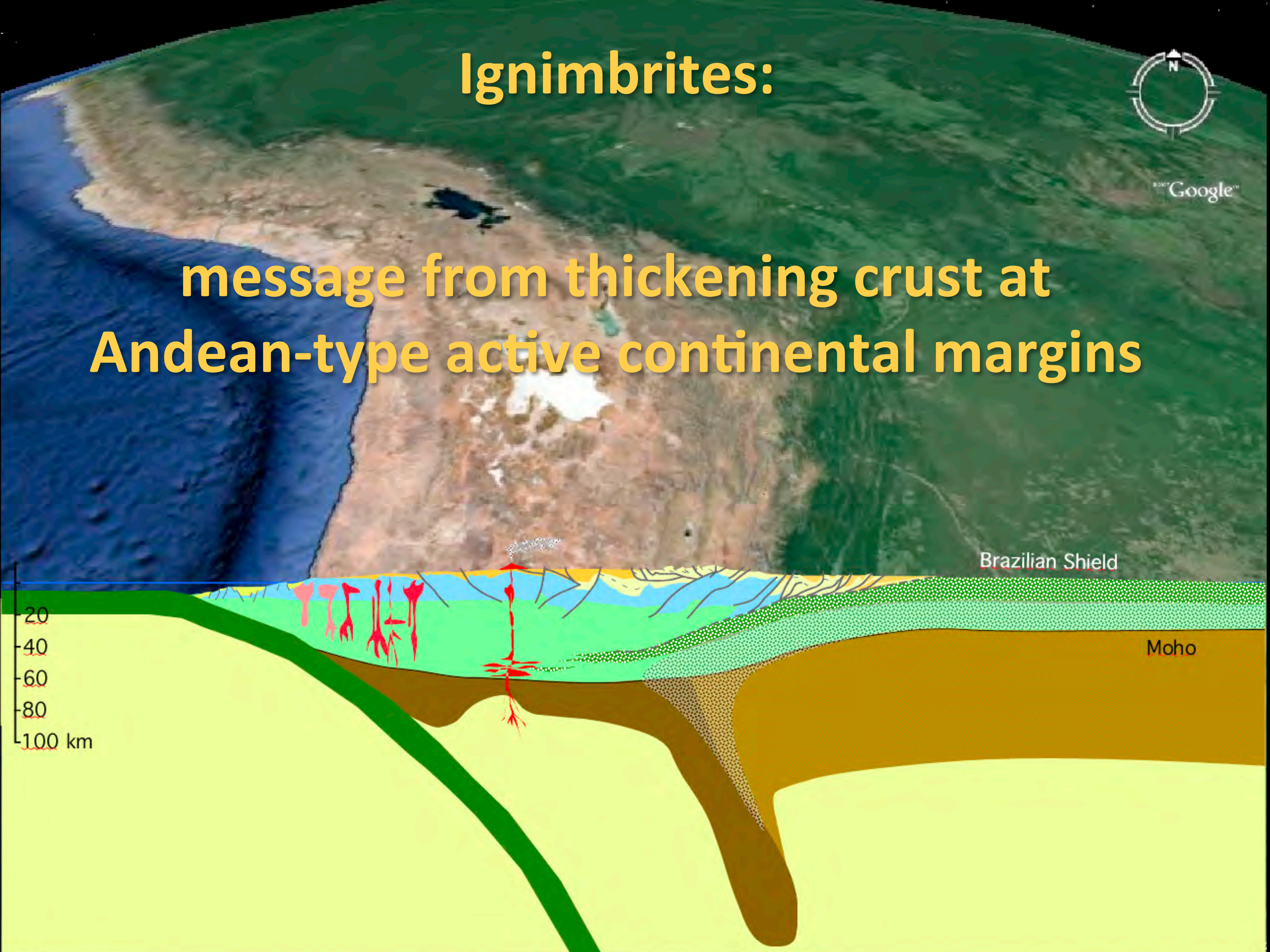
Results (in a nutshell)

-> Contributions of large volume ignimbrite magmas increase from 20 to 70% with thermal maturation of increasingly thickened Andean crust

-> Individual ignimbrite units are isotopically heterogeneous and are amalgamations of crustal melts from distinct Proterozoic sources w/r to age and composition

Ignimbrites:

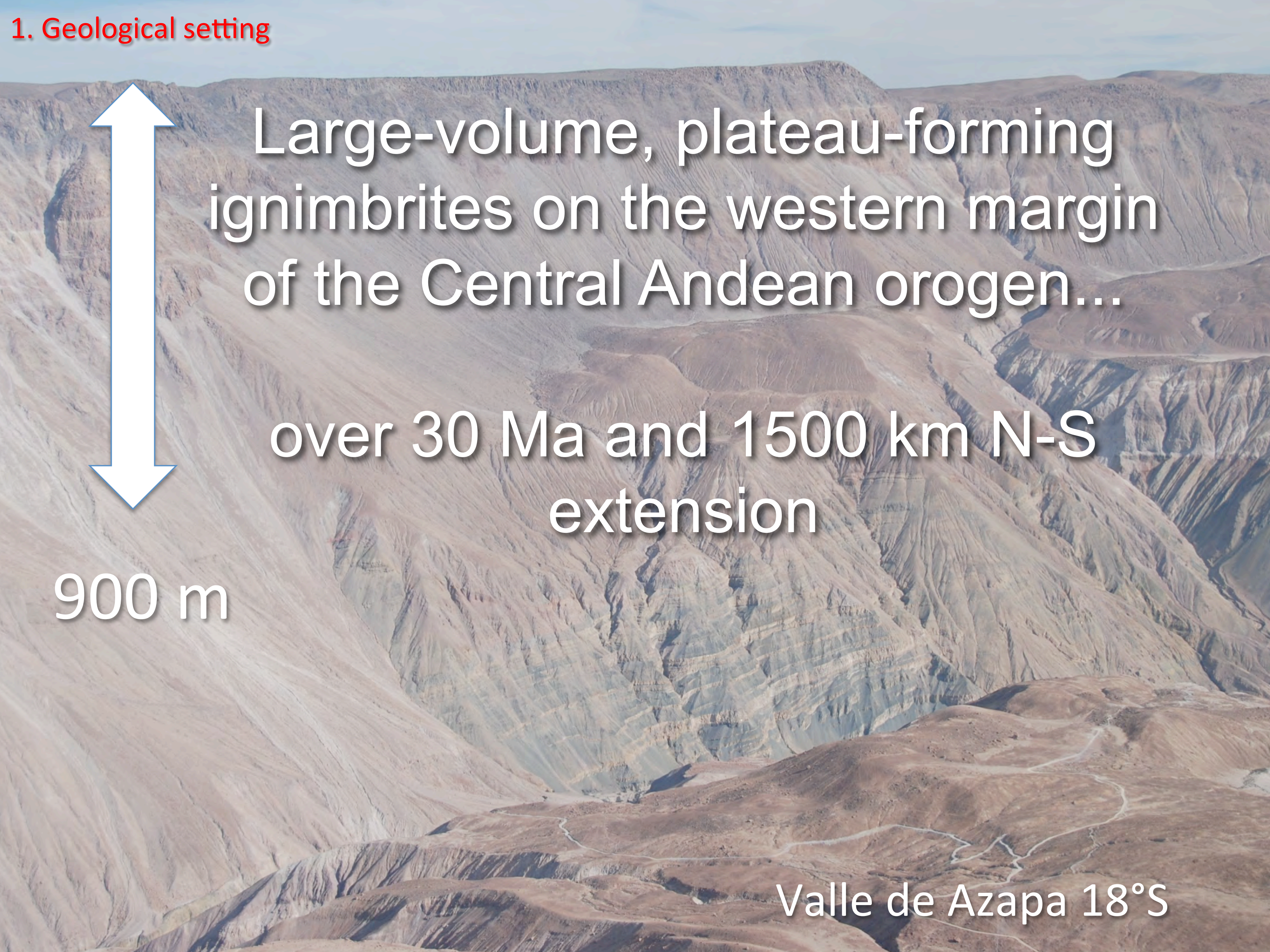
message from thickening crust at Andean-type active continental margins



1. Geological setting

Large-volume, plateau-forming ignimbrites on the western margin of the Central Andean orogen...

over 30 Ma and 1500 km N-S extension



1. Geological setting

Cuno Cuno Section

with > 24 Ma old marine sediments at 1900 m (S. Peru)

Uplift, erosion and sedimentation prior to „ignimbrite flares“

1. Geological setting

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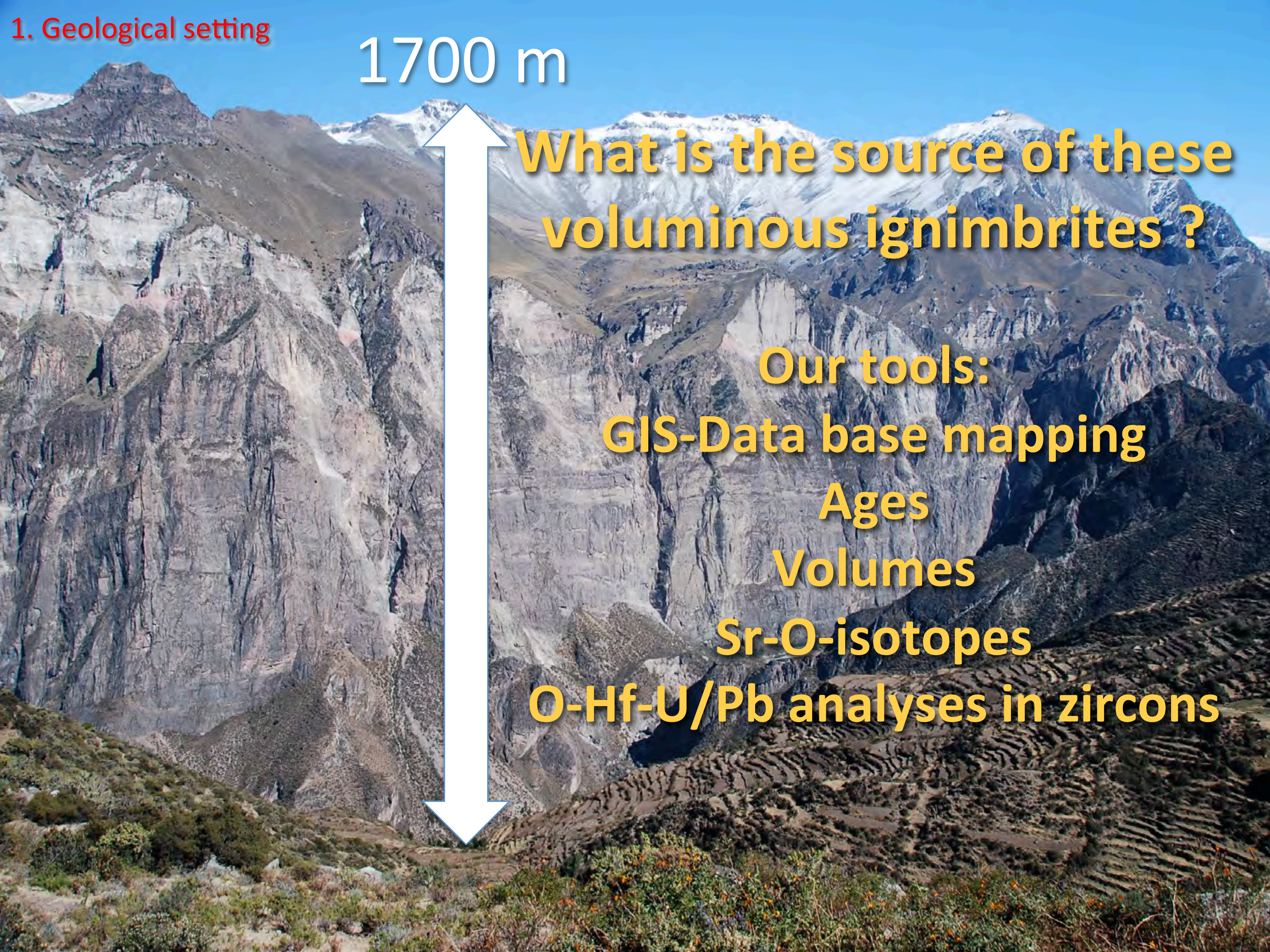

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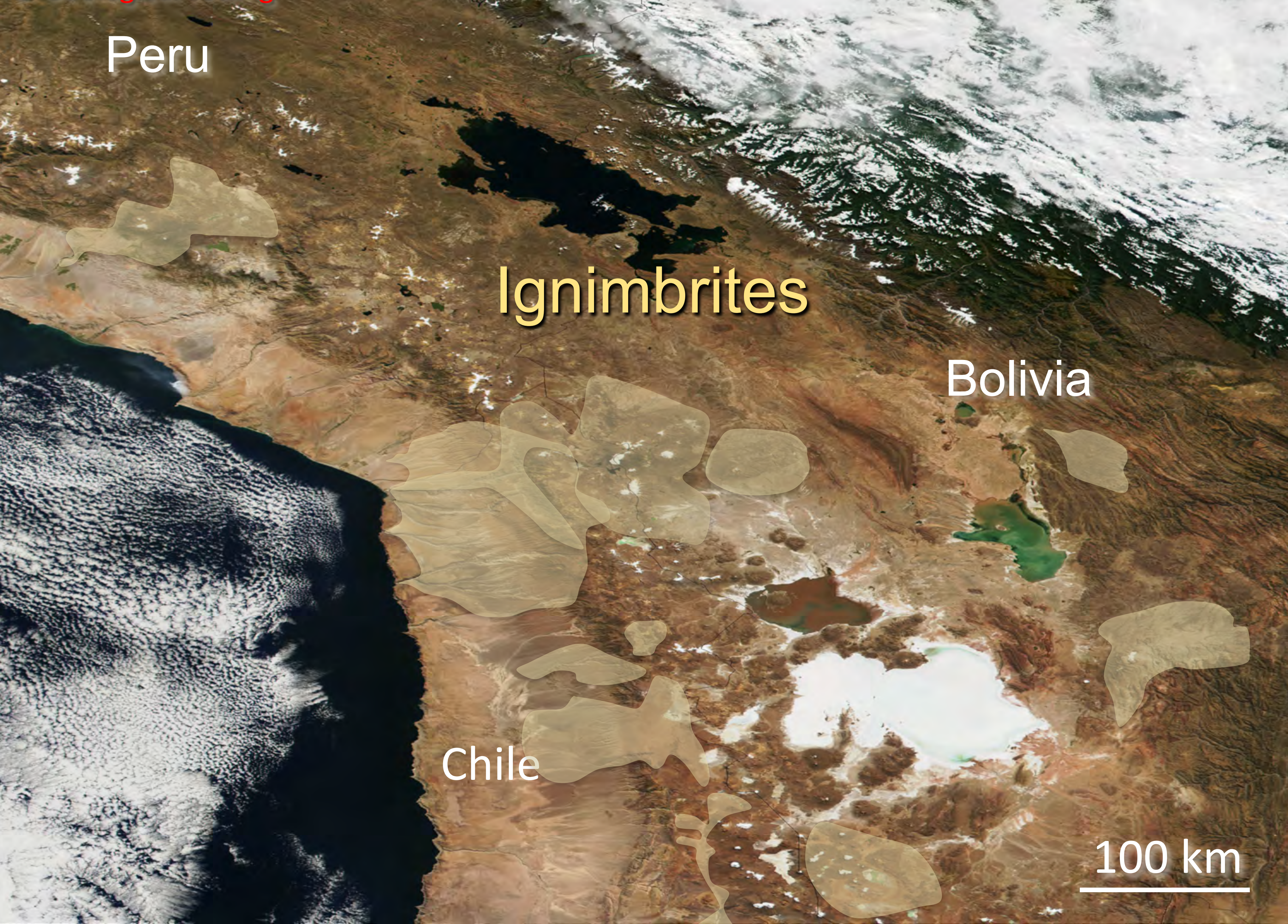

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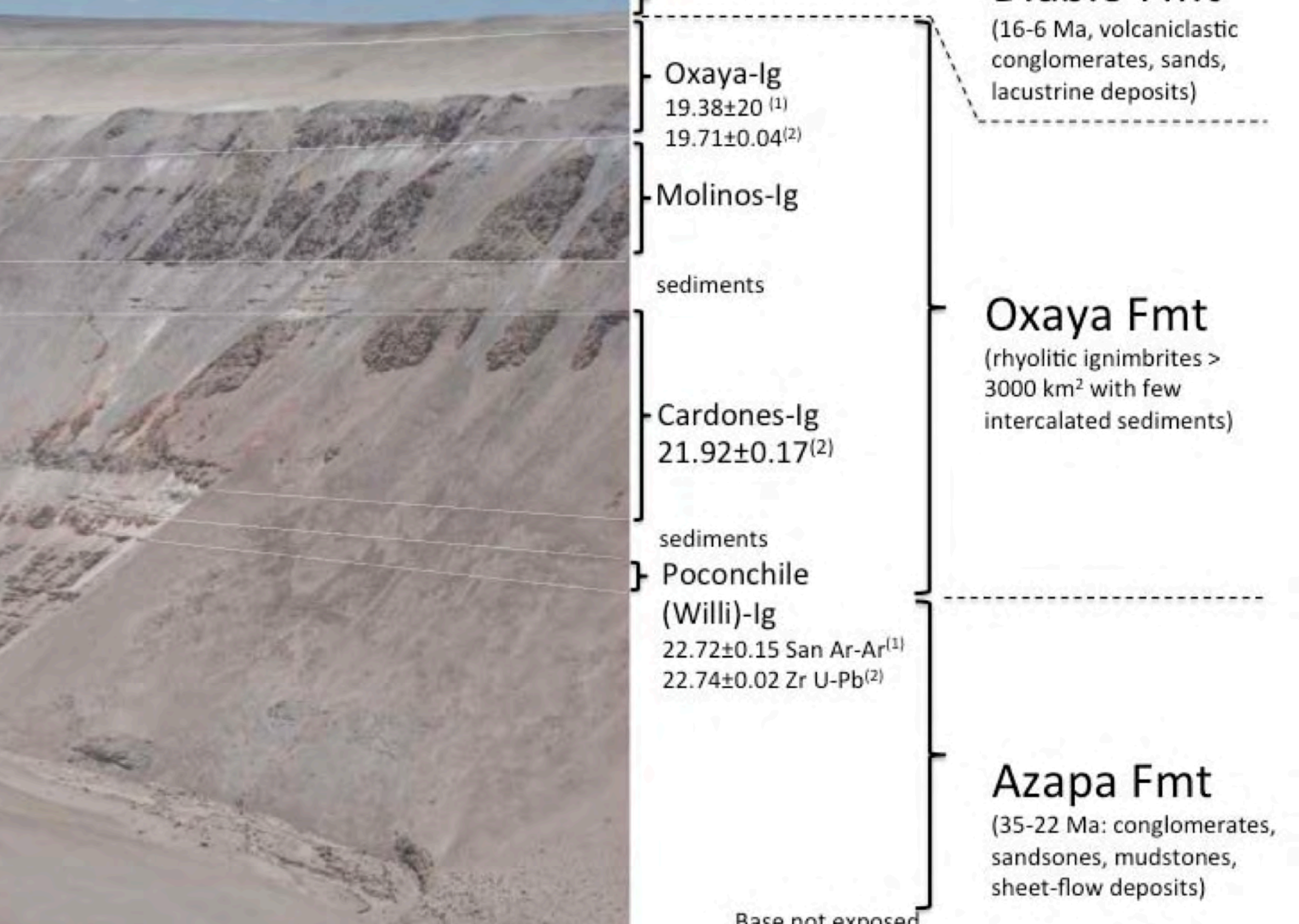

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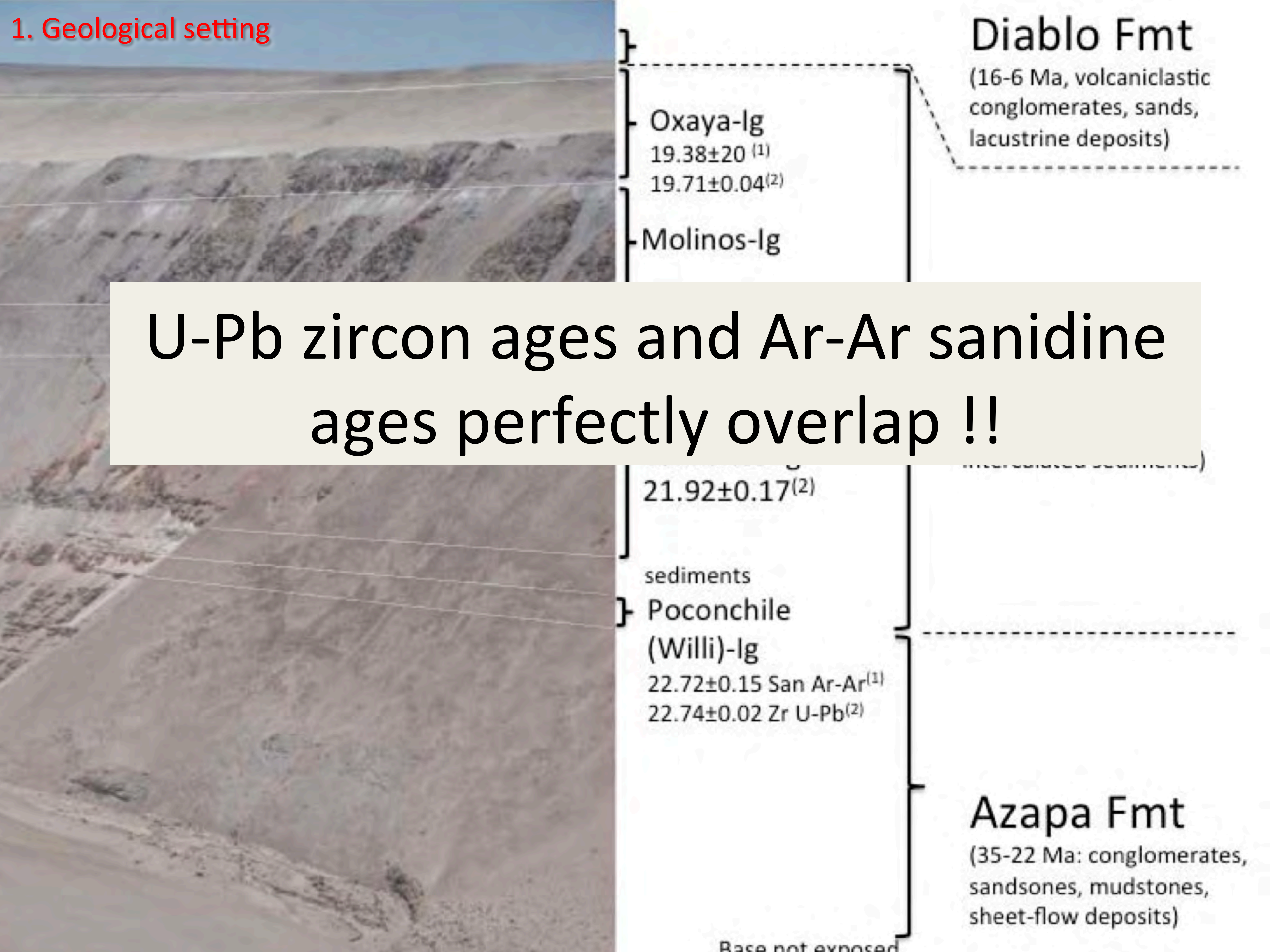


U-Pb zircon ages and Ar-Ar sanidine ages perfectly overlap !!

Temporal and compositional evolution of „ignimbrite flares“

Based on our Andes Ignimbrite Database (AIDA)

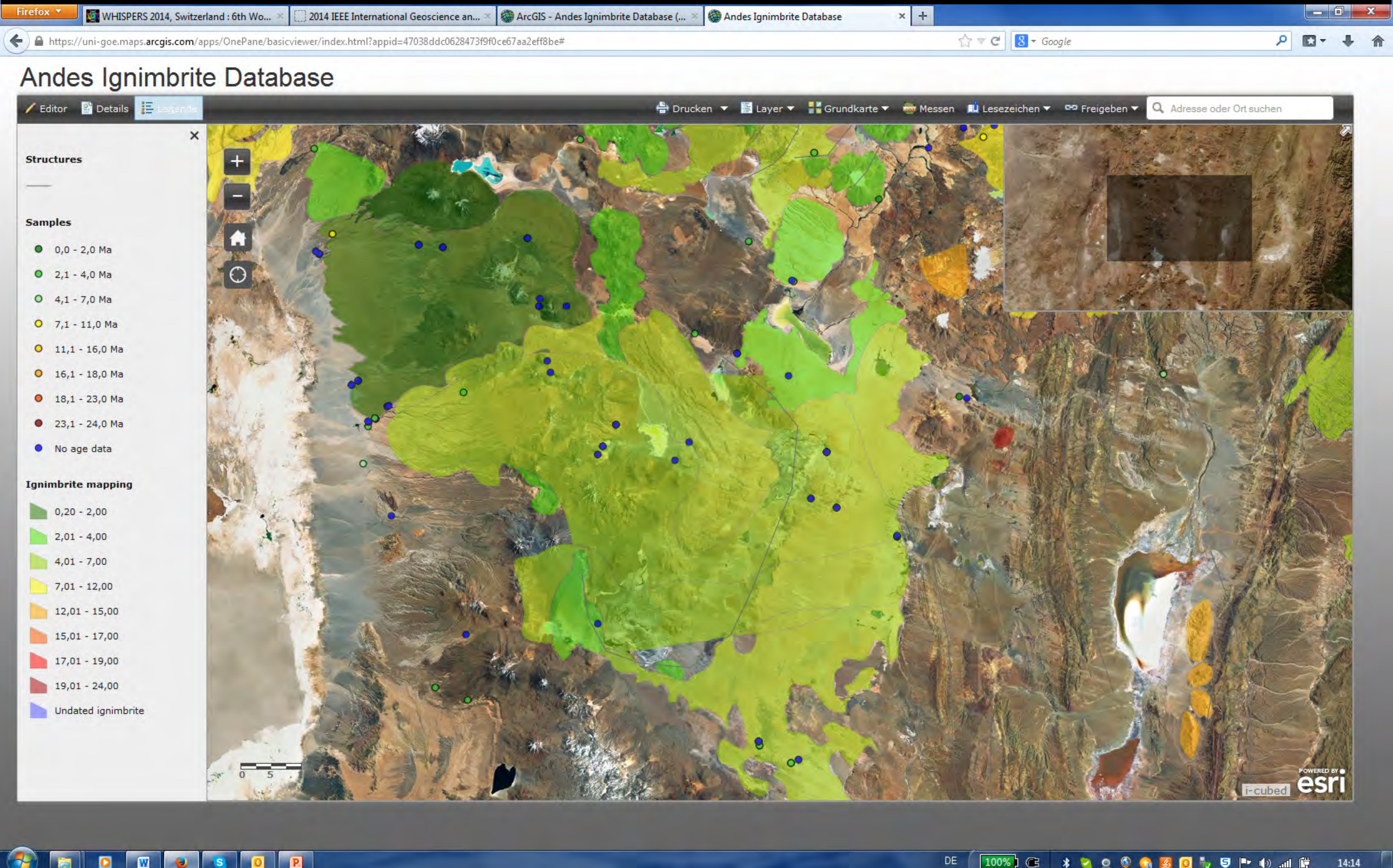
More than 200 ignimbrite sheets GIS-mapped,

more than 1600 samples with geochemical, isotopic, and many with age data

APVC, 3-10 Ma, 23°S

2. Ignimbrite compositions

…La Pacana caldera…as an AIDA - example



Brandmeier and Wörner AIDA Website

2. Ignimbrite compositions

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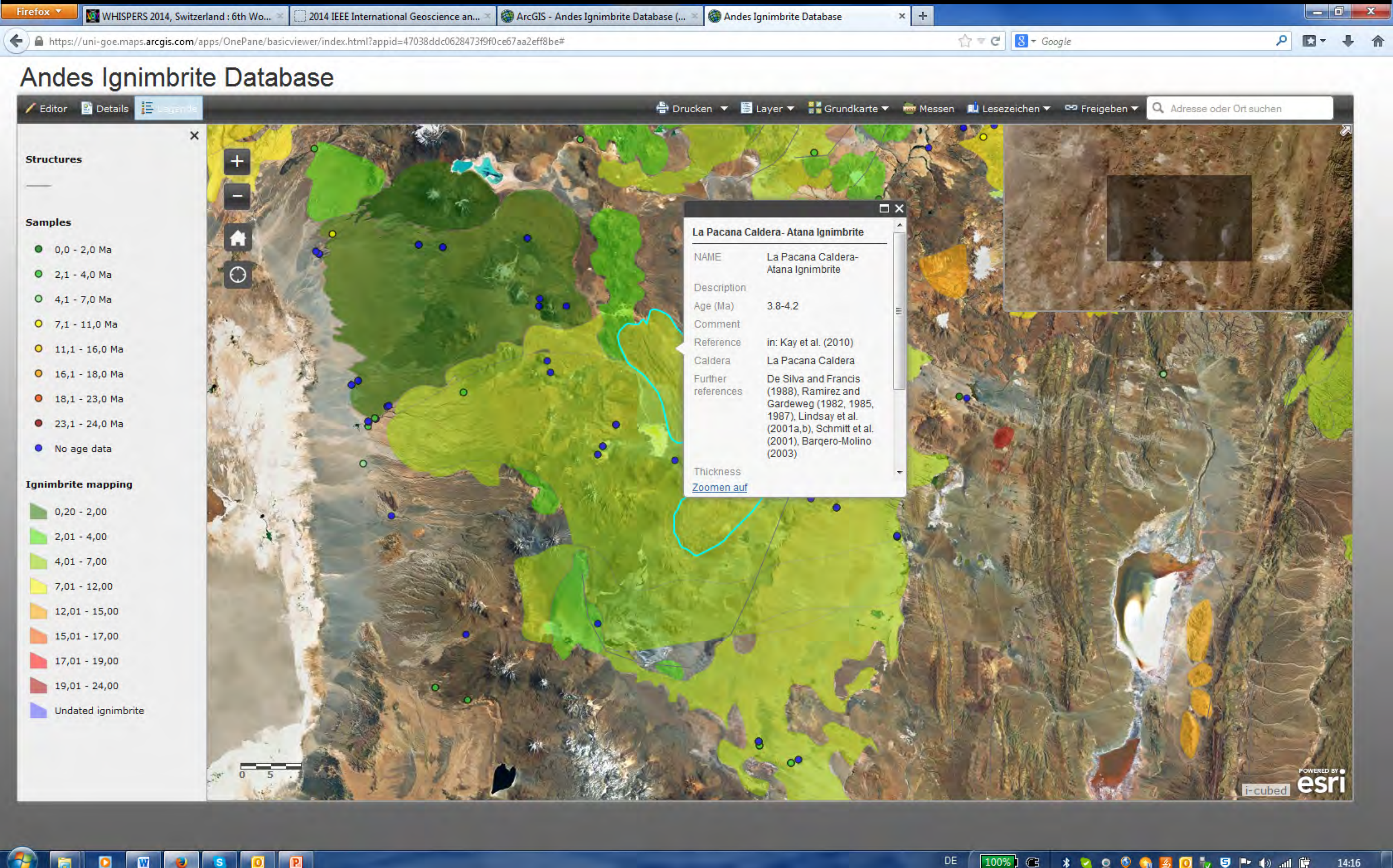

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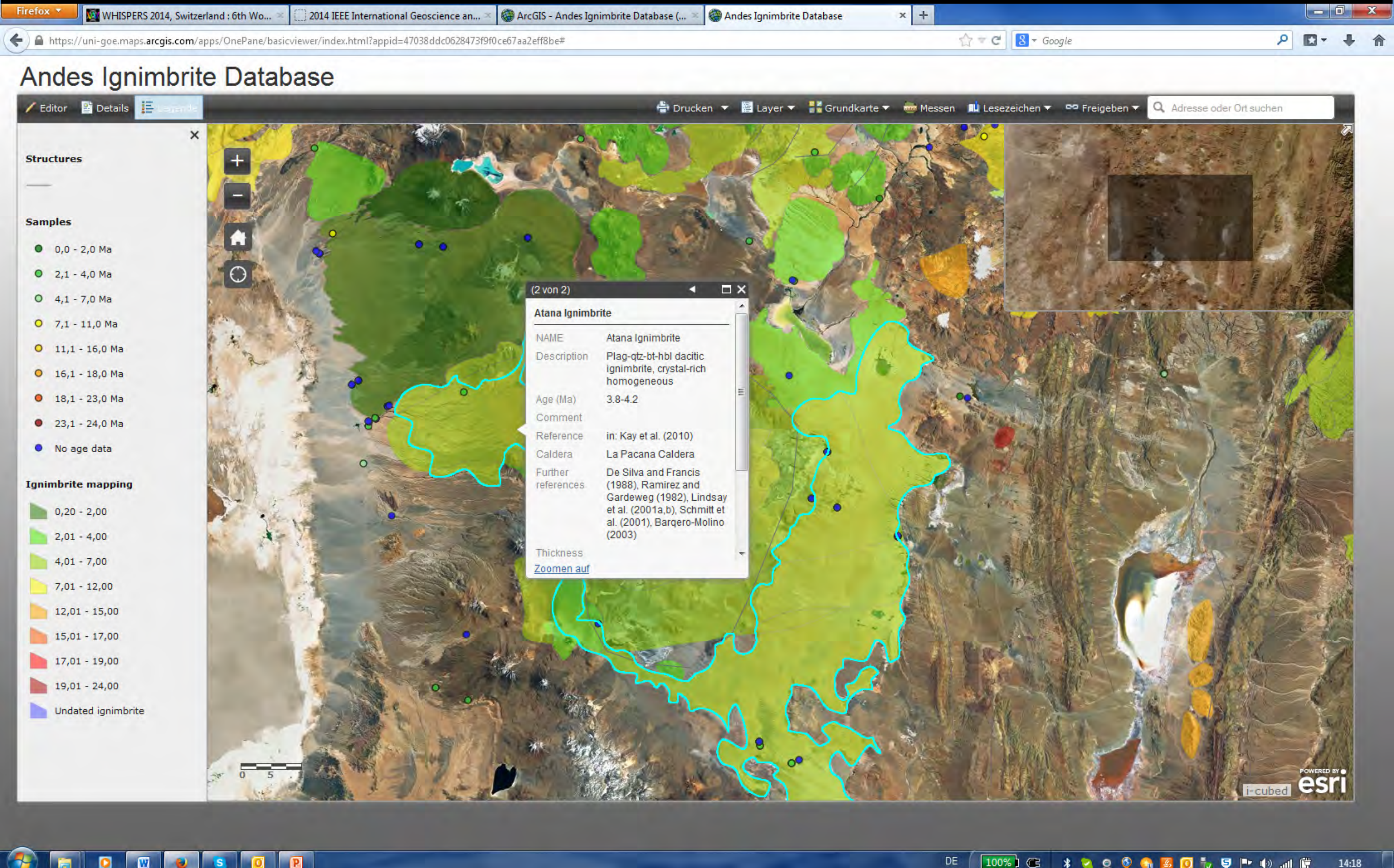

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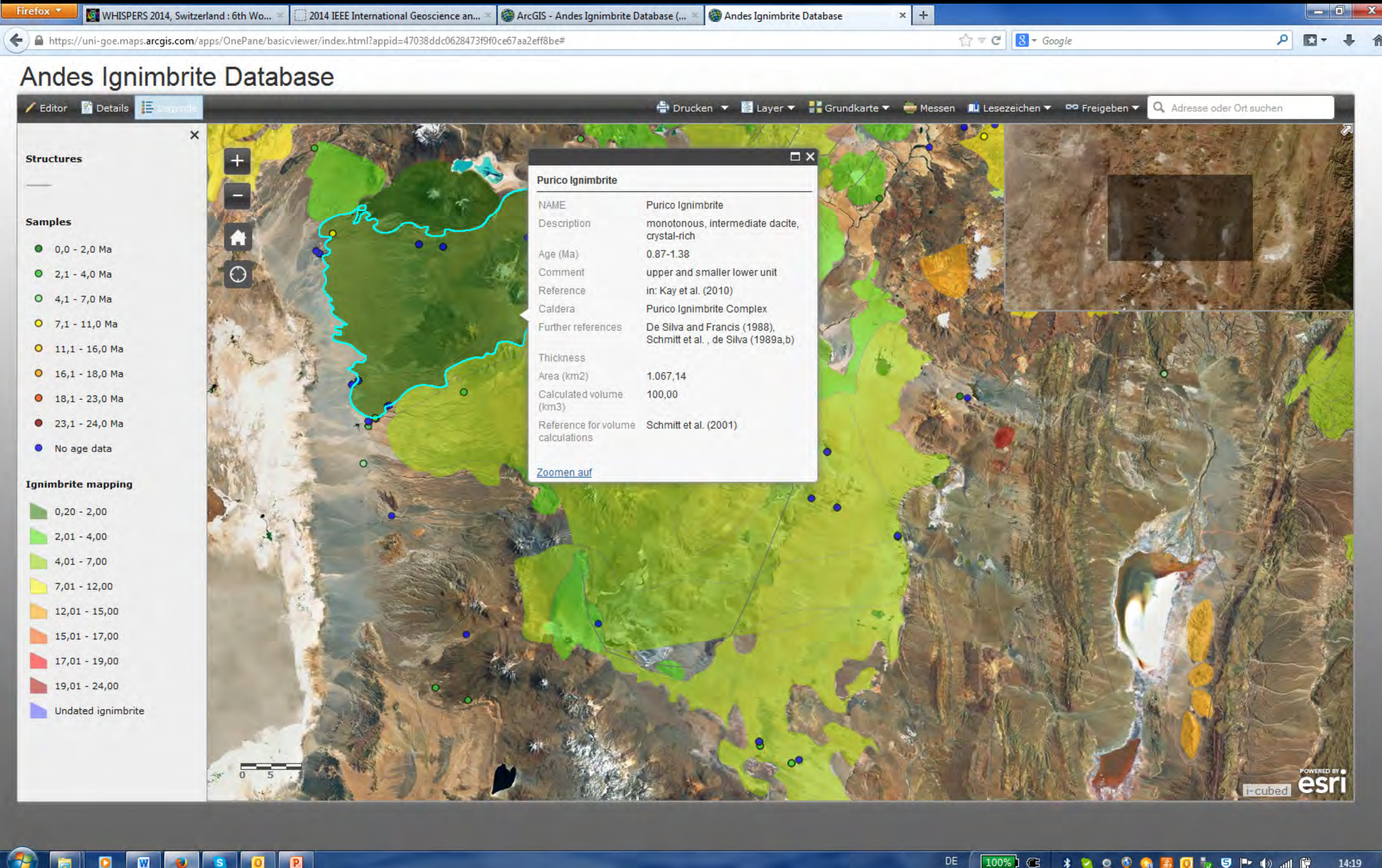
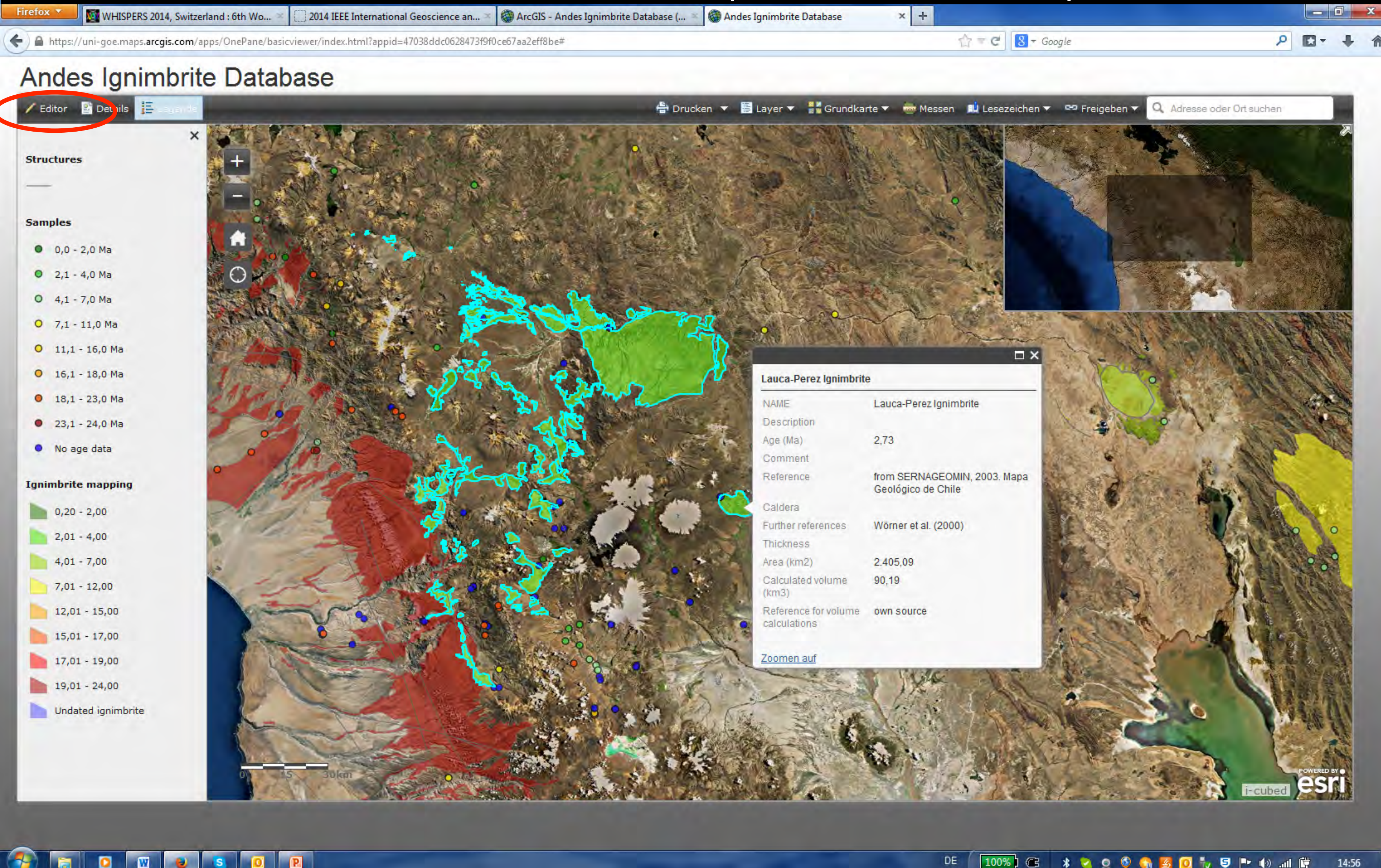


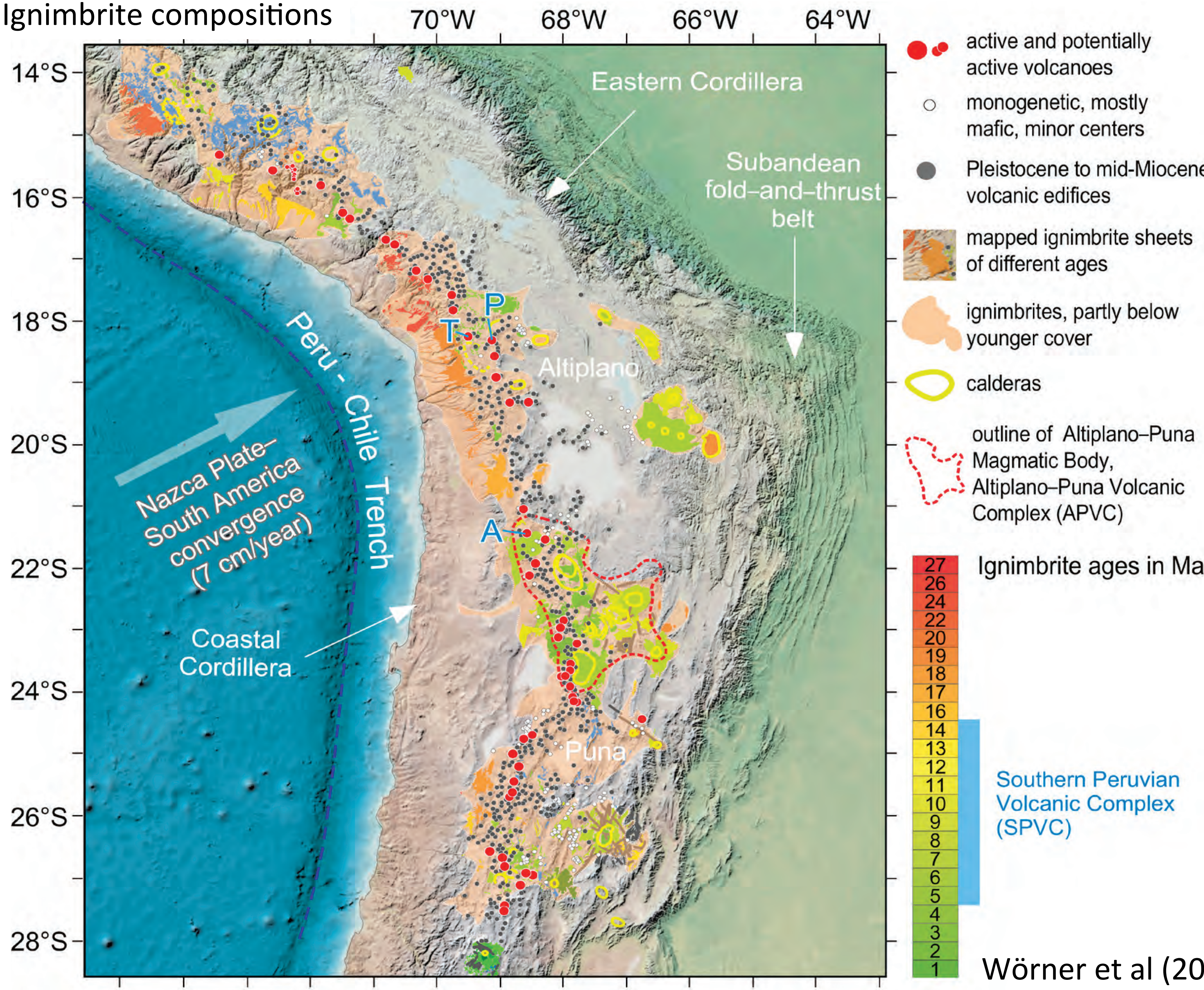
Brandmeier and Wörner AIDA Website

2. Ignimbrite compositions

Example Lauca and Oxaya ignimbrites : Edit and update the database by authorized users



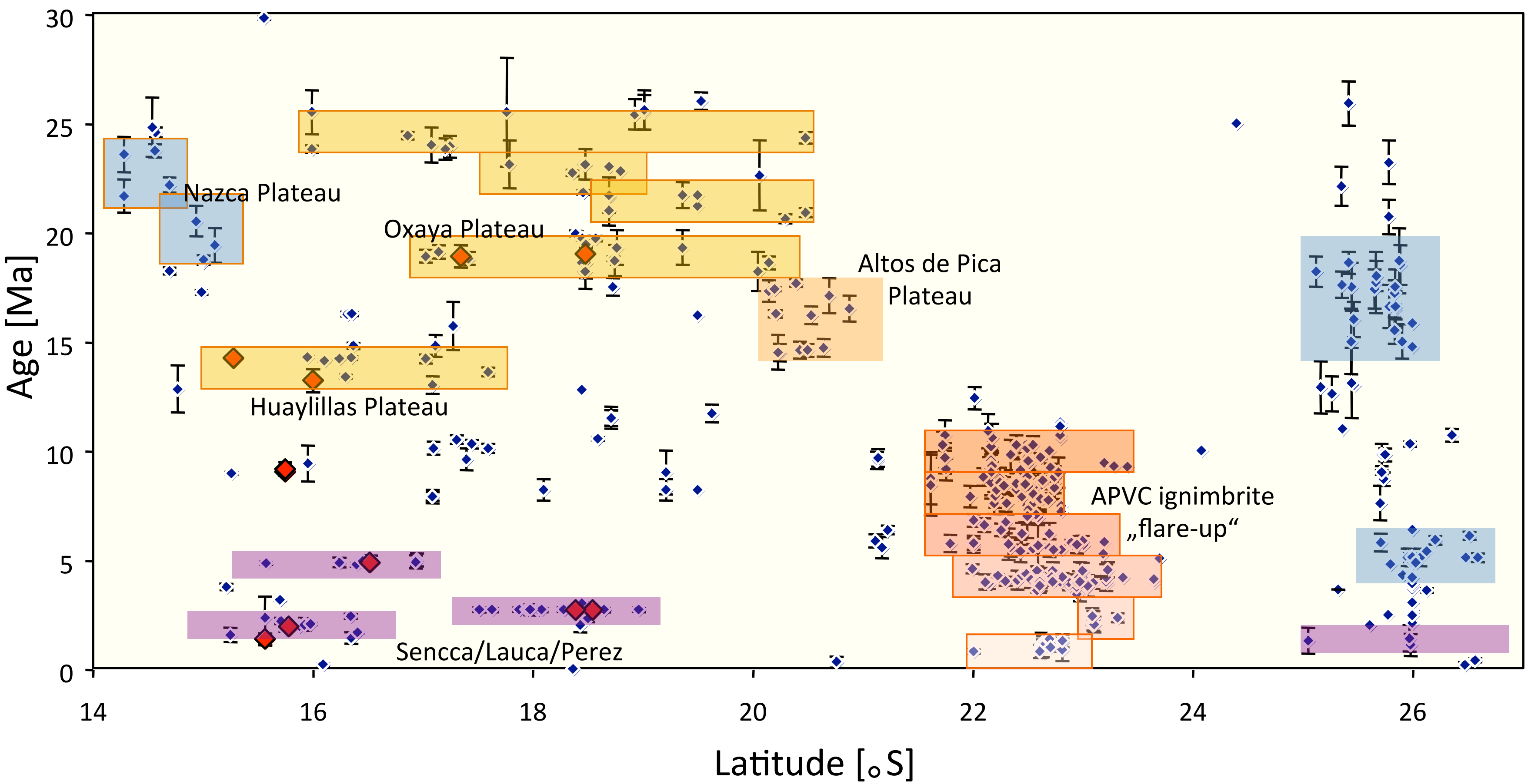
2. Ignimbrite compositions



Wörner et al (2018)

2. Ignimbrite compositions

Age migration of Central Andean Ignimbrites



Freymuth et al (2015)

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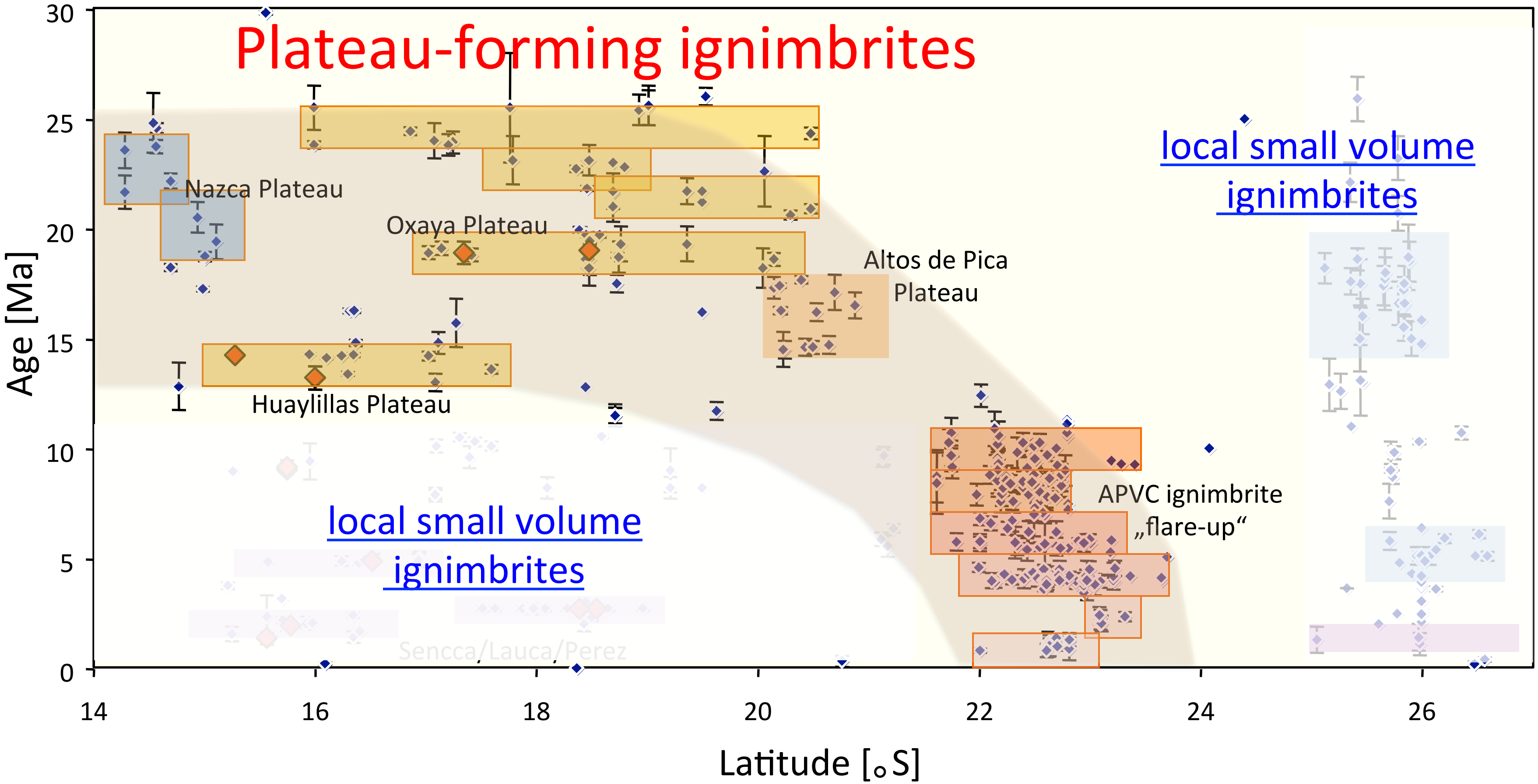
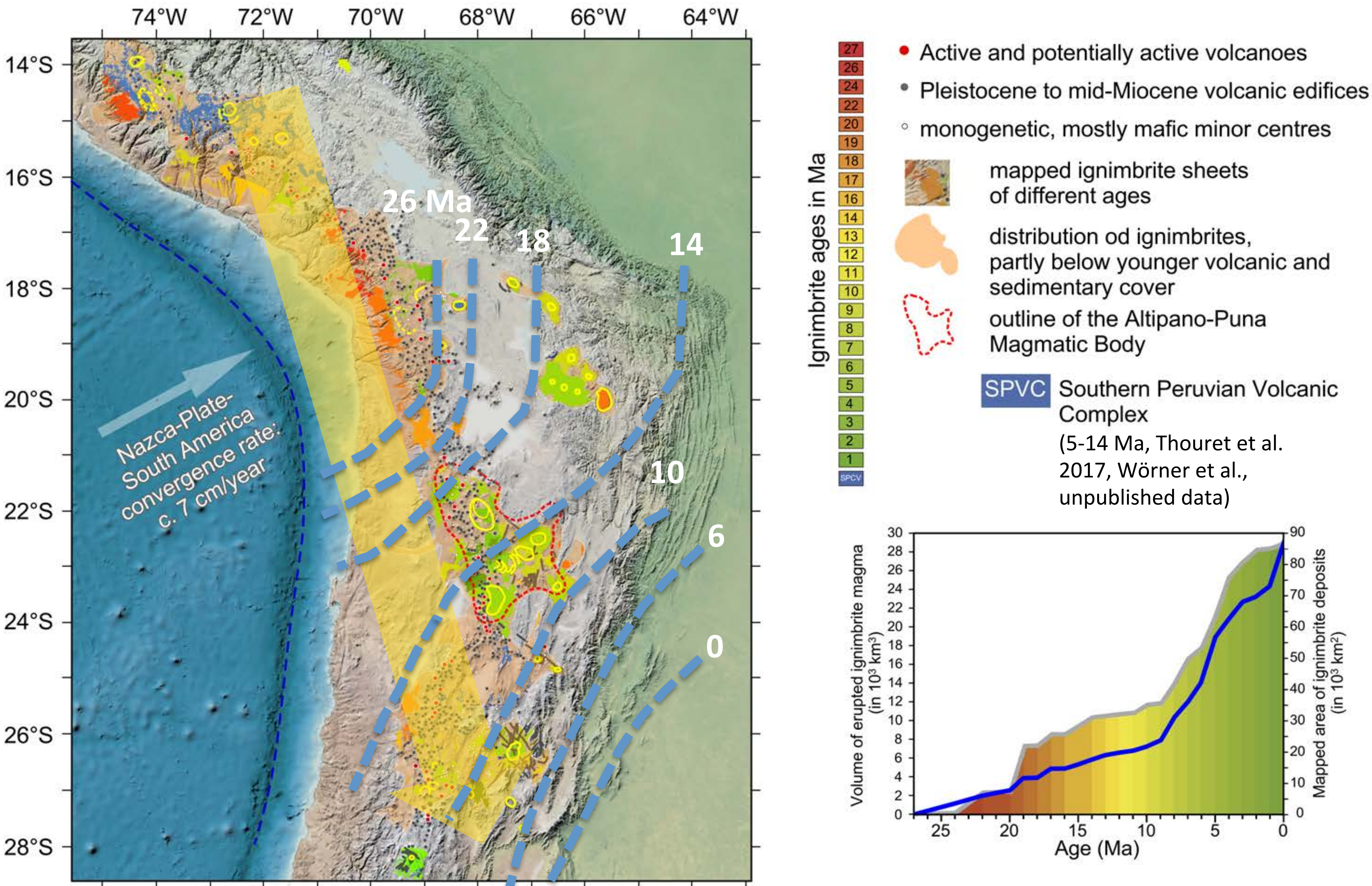


Freymuth et al (2015)

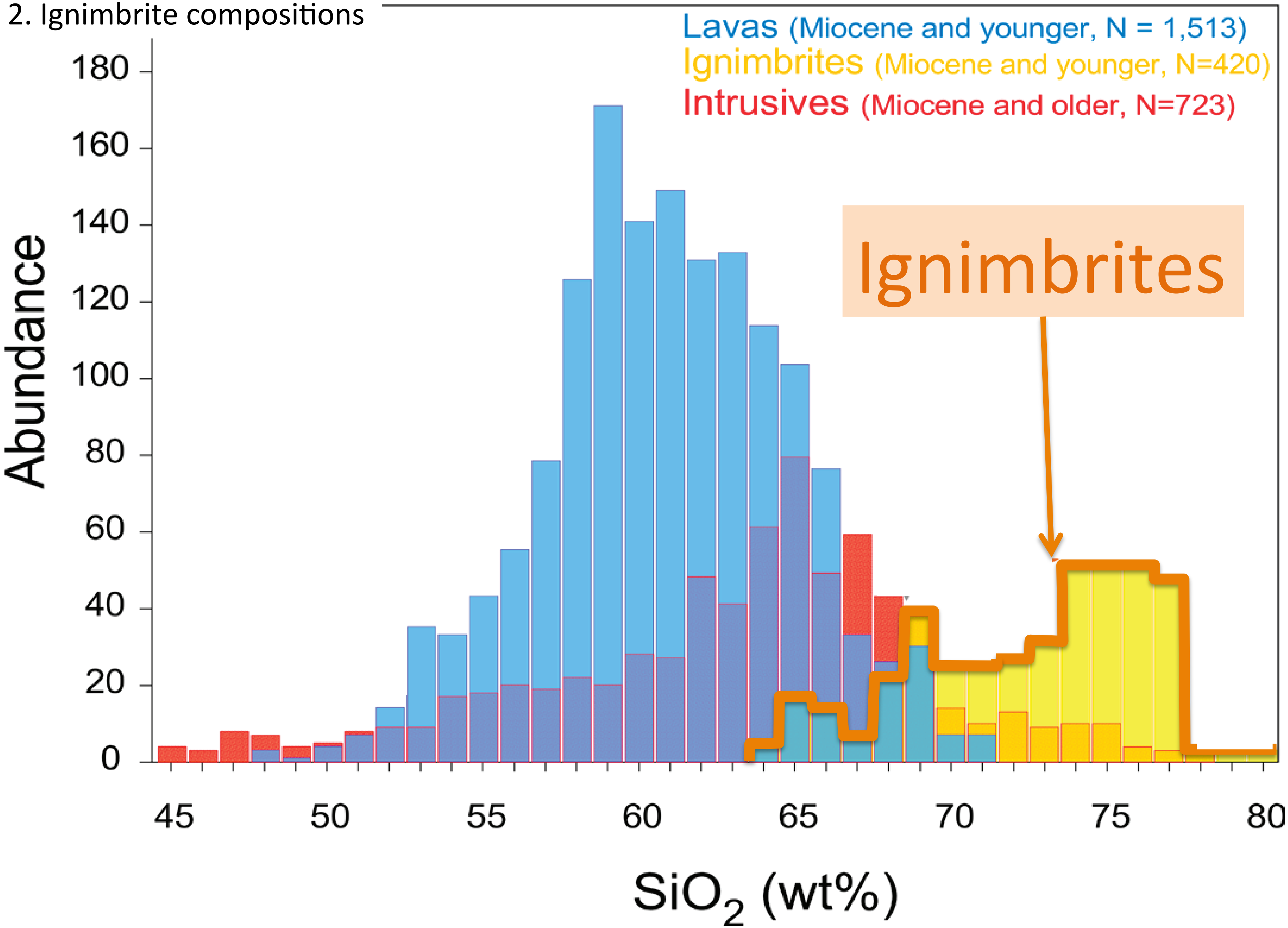
Age migration of Central Andean Ignimbrites



Freymuth et al (2015)

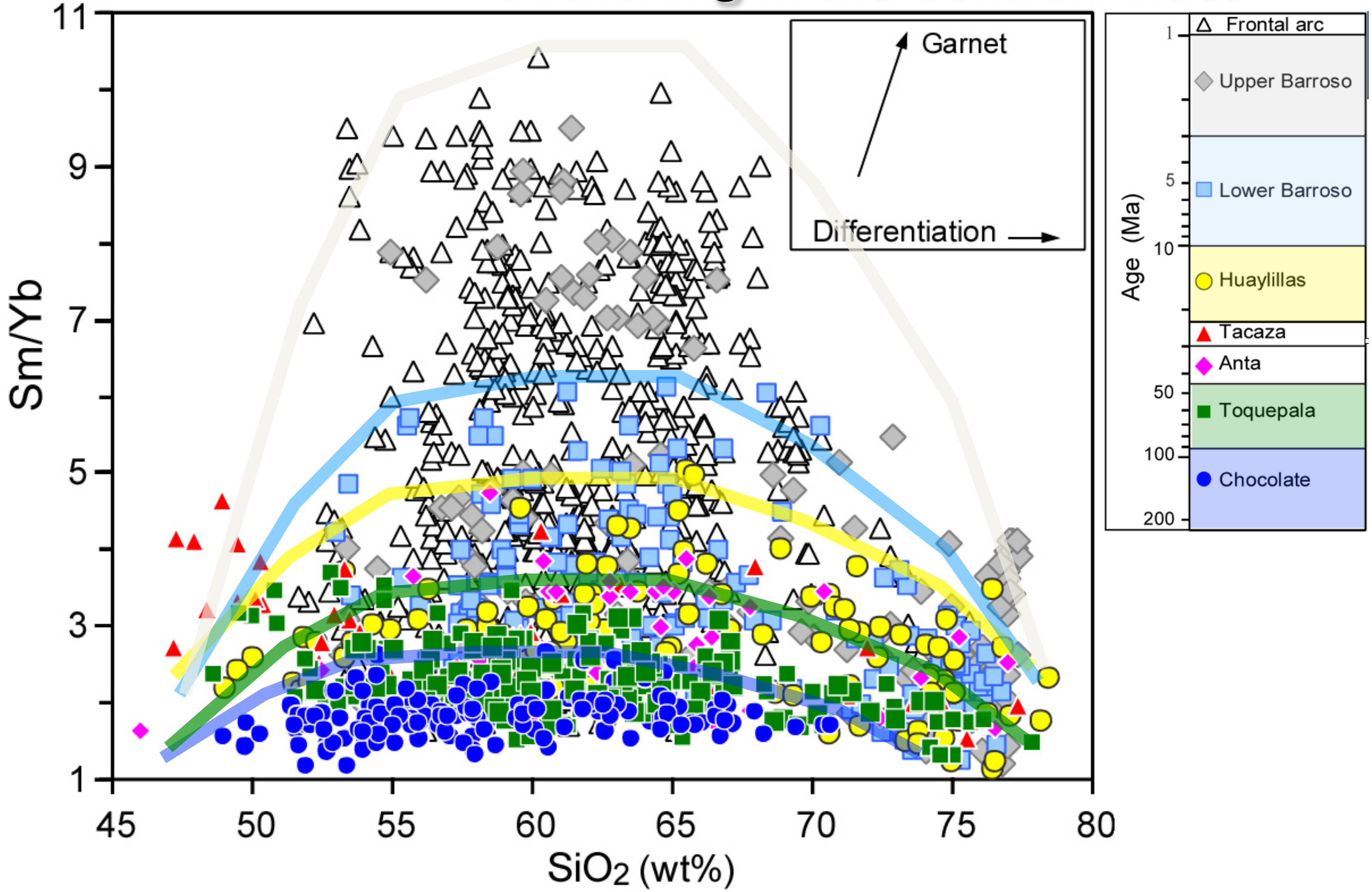
Magmatic compositions

2. Ignimbrite compositions



after Wörner et al (2018)

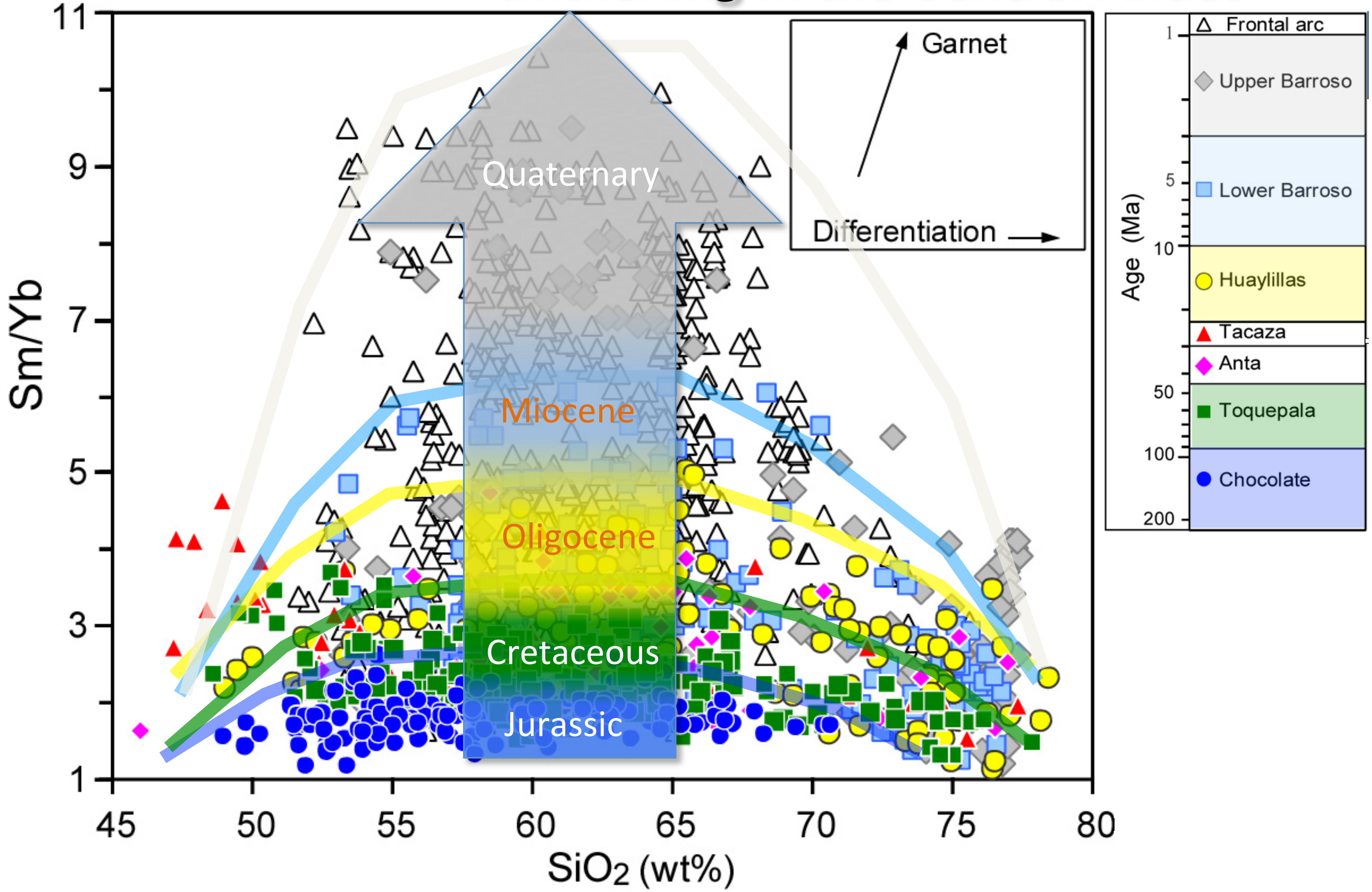
Systematic temporal changes in trace element patterns through time during crustal thickening in the Central Andes



Mamani et al. (2011) Geol Soc Am Bull

2. Ignimbrite compositions

Systematic temporal changes in trace element patterns through time during crustal thickening in the Central Andes



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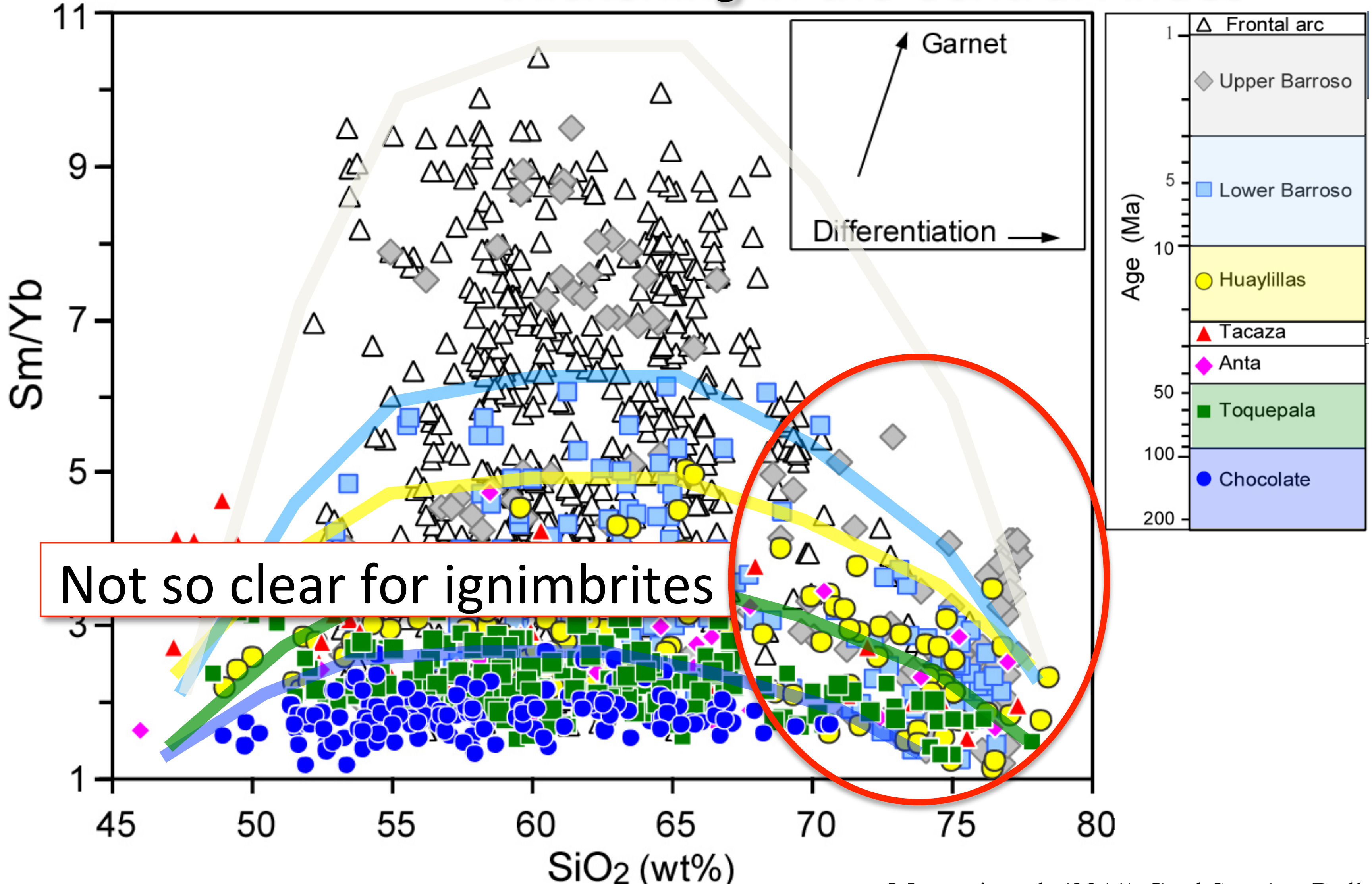
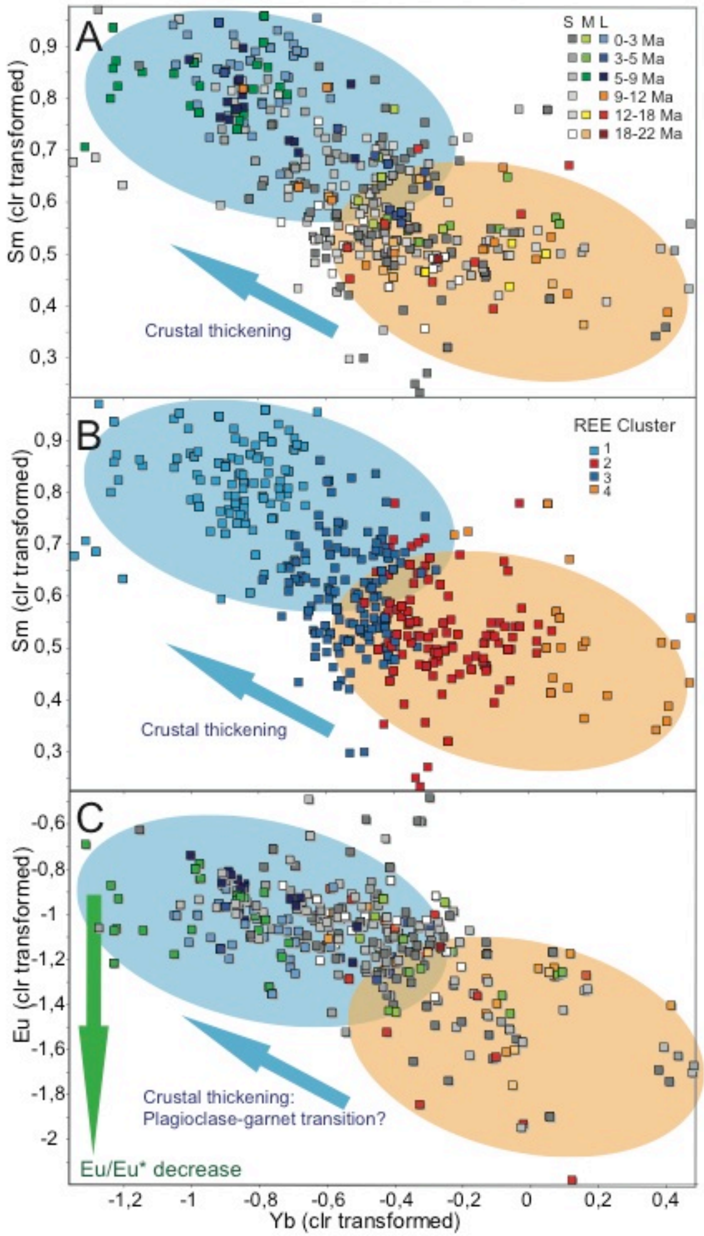
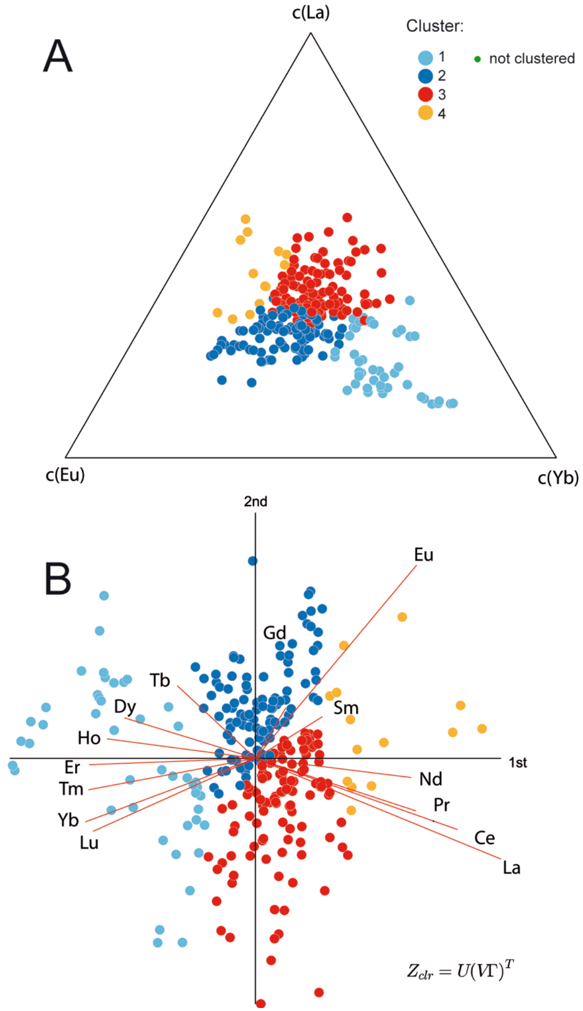
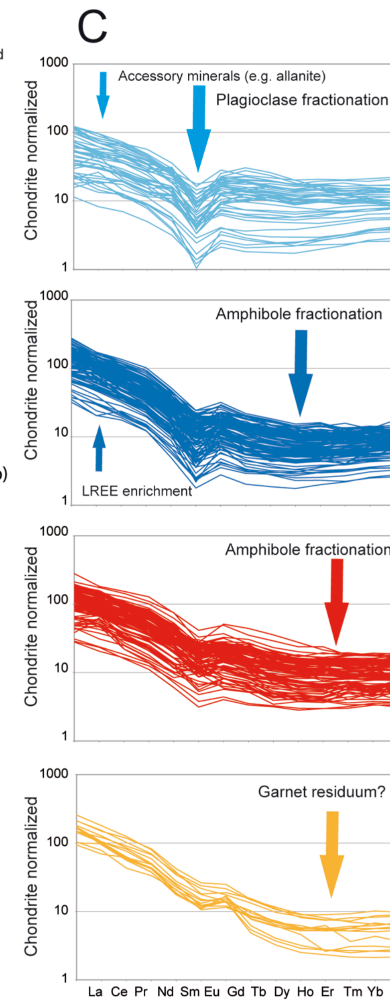


Mamani et al. (2011) Geol Soc Am Bull

Compositional variation related to crustal thickening







This study applies cluster analysis (CA) and linear discriminant analysis (LDA) on log-ratio transformed data.

Brandmeier and Wörner (1916)

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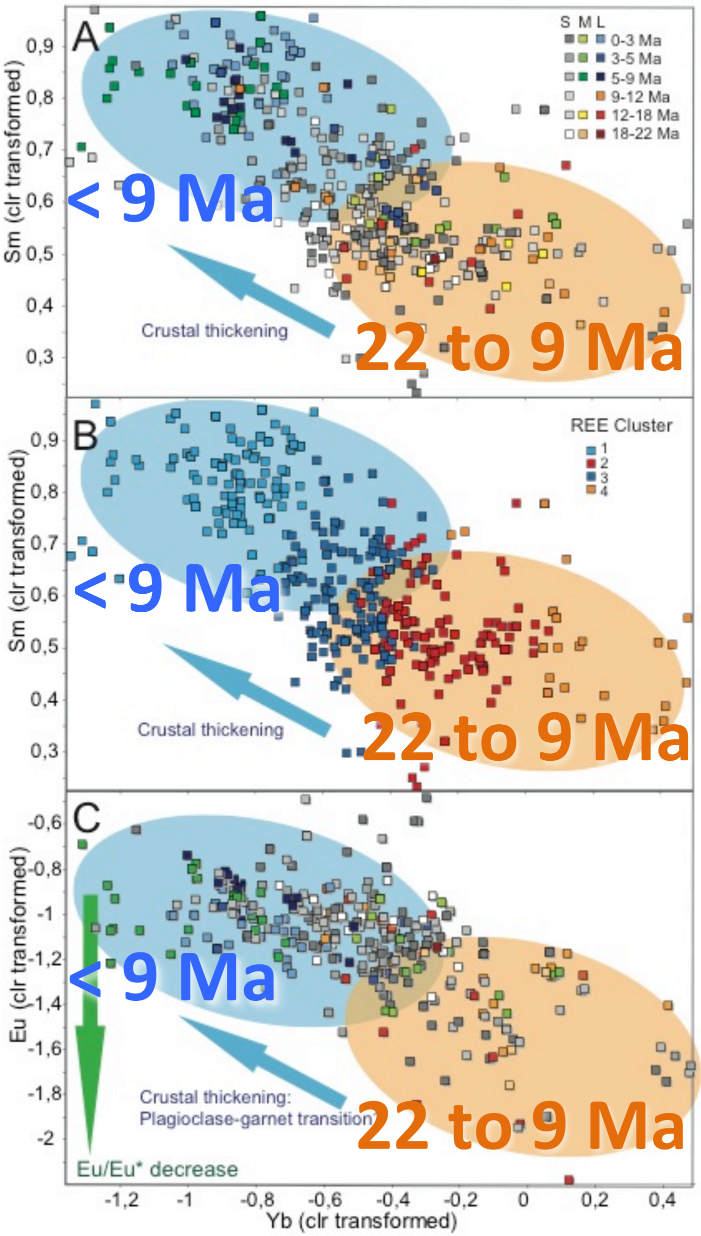

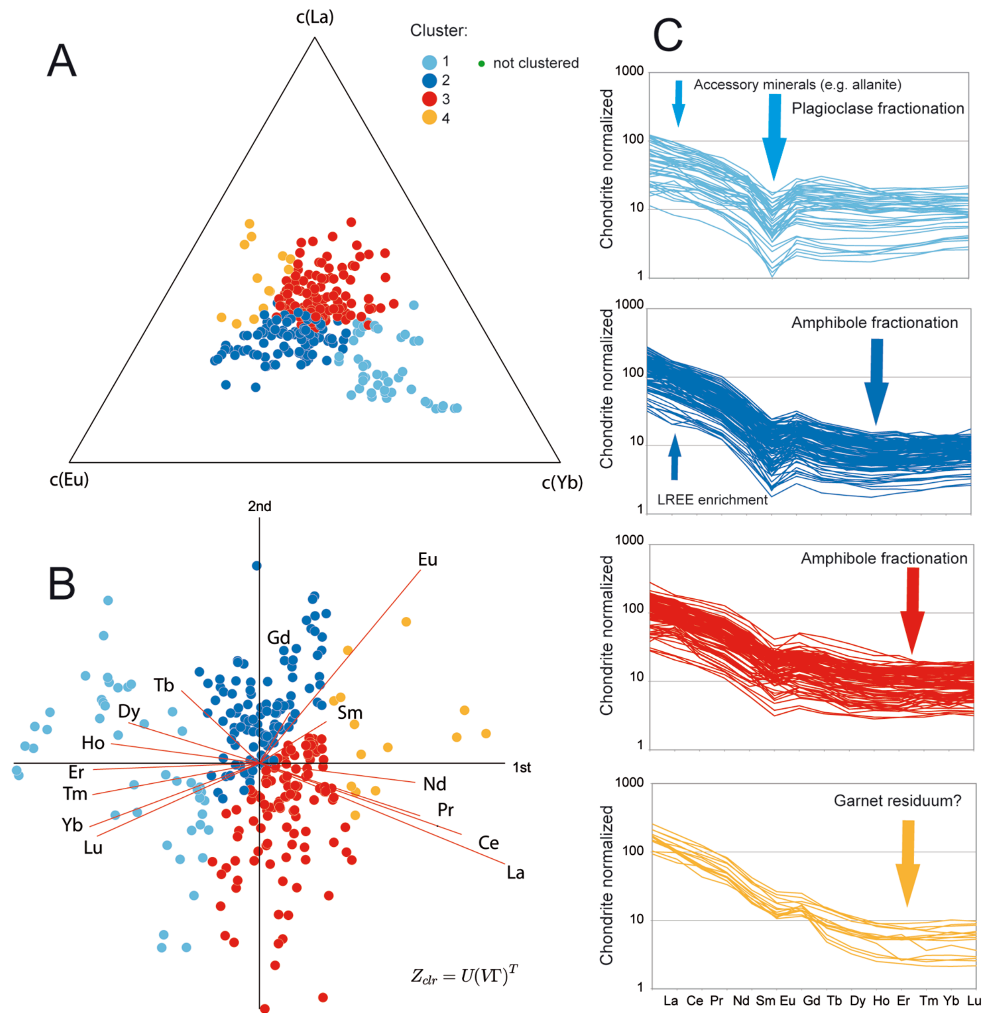

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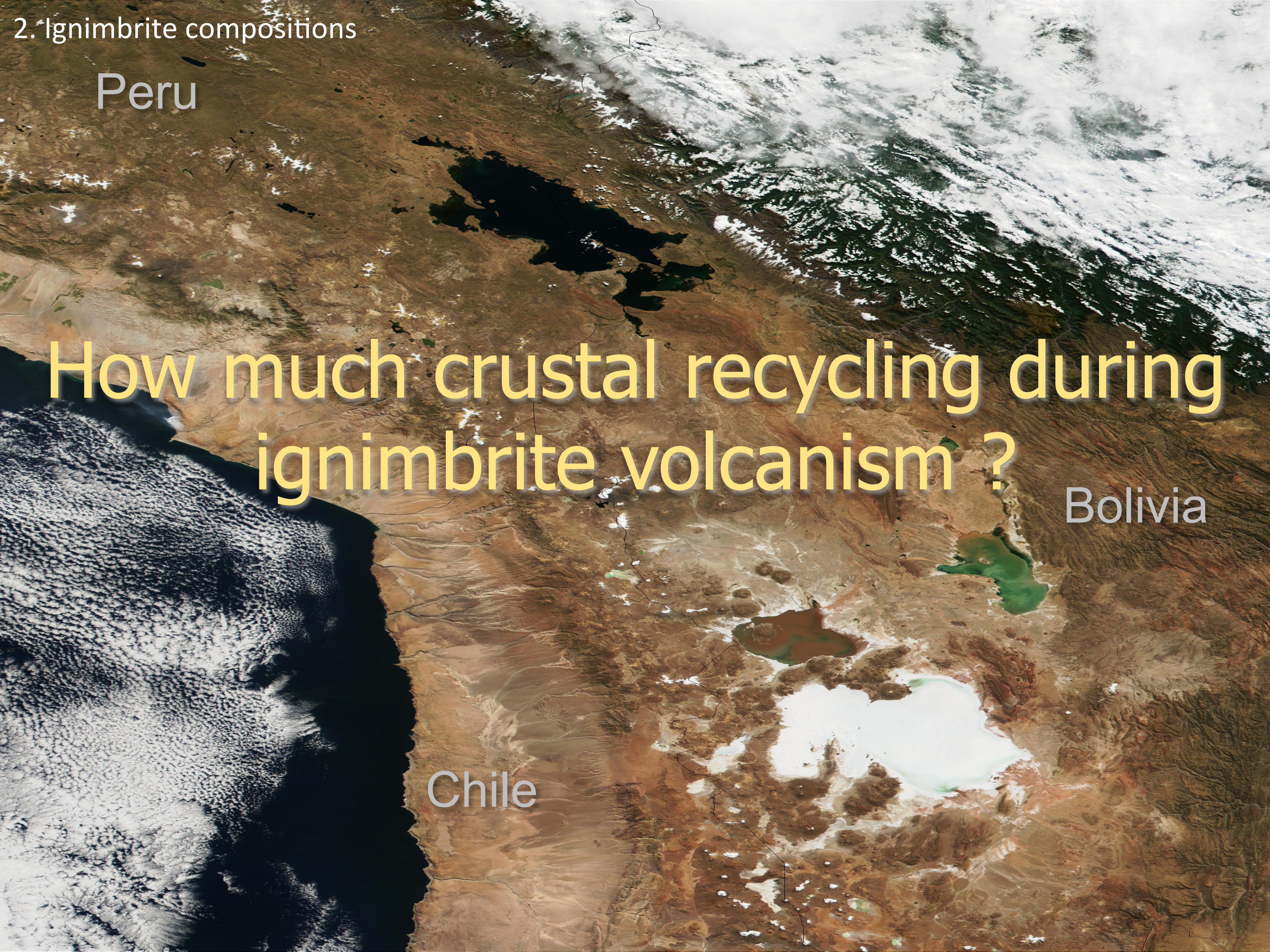
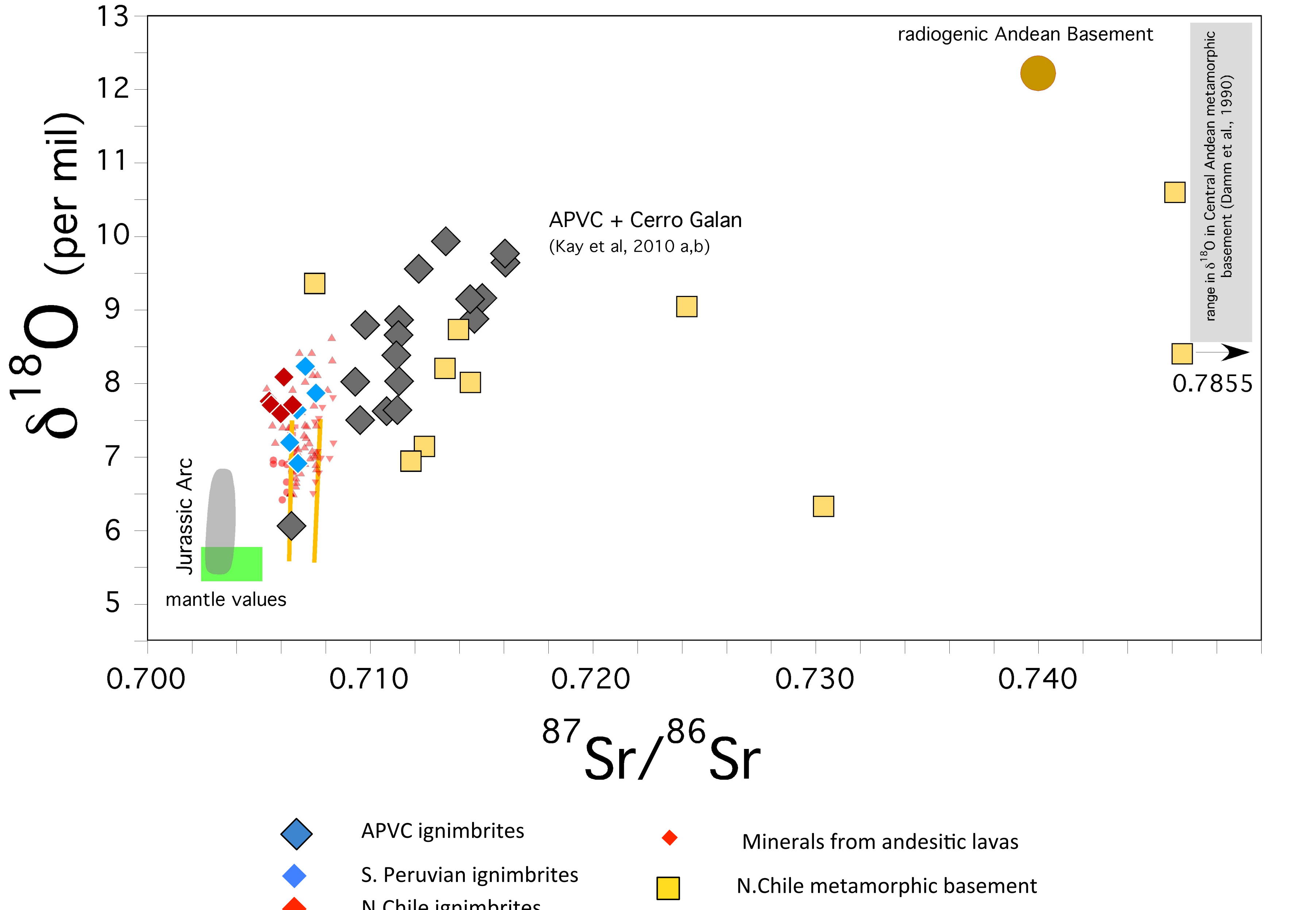
Brandmeier and Wörner (1916)

How much crustal recycling during ignimbrite volcanism ?



3. Evidence for large crustal contributions



Freymuth et al (2015)

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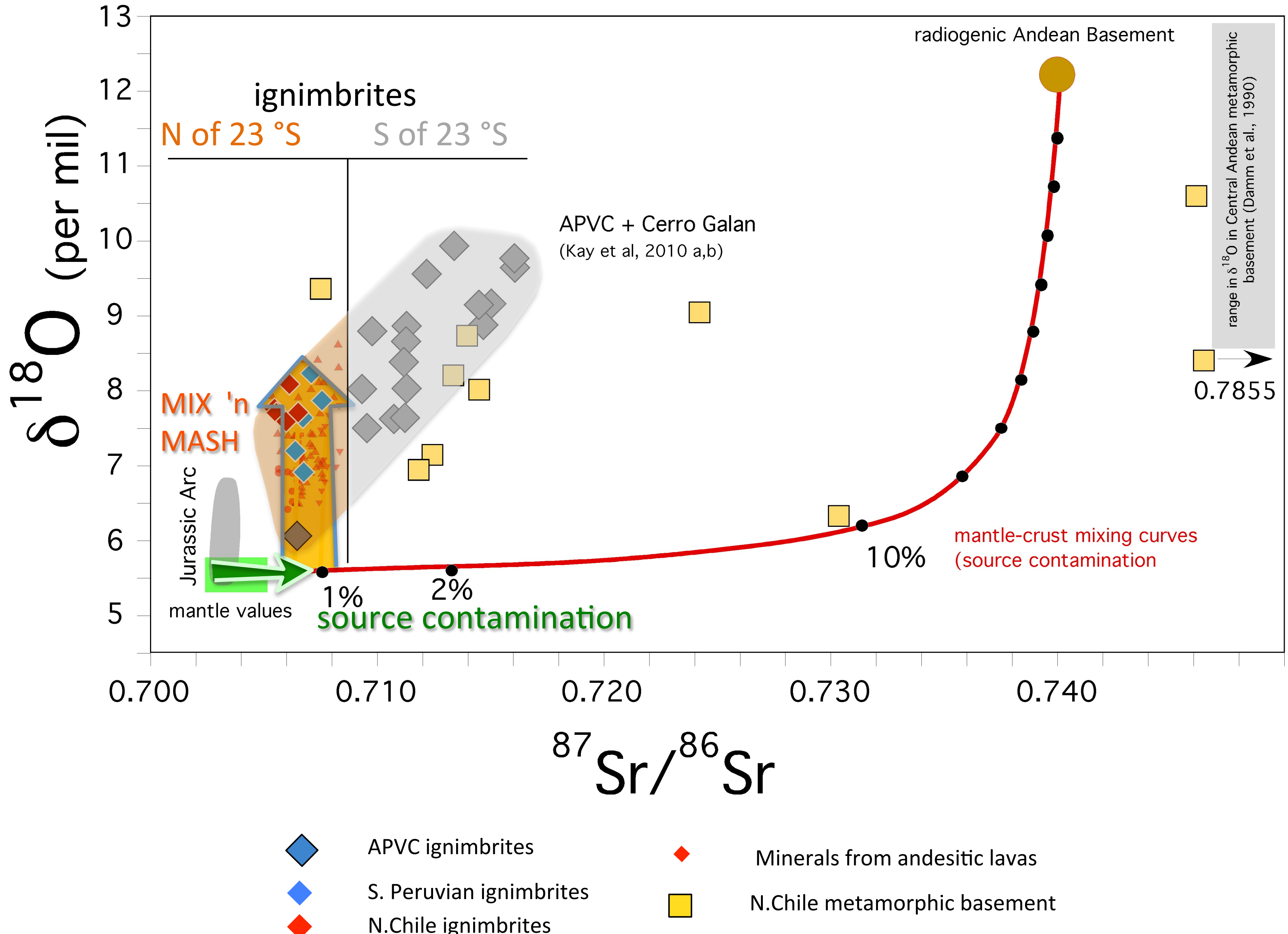

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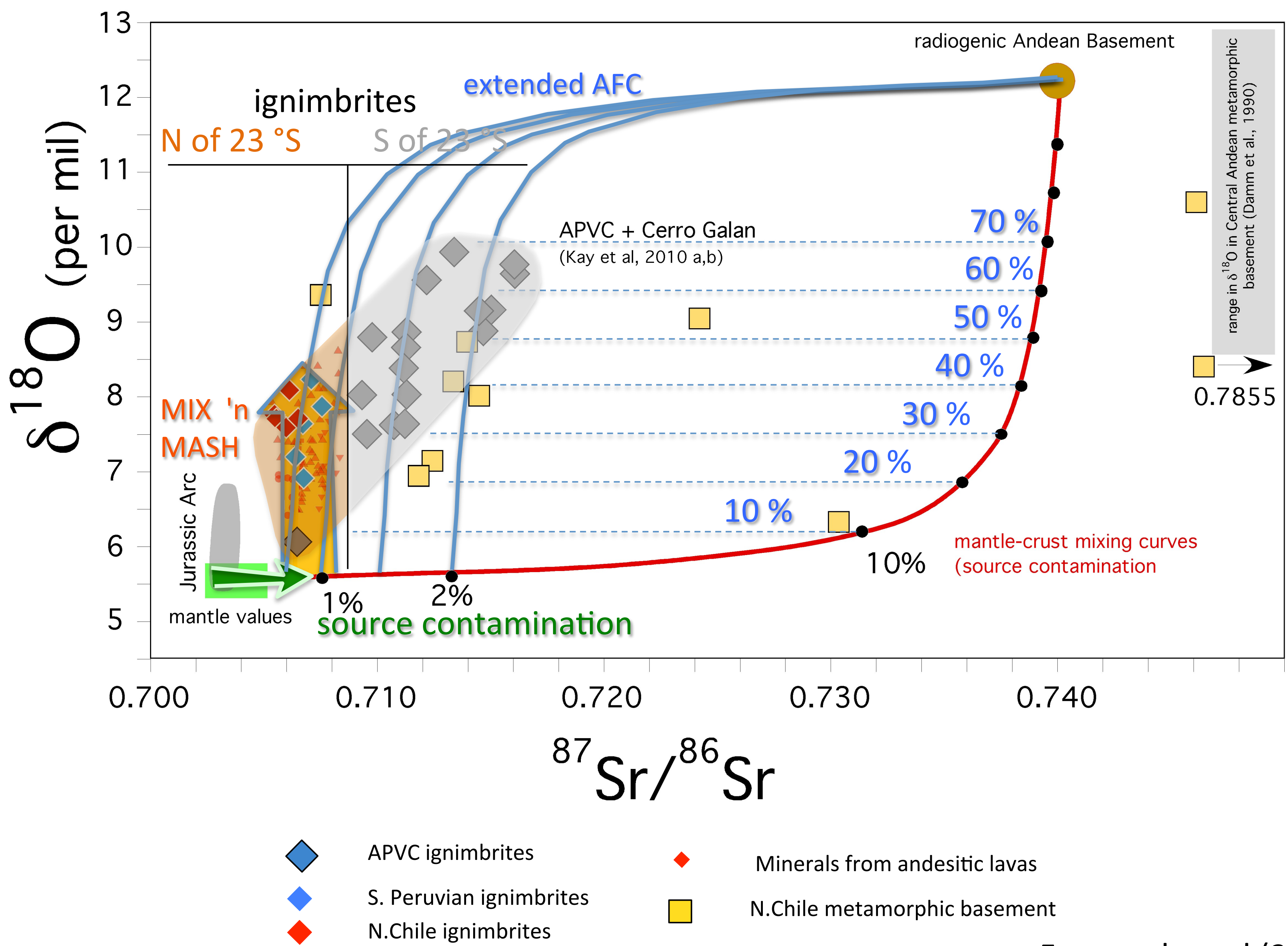

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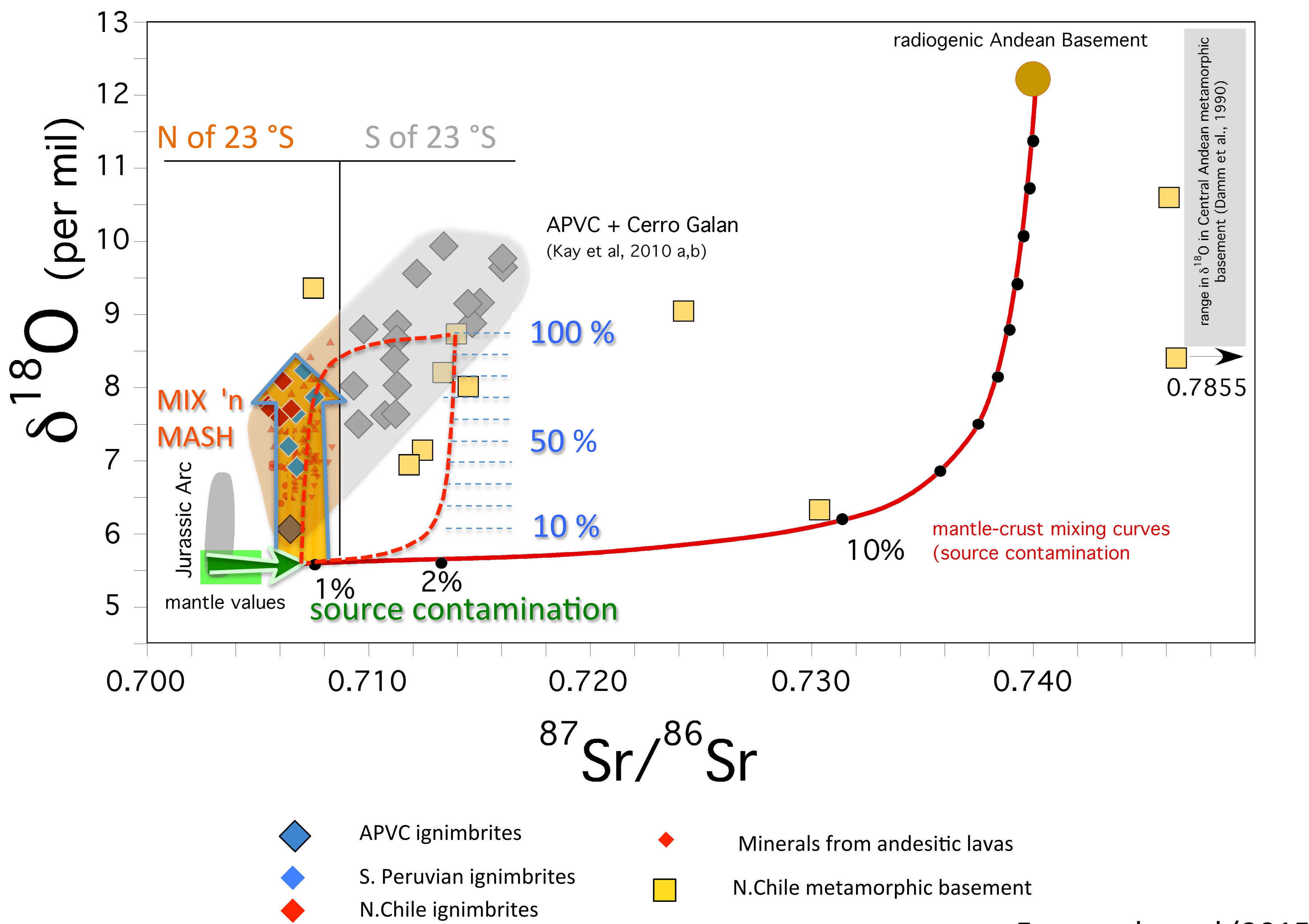

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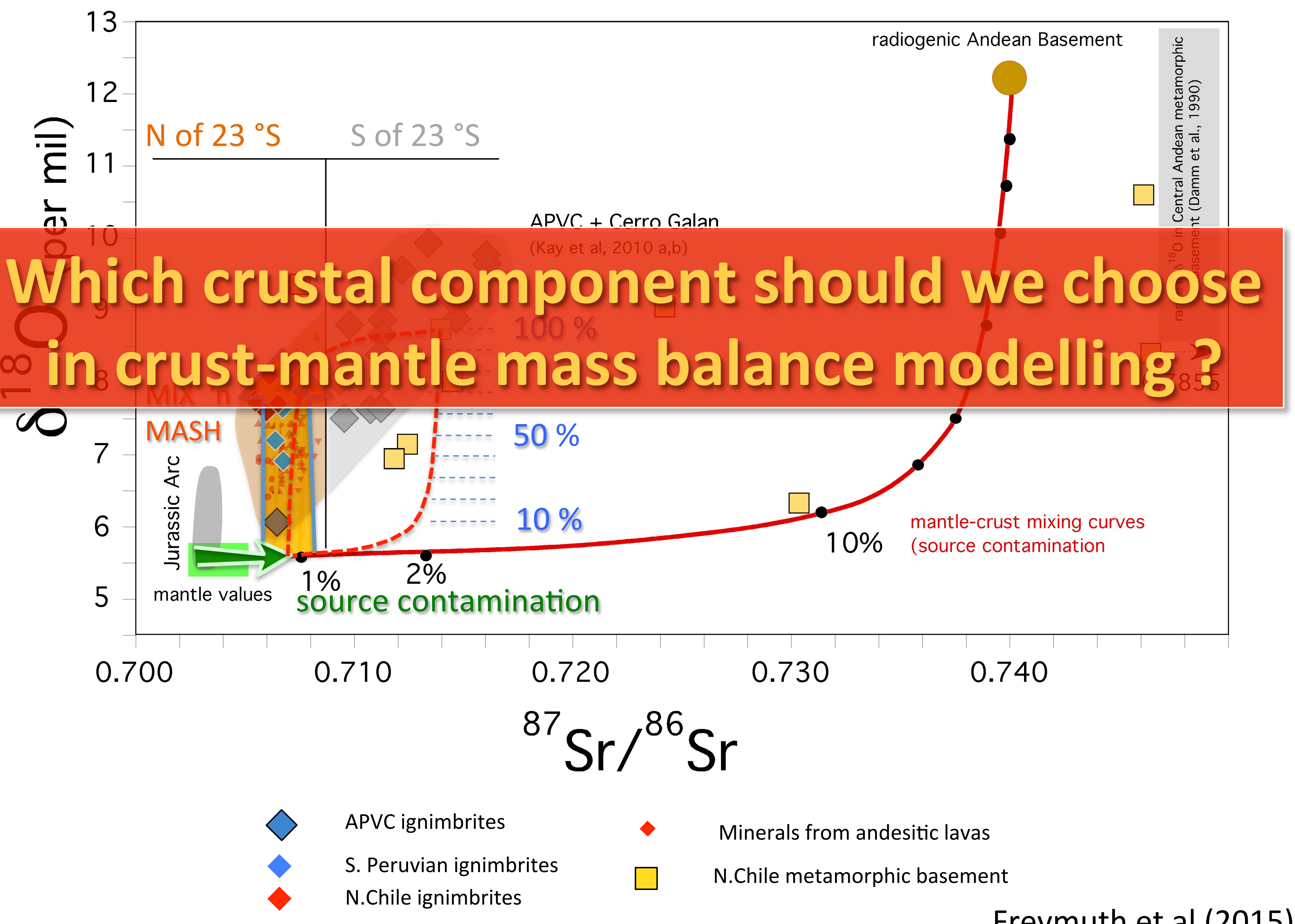
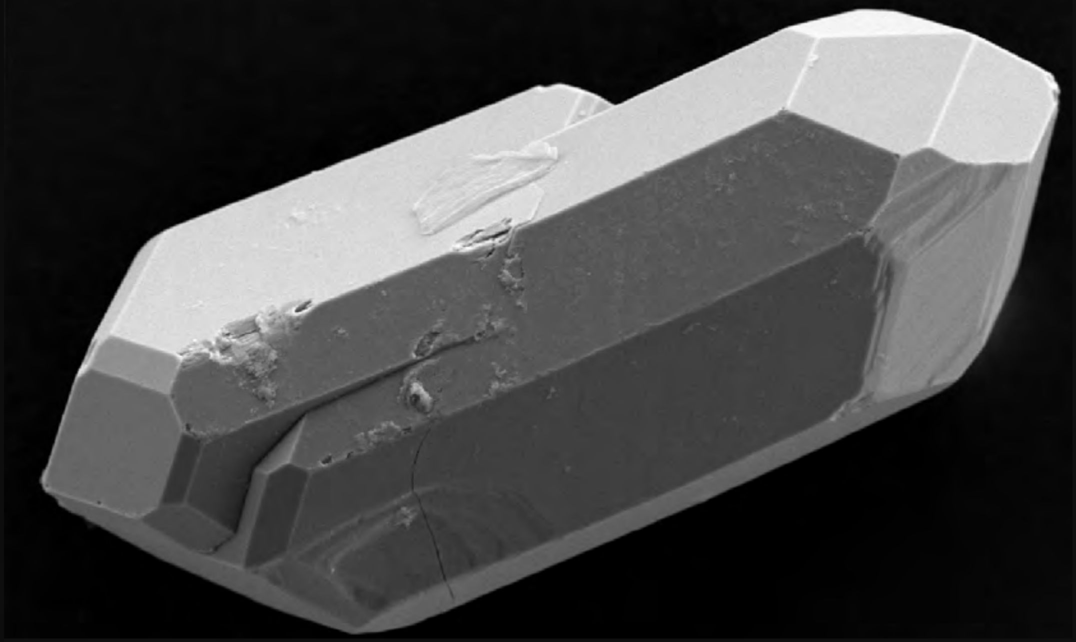


Which crustal component should we choose in crust-mantle mass balance modelling ?

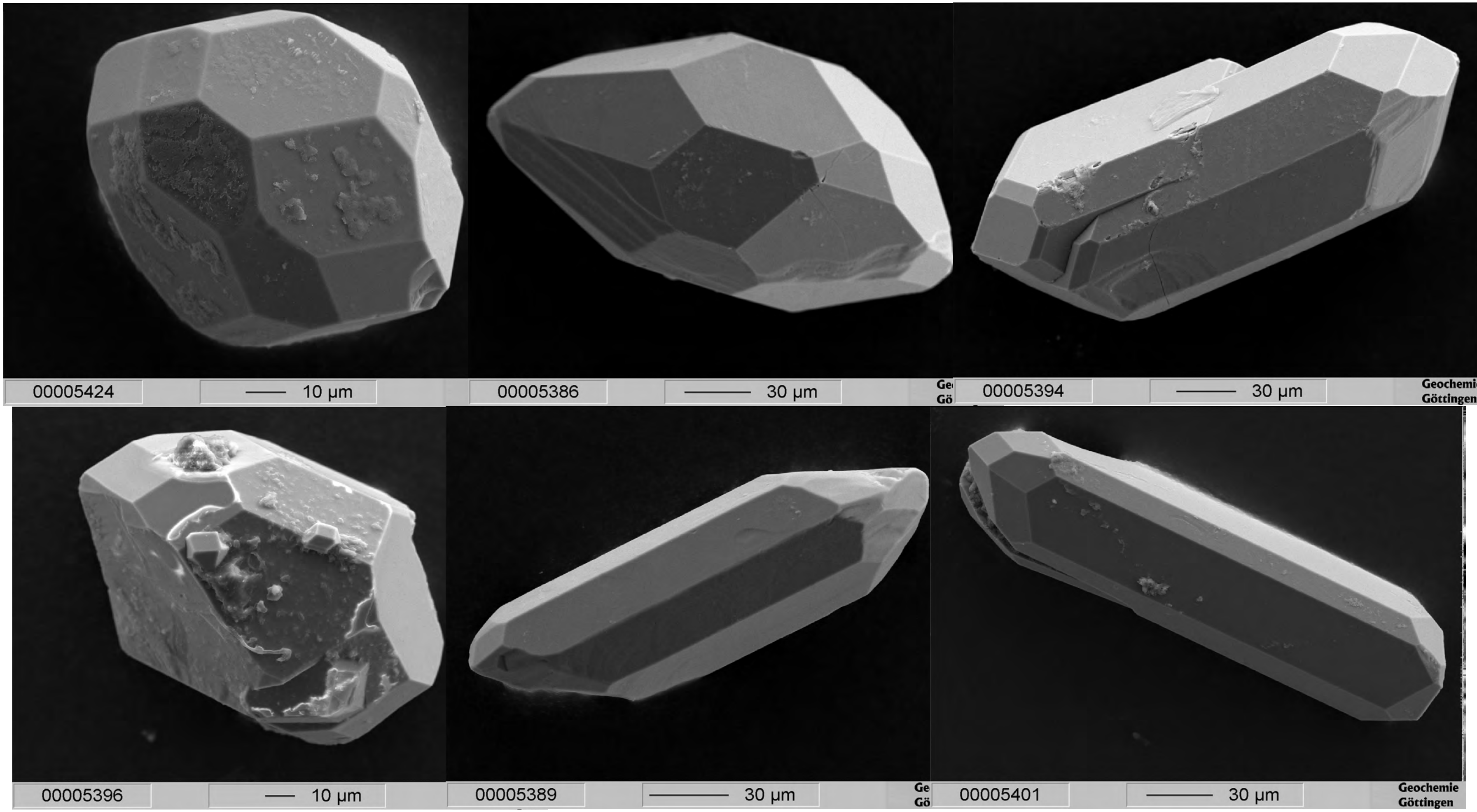
Freymuth et al (2015)

4. Zircon U/Pb dating combined with O-isotope and Hf- isotope analyses

Are zircons the solution ?



Zircon phenocrysts from Oxaya Fmt Ignimbrites
(19 – 22 Ma): Shapes



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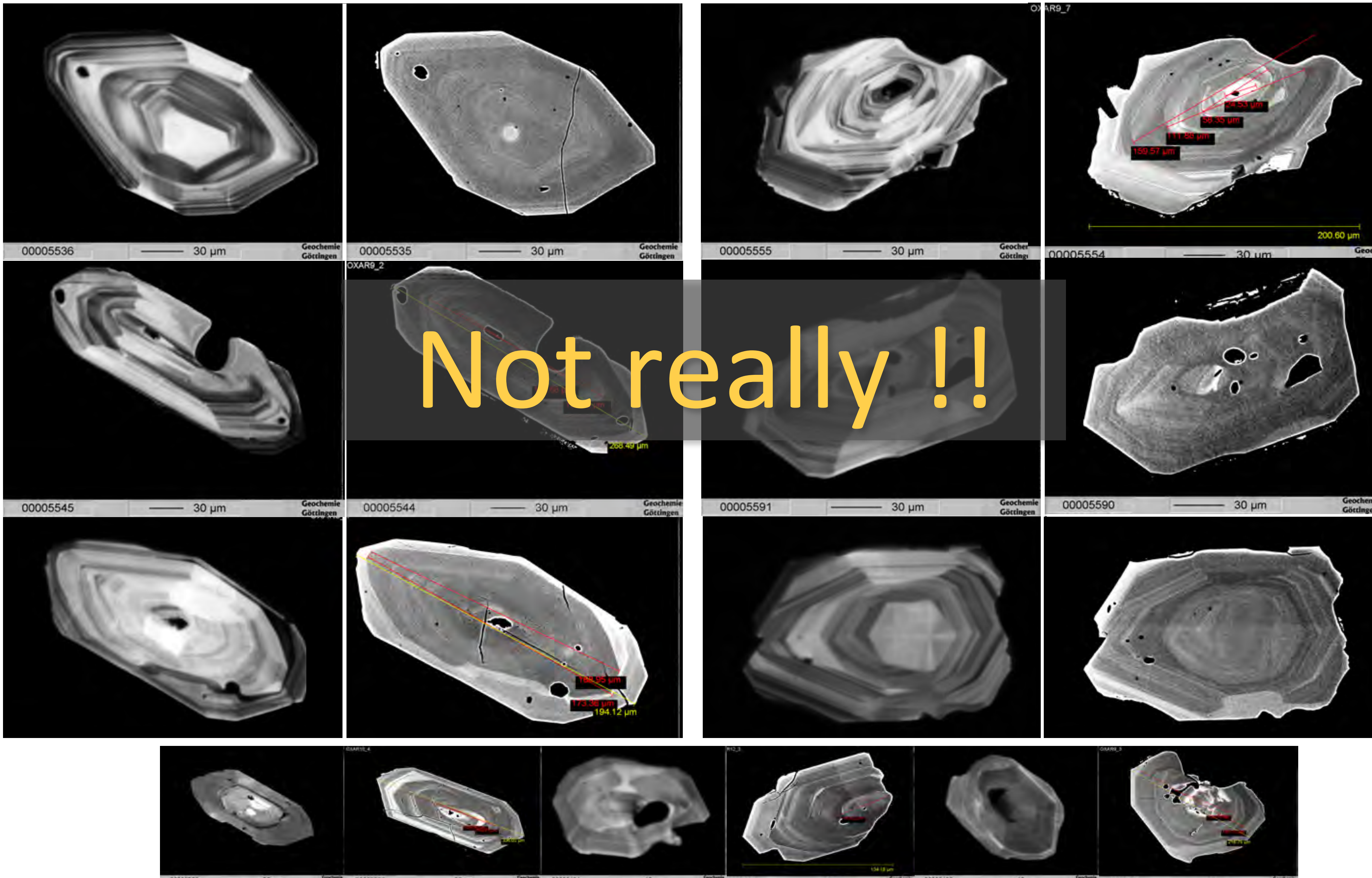
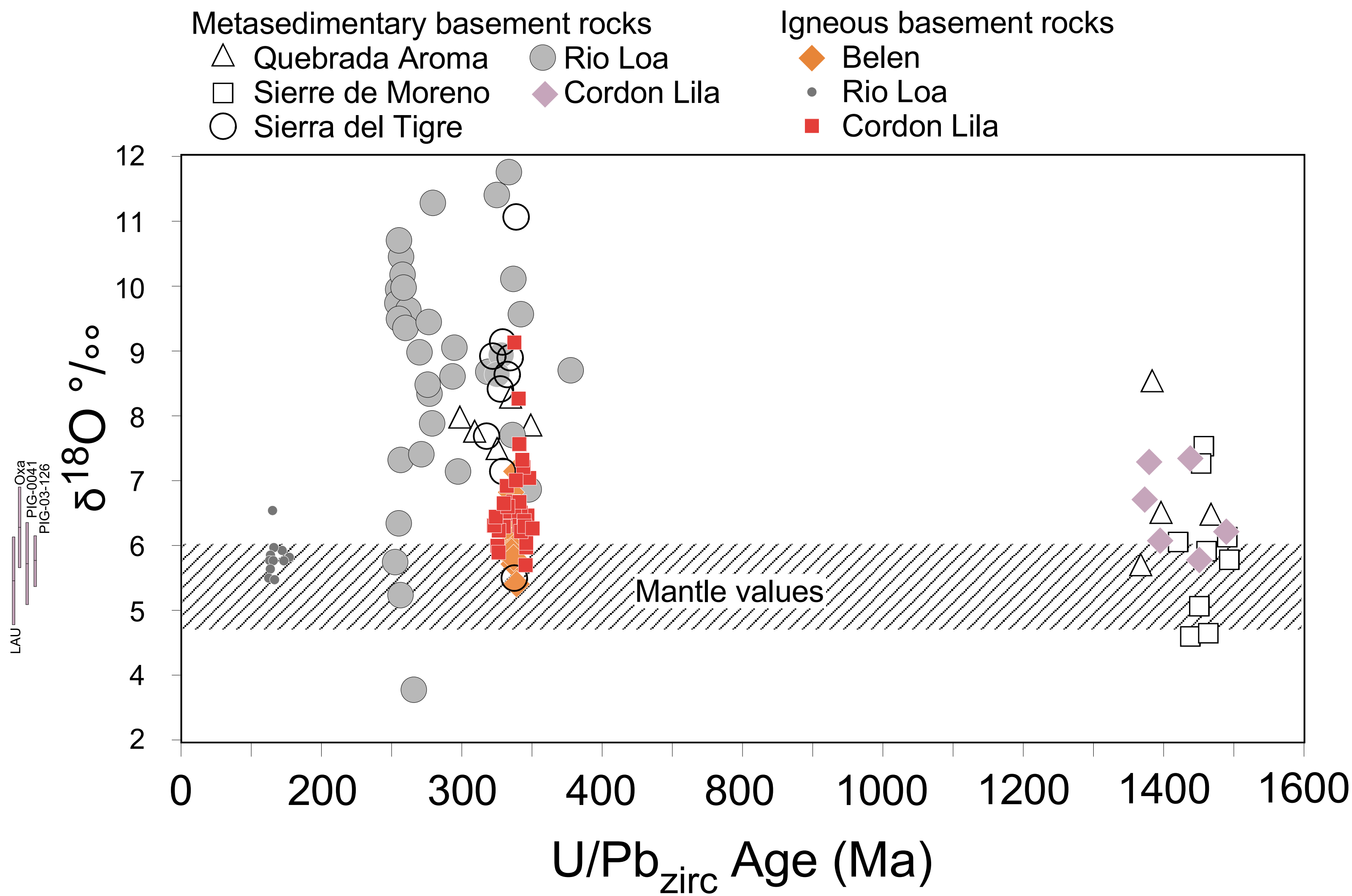
Zircon phenocrysts from Oxaya Fmt. Ignimbrites

Zonation : inherited zircons ?



Reference data for potential crustal components in ignimbrite magmas



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basement data from
Pankurst et al (2016) Earth Sci Rev
152:88-105

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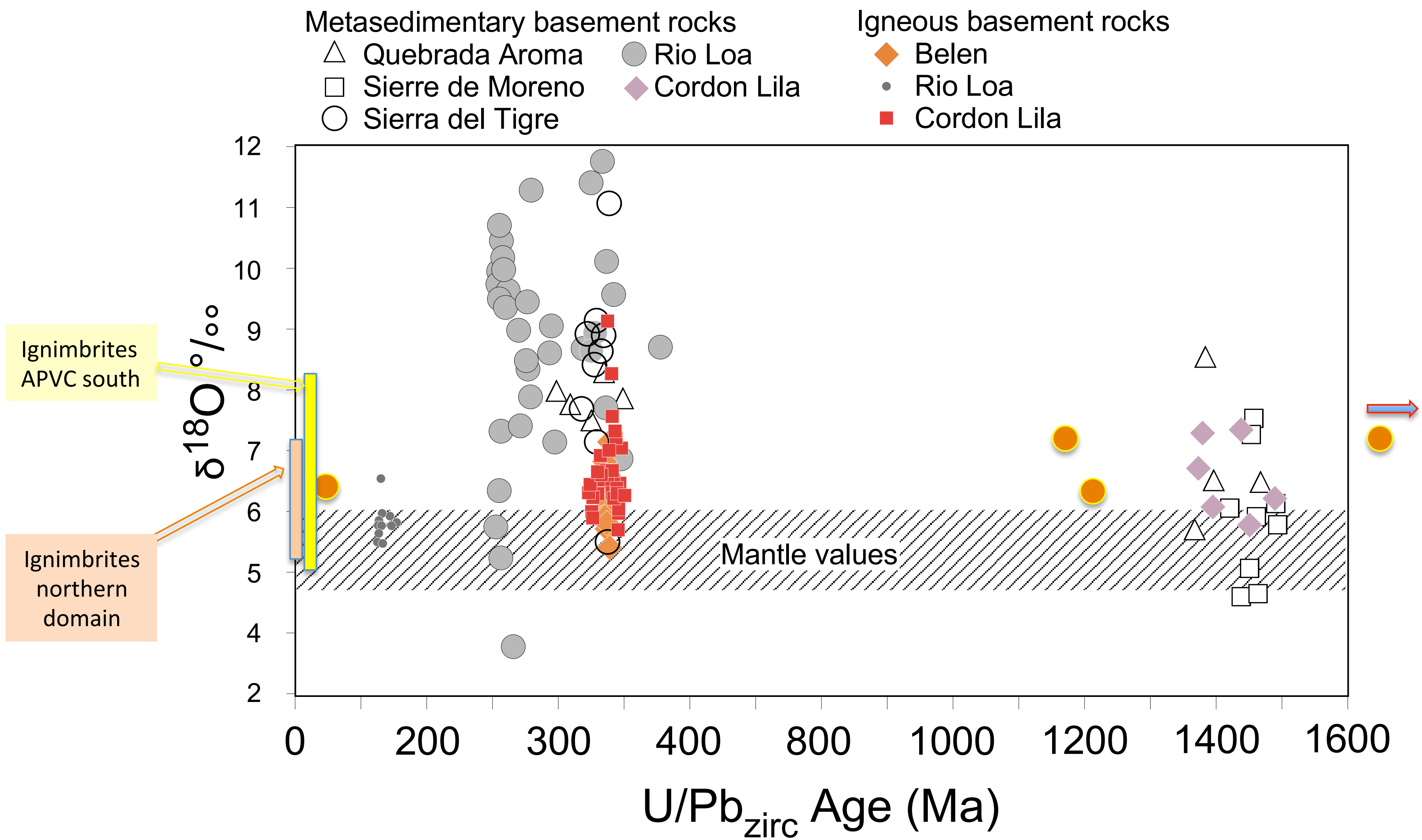

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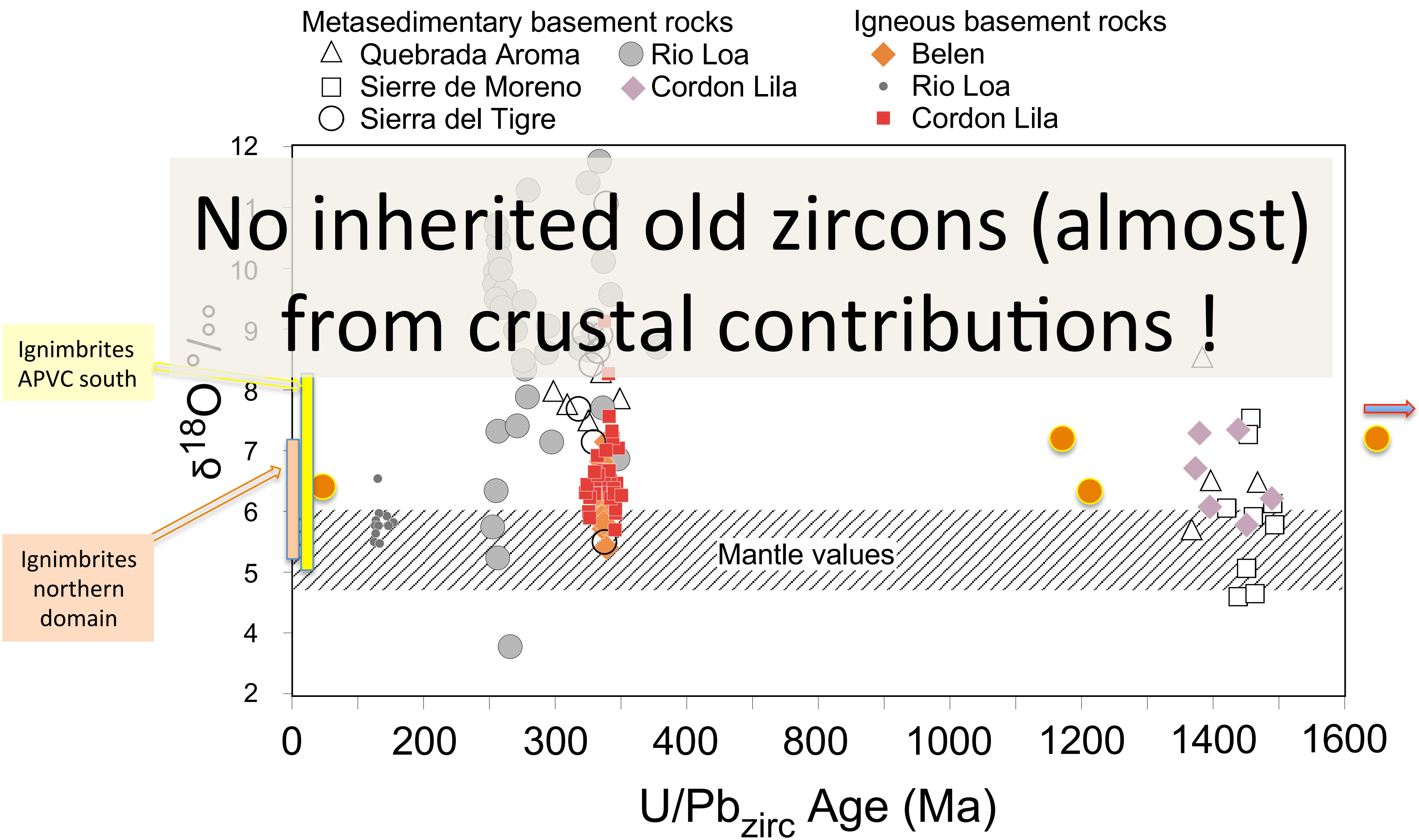
Reference data for potential crustal components in ignimbrite magmas: basement rocks



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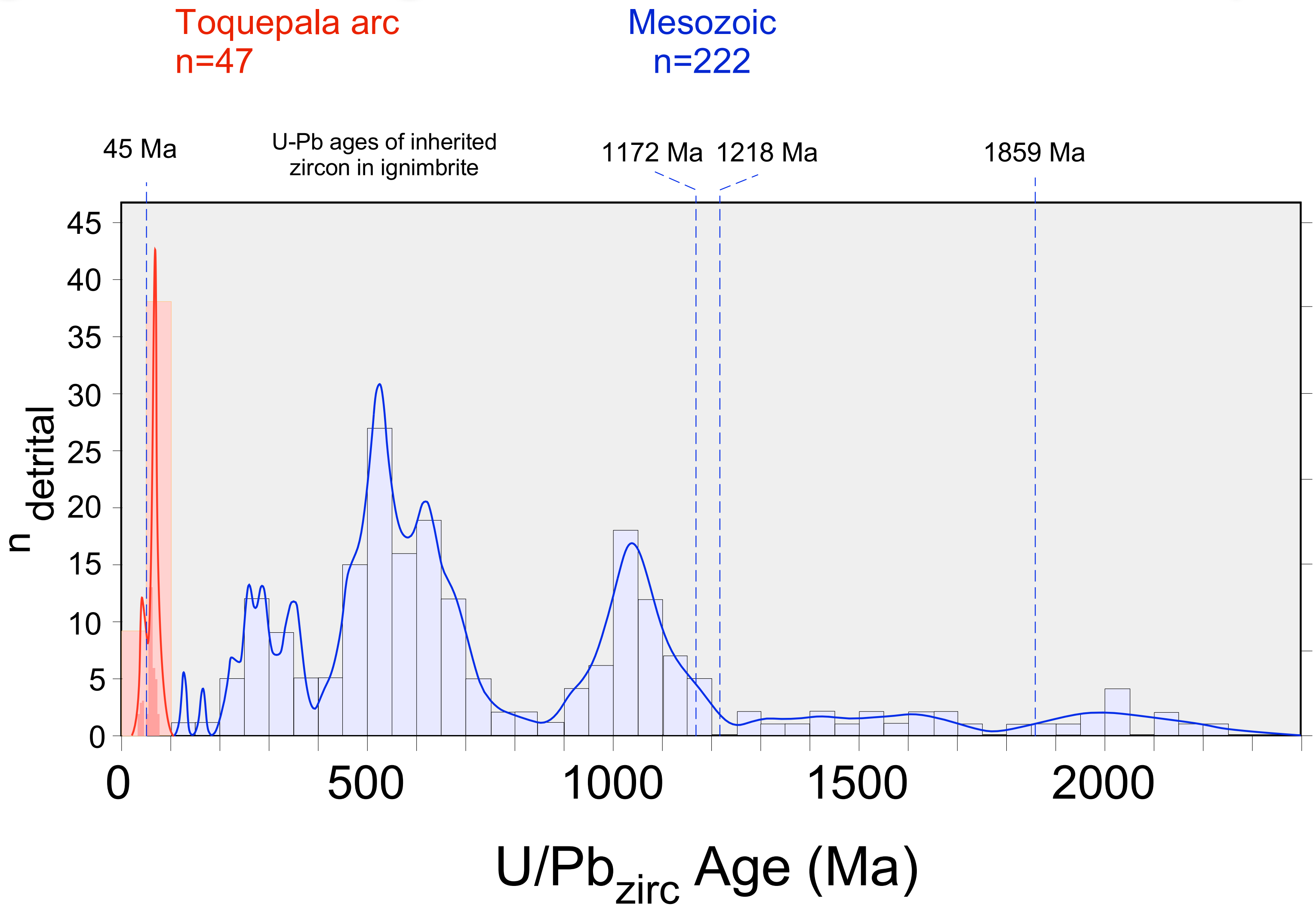
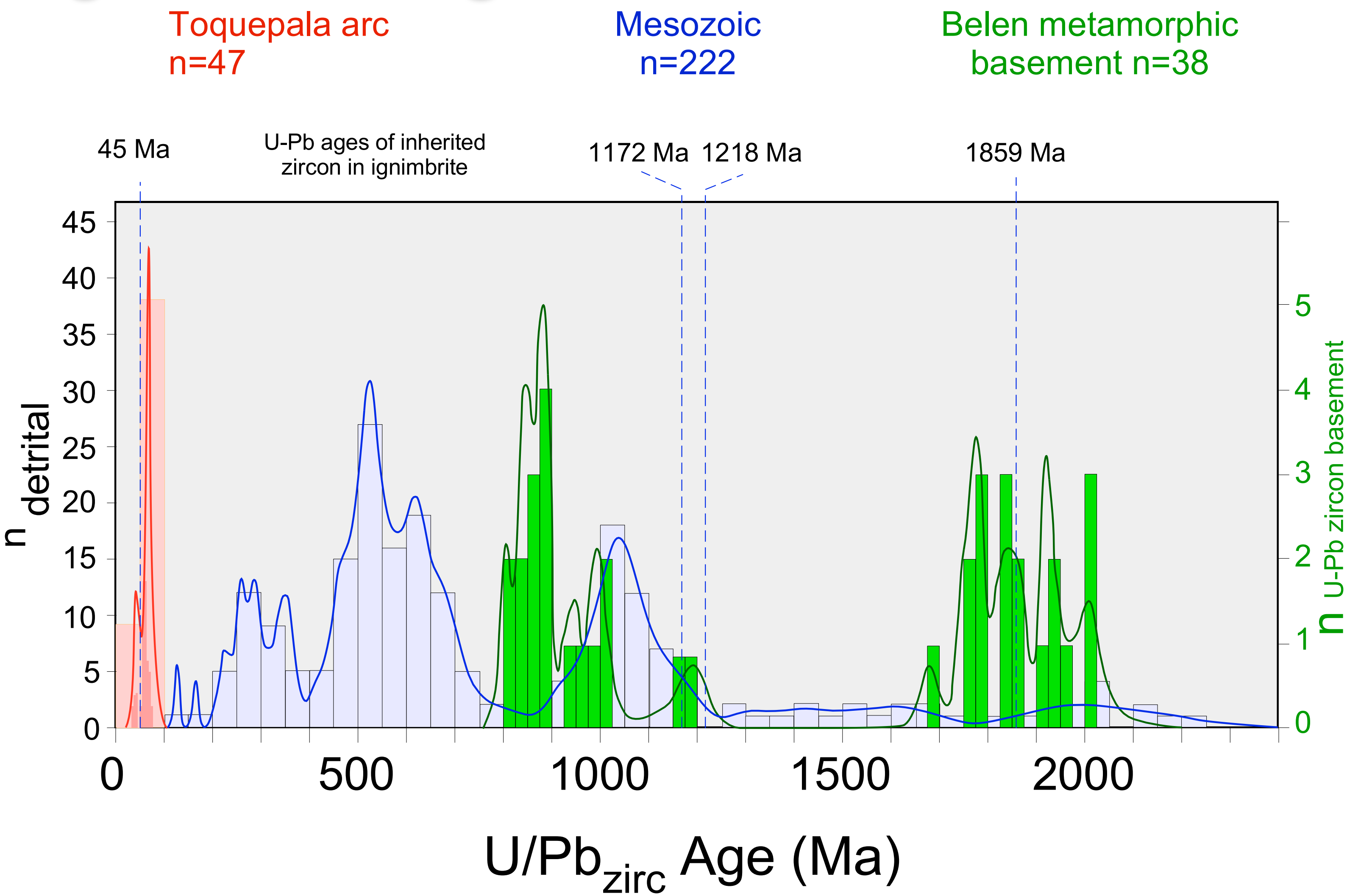
basement data from Pankurst et al (2016) Earth Sci Rev 152:88-105

Reference data for potential crustal components in ignimbrite magmas: zircons in sedimentary archives



Detrital zircons ("Toquepala arc" and "Mesozoic") from Wotzlaw et al (2011)

Reference data for potential crustal components in ignimbrite magmas: zircons in basement rocks



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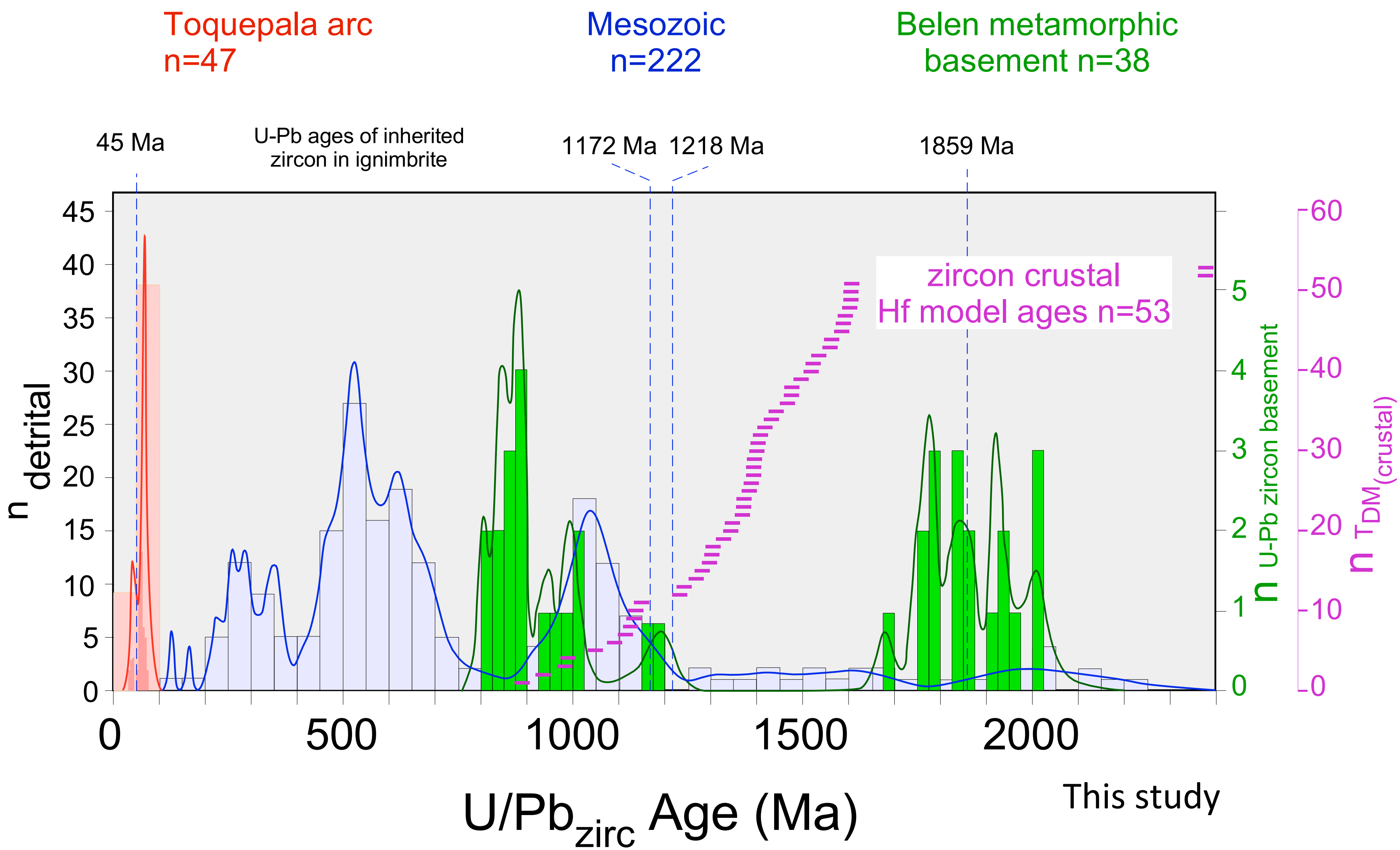
Belen zircons from the Arequipa metamorphic basement from Pankhurst et al (2016)

Zircons in ignimbrites



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$T_{DM(crustal)}$ calculated with

$\lambda^{176}Lu = 1.865 \times 10^{-11}$ (Scherer et al., 2001)

$^{176}Lu/^{177}Hf$ (crust) = 0.015

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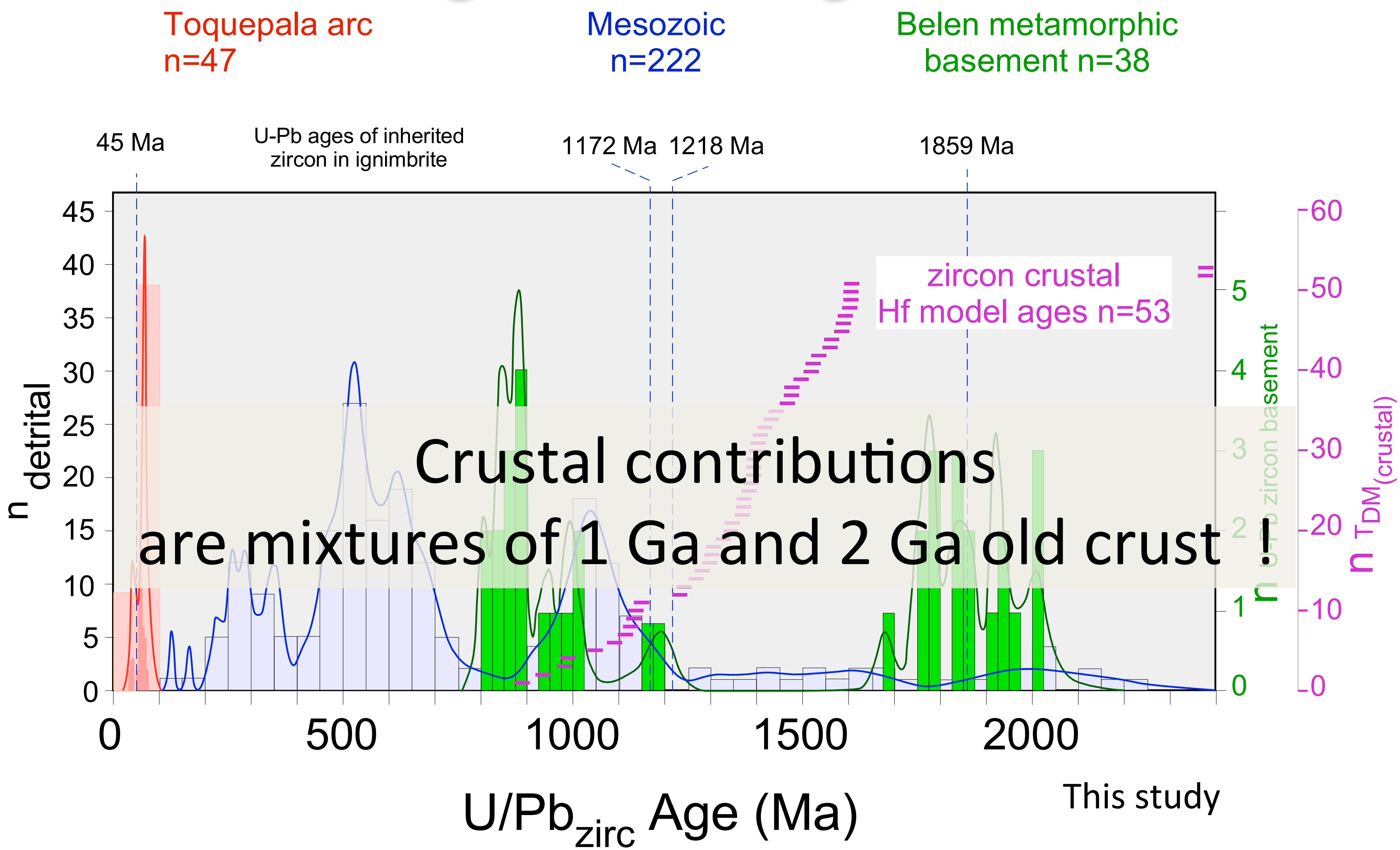

Crustal contributions are mixtures of 1 Ga and 2 Ga old crust !

This study

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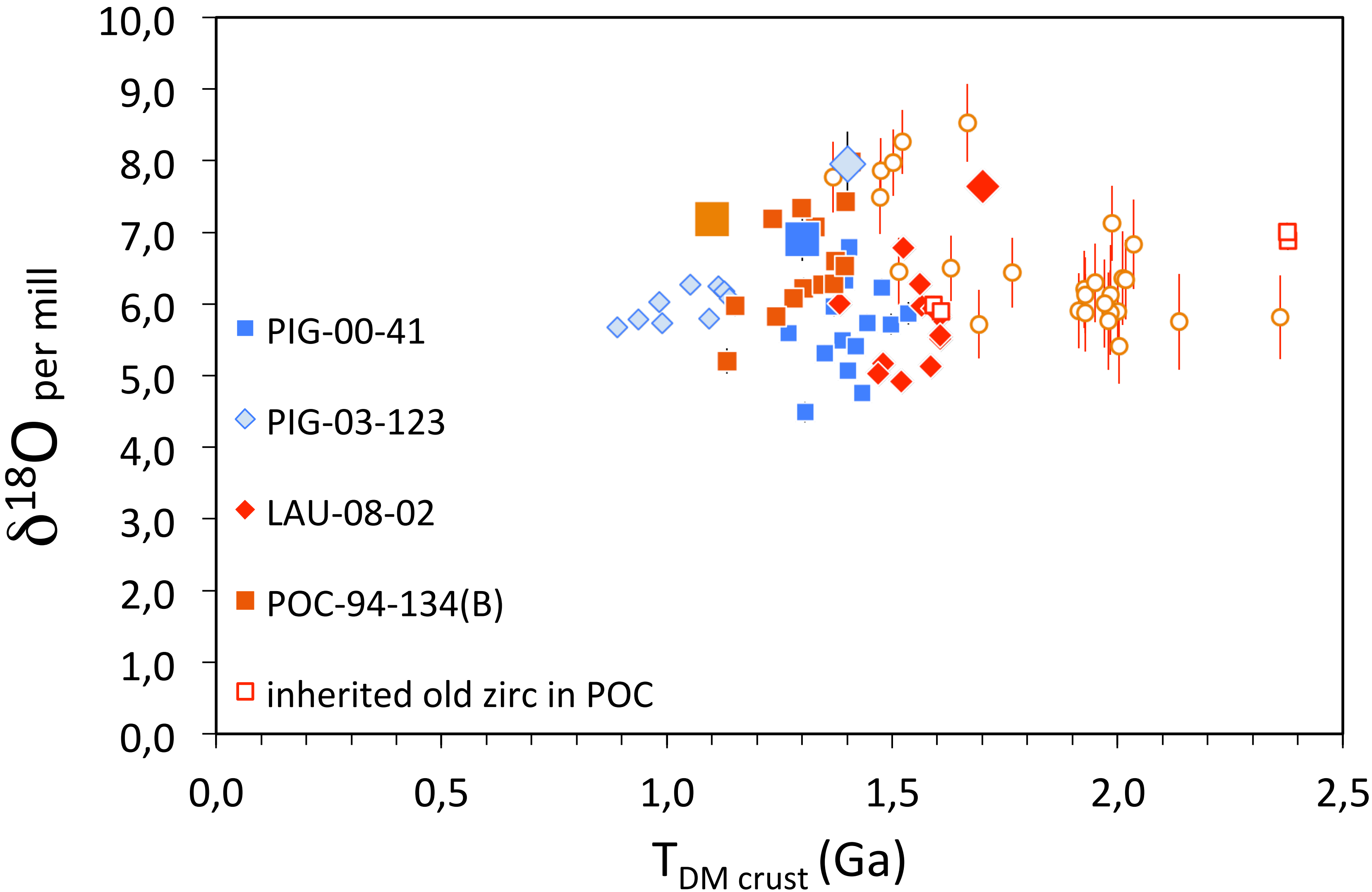
Old crustal components in ignimbrite magmas



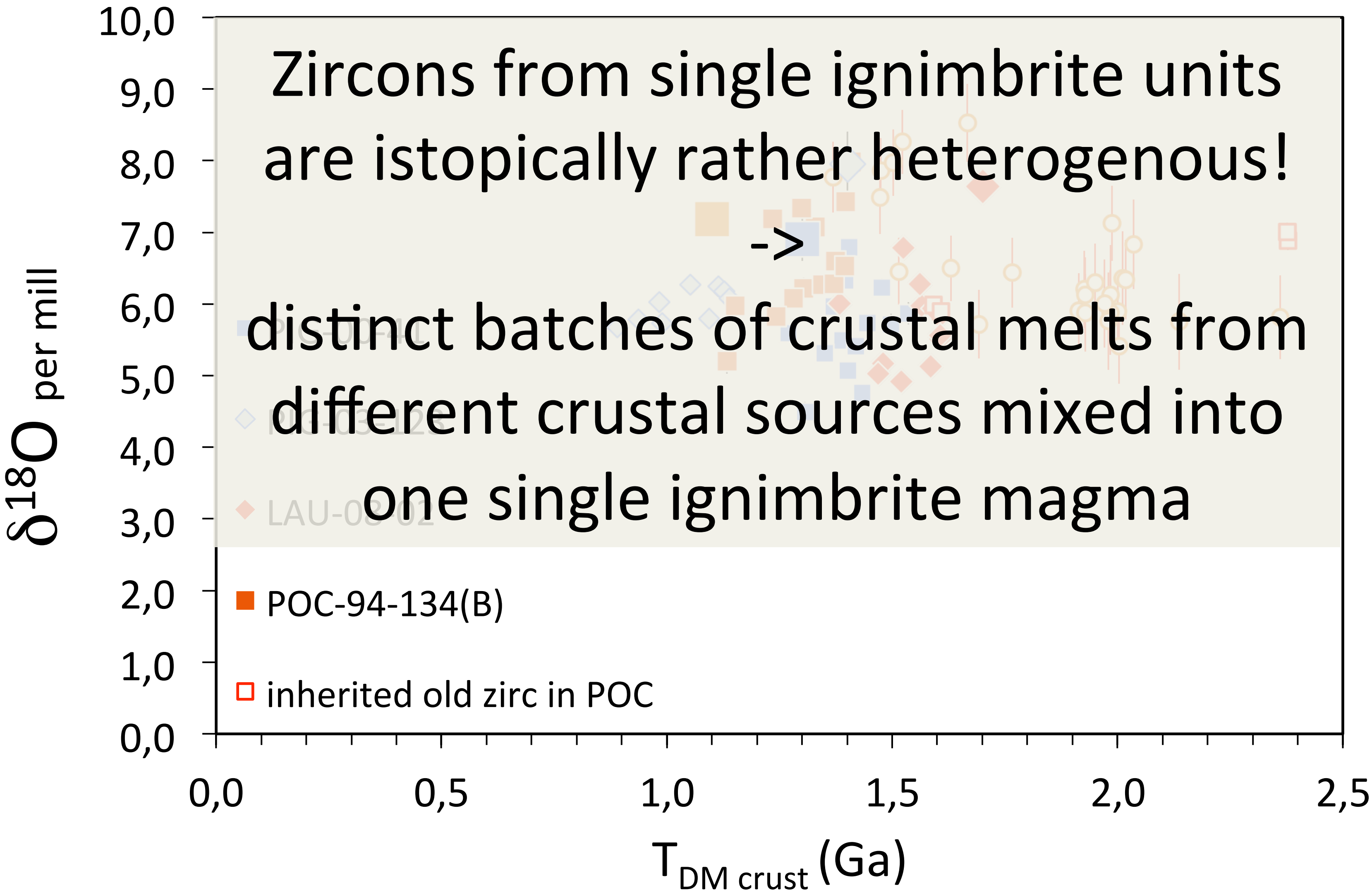
4. Zircon U/Pb dating combined with O-isotope and Hf- isotope analyses

Old crustal components in ignimbrite magmas

Zircons from single ignimbrite units are istopically rather heterogenous!

->

distinct batches of crustal melts from different crustal sources mixed into one single ignimbrite magma



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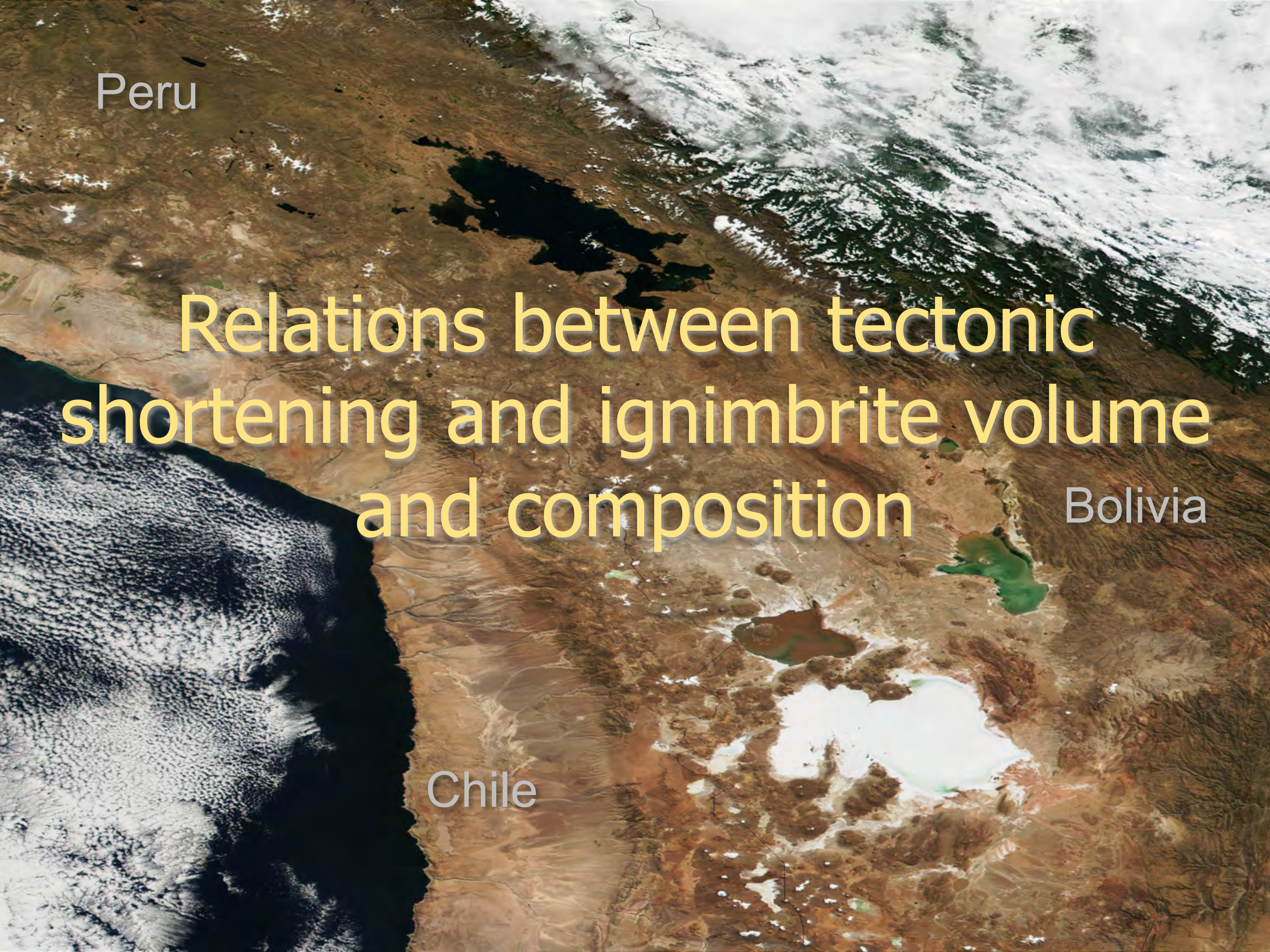
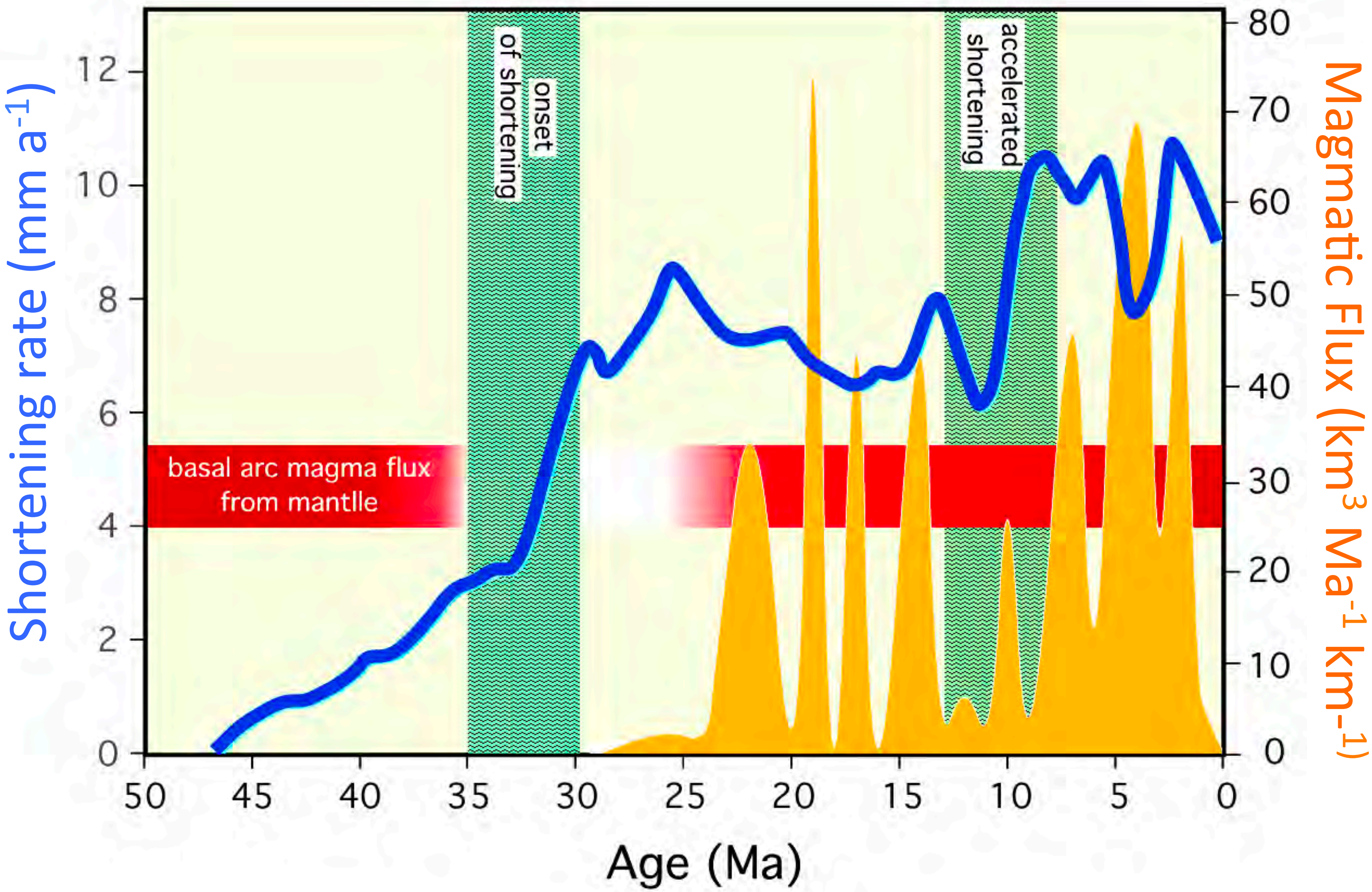
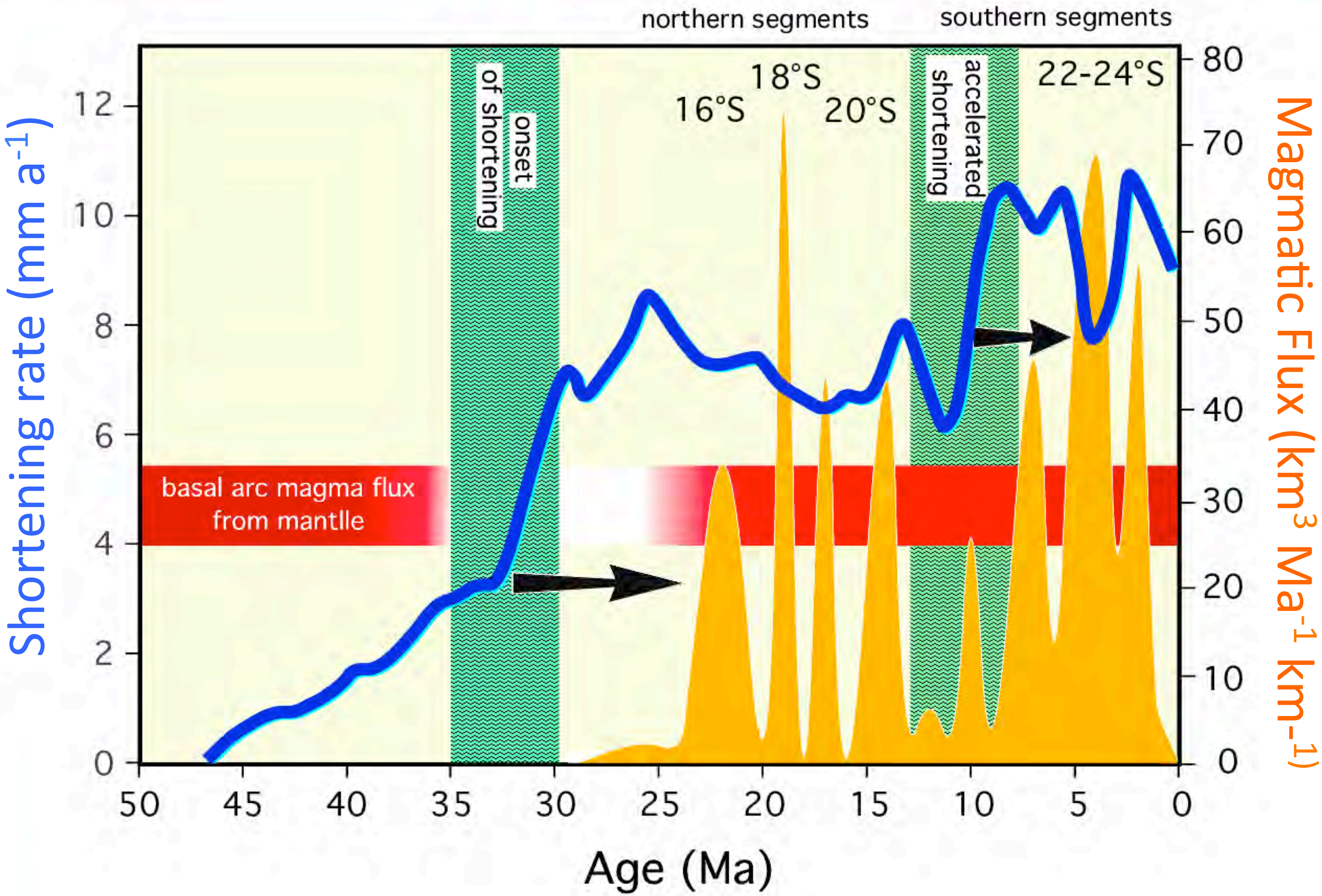
Relations between tectonic shortening and ignimbrite volume and composition



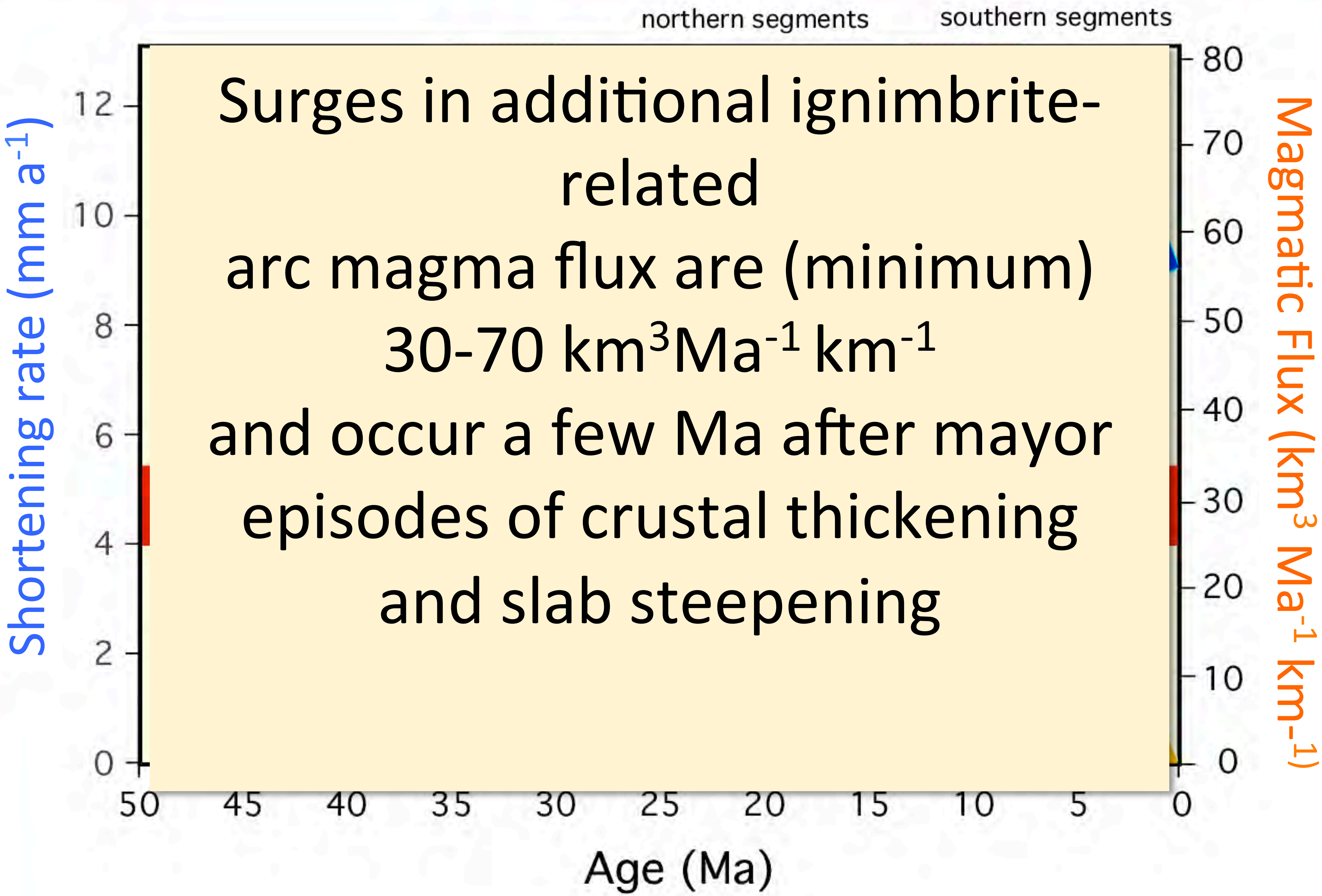


Freymuth et al (2015)



Freymuth et al (2015)

Surges in additional ignimbrite-related arc magma flux are (minimum) 30-70 $km^3 Ma^{-1} km^{-1}$ and occur a few Ma after mayor episodes of crustal thickening and slab steepening



Freymuth et al (2015)

Summary
Origin of ignimbrite magmas

Ignimbrite „flare-ups“ migrate from N to S and evolve after the passage of the Juan Fernandez-Ridge ("flat slab")

....related to subsequent steepening/roll-back of the slab

Ignimbrite are 20/80 to 70/30 mixtures of crustal melt and magmas derived from the mantle wedge.

Variable compositions and crustal contribution reflect thickness and thermal maturity of the continental crust

Additional ignimbrite-related arc magma flux are 30-70 $km^3 Ma^{-1} km^{-1}$ and occur after crustal thickening and slab steepening