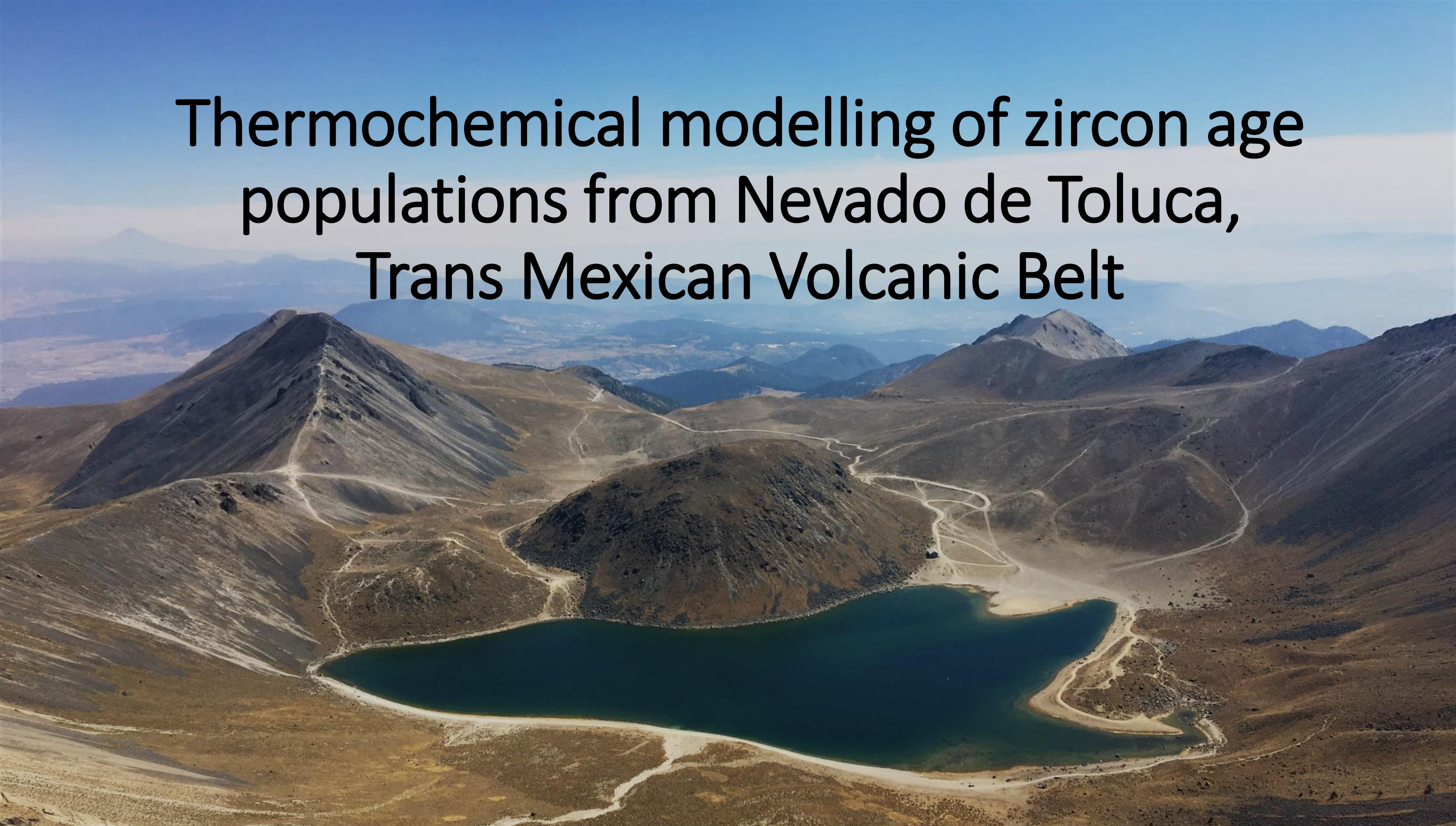
Thermochemical modelling of zircon age populations from Nevado de Toluca, Trans Mexican Volcanic Belt



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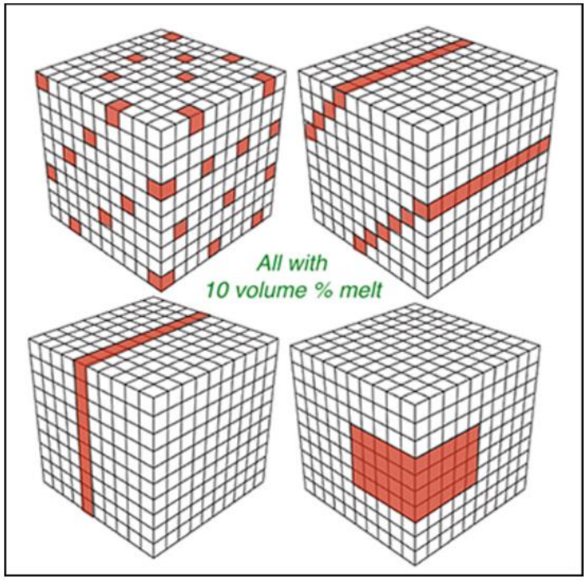
Motivation

Understanding of subvolcanic reservoirs important to evaluate volcanic hazard potential

Geophysical imaging



Lowenstern et al., 2017

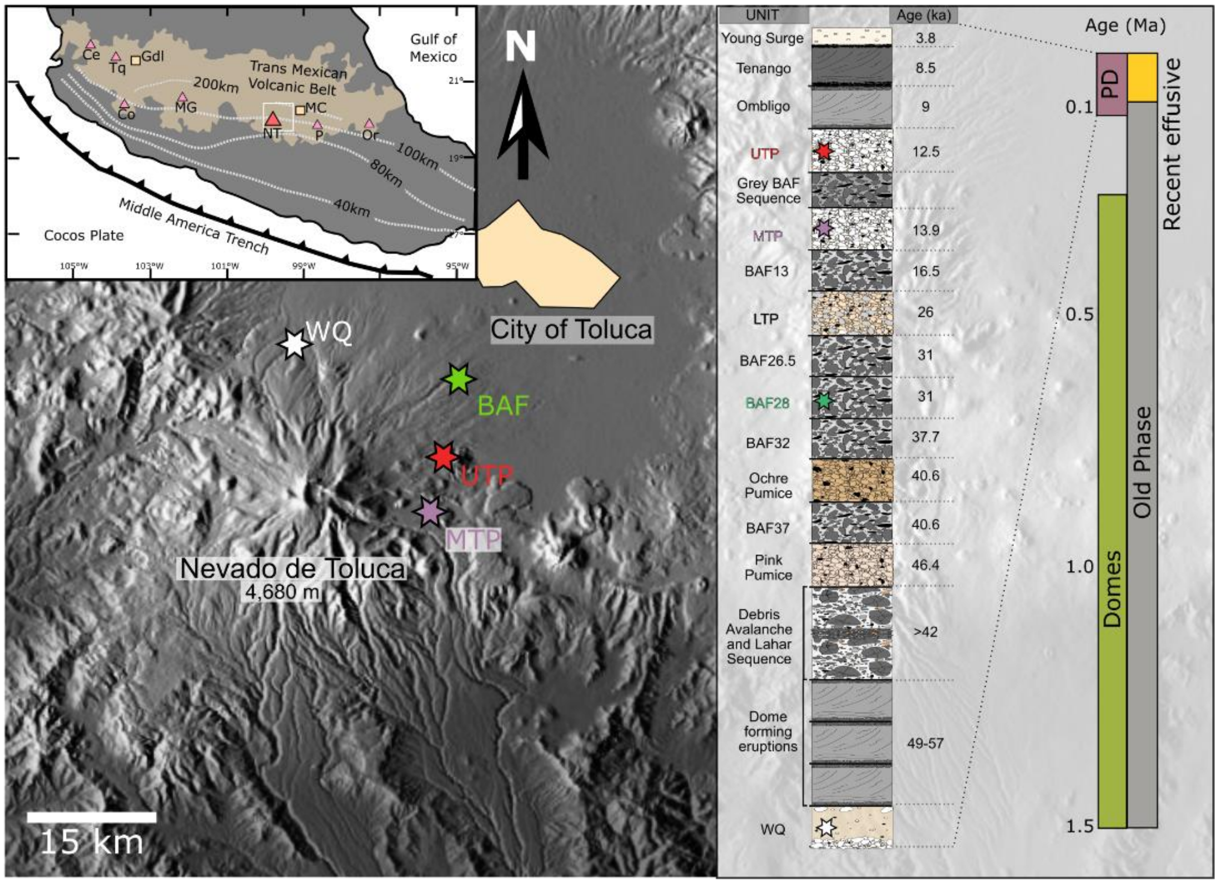
Lacks spatial resolution

Geological/Geochemical records

Does not reflect present day state

Aim: Constrain present state and size of magma reservoirs using zircon and thermal modelling

Case study: Nevado de Toluca (Mexico)

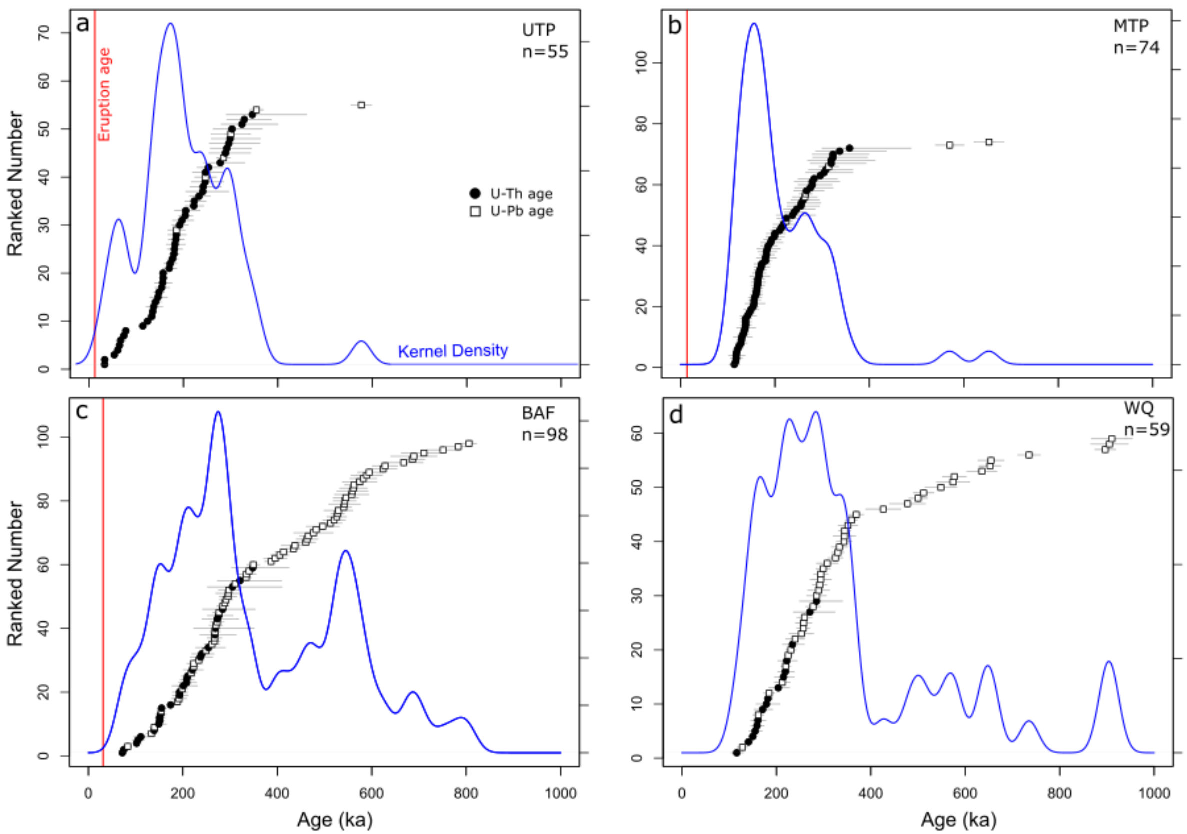


Background in brief:

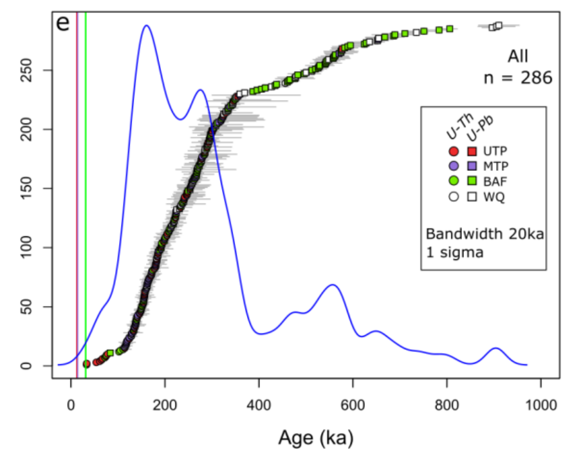
- 80 km SW of Mexico City
- Typical arc volcano
- 1.5 Ma eruptive history
- Only dacites (±andesite)
- Effusive and explosive
- Dormant for millennia
- Densely populated area

We focus on zircons from three eruptions: UTP (12.5 ka), MTP (13.9 ka), WQ (? ka) and one block-and-ash flow deposit: BAF28 (31 ka)

Zircon age distributions



Combined distribution

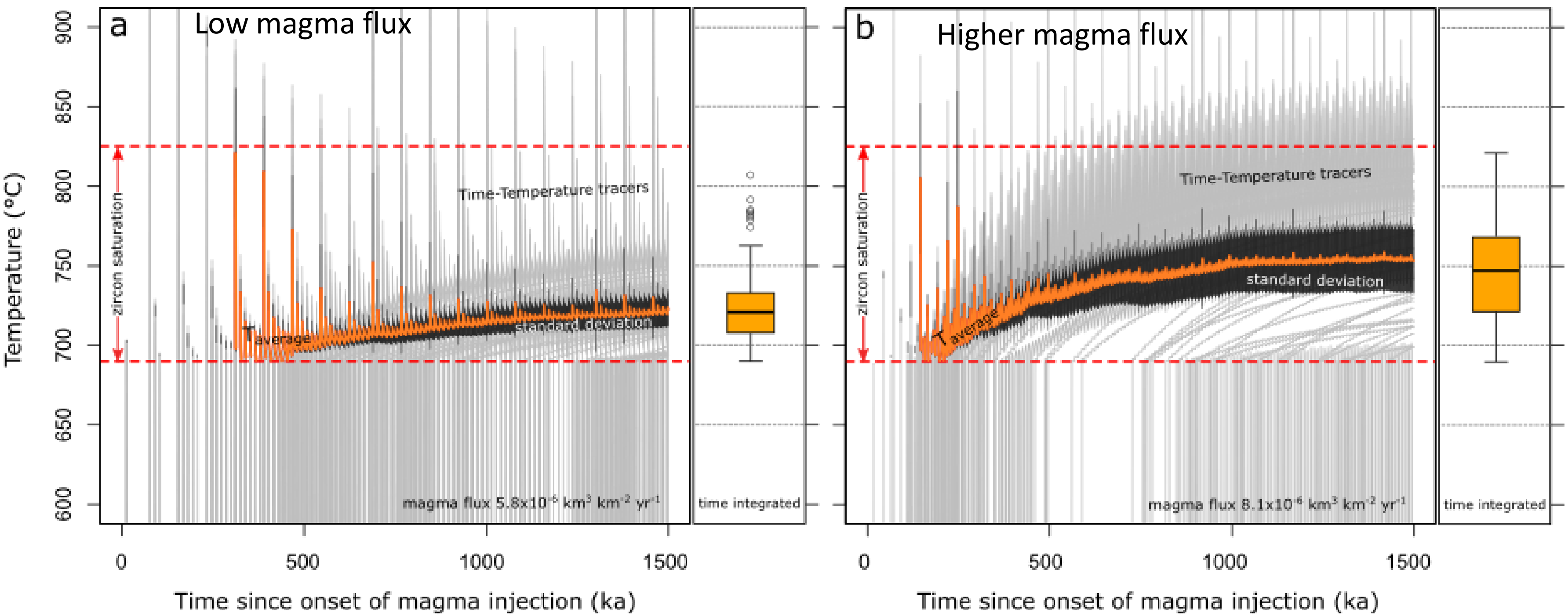


Eruption ages from Macias et al., (1997)

- Zircon age distributions overlap for different eruptions
- Youngest age typically older than eruption age
- Protracted crystallization for about 900 ka (large fraction of eruptive history)
- Same overall population sampled in different eruptions (trace elements also overlap)

Thermal modelling of magma assembly

- Numerical modelling of pulsed magma injection into upper crustal magma reservoir
- Temperature distribution tracked in time at a large number of positions in the reservoir (grey lines)

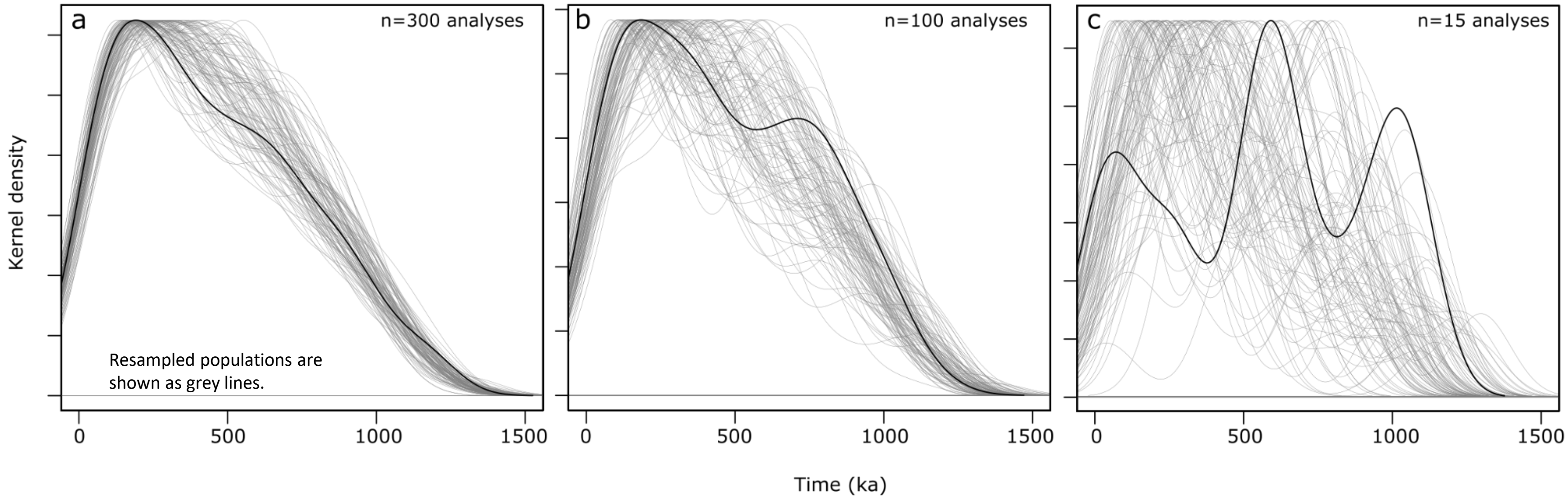


Differences in temporal evolution and distributions of temperatures as a function of magma fluxes resolvable

Synthetic zircon age distributions

We calculate synthetic zircon age populations from the thermal model:

- Tracked T-t path in 500 numerical nodes
- Calculate the cumulative fraction of zircon crystallizing as function of T (Tierney et al., 2016)
- Number measureable zircons proportional to fraction of crystallizing zircon

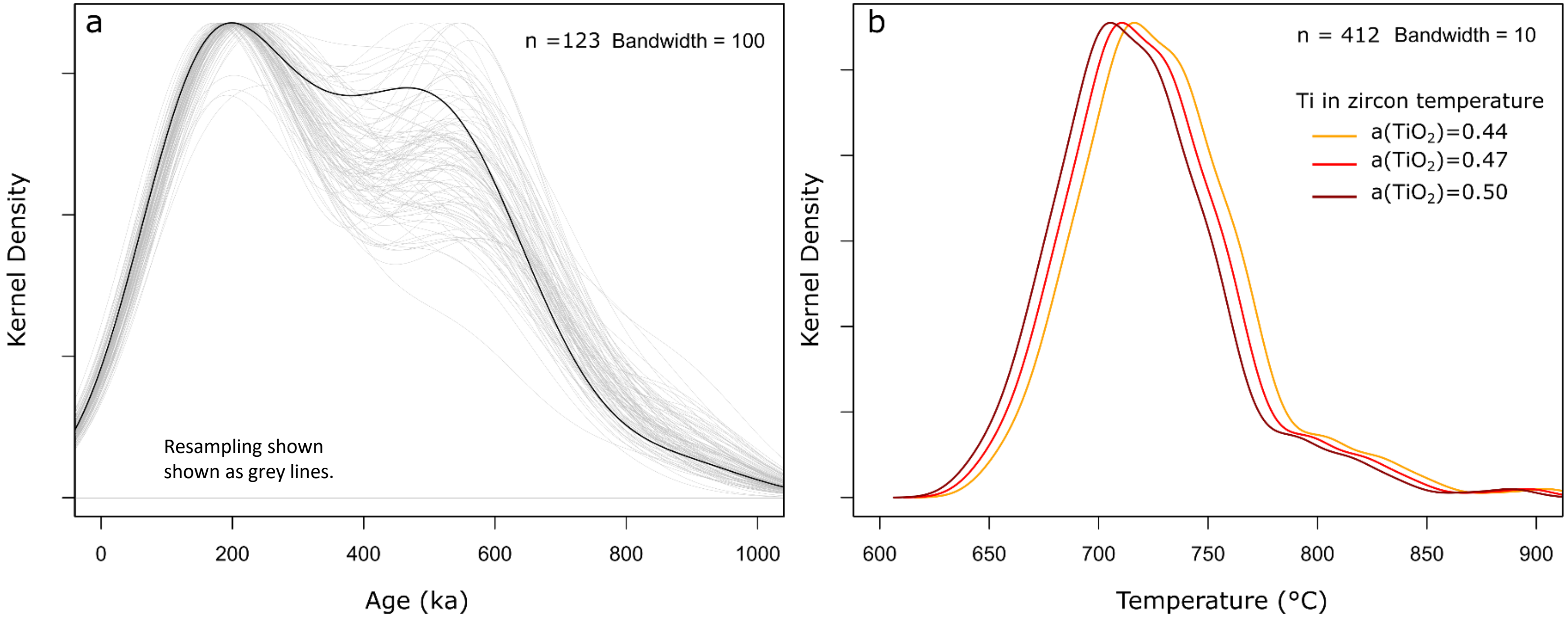


Shown are synthetic populations with 300, 100 or 15 analysed zircons for the same model.

- Shape of distributions entirely related to sampling as magma input is modelled in regular intervals:
- Care should be taken, when interpreting natural data: **Peaks and shoulders in distributions may not reflect magmatic processes for low number of analysed zircons.**

Natural zircon age distributions and Ti-in zircon temperatures

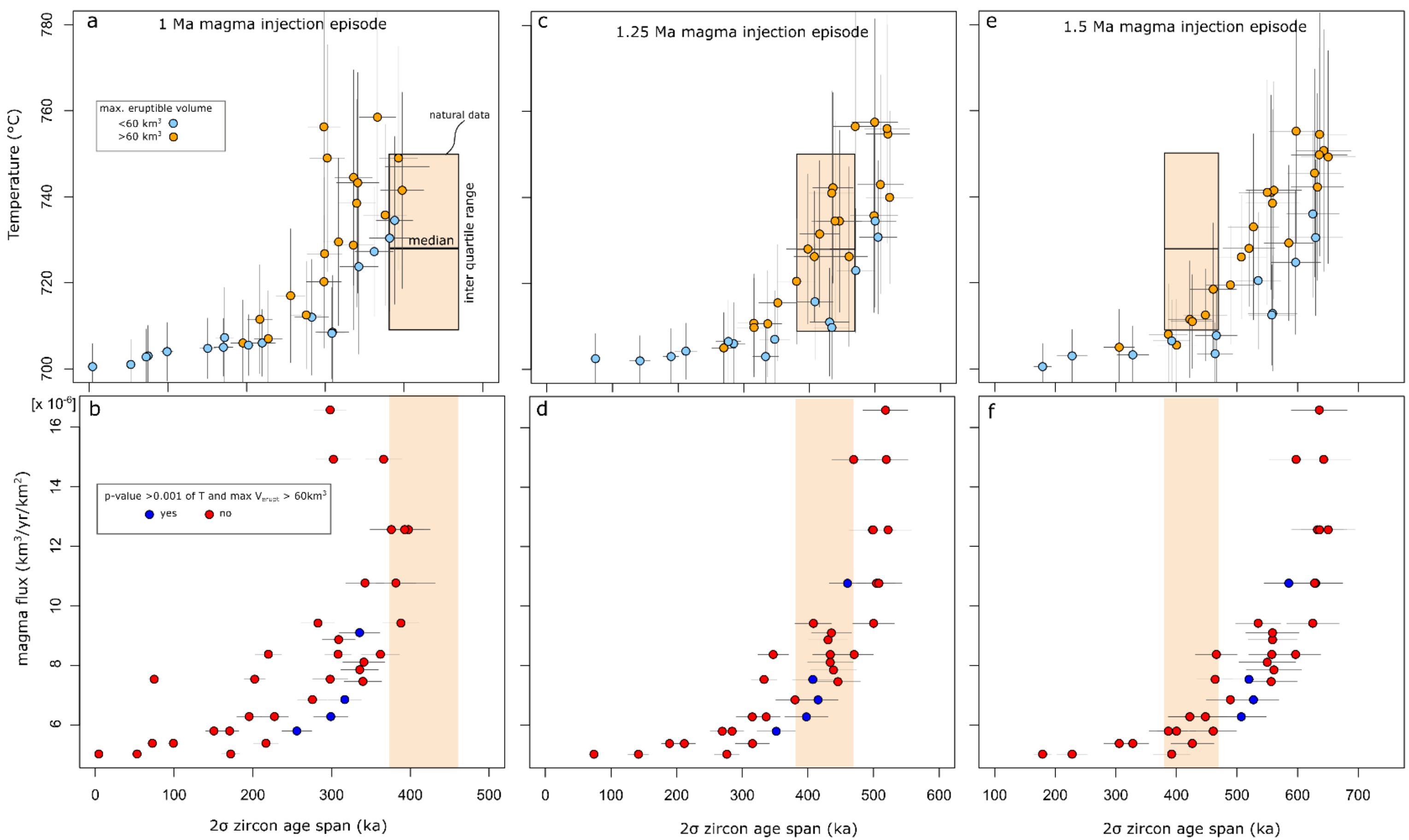
Ti activity contrained by MELTS (Gualda et al., 2012)



To compare to modelling results and natural data we calculate:

- The spread in zircon ages (within 2SD)
- The time integrated temperature distribution (Ti-in-zircon thermometry)

Constraining magma fluxes

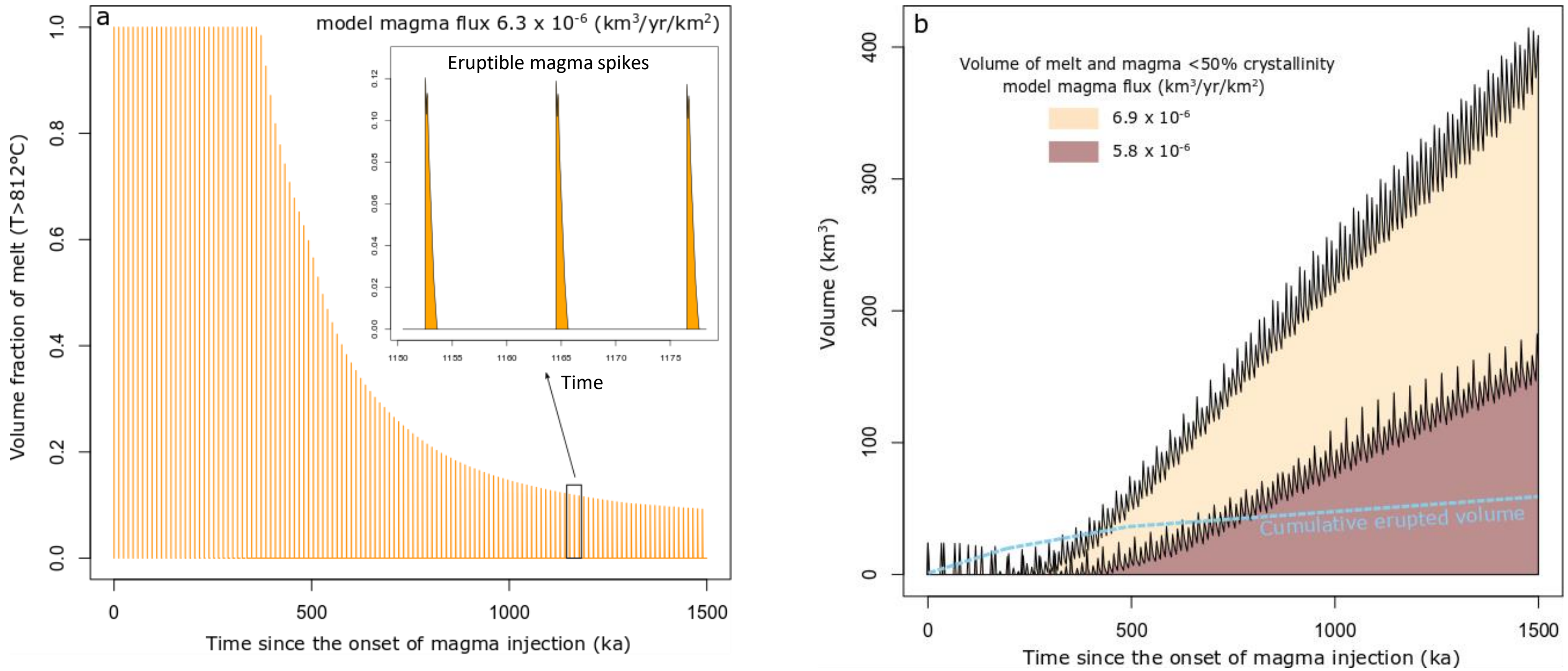


Three criteria to match:

- Age spread of natural data and model overlaps within uncertainty
- Temperature distributions agree (Welch's t-test)
- Eruptible magma in model > minimum output of the volcano

Hazard potential of Nevado de Toluca

Simulations that match natural data constrain
magma flux: 5.8×10^{-6} and 7.5×10^{-6} $km^3\ km^{-2}\ yr^{-1}$
extrusive:intrusive ratio: 0.02-0.04



- **Eruptible magma only transiently present (years to centuries)**
- **Up to 350 km^3 melt beneath the volcano today**
- **Potential for large eruptions if magma input resumes**

Summary

- New high resolution method to constrain magma fluxes, E:I ratio, size and state of subvolcanic reservoirs
- Dormant volcanoes, like Nevado de Toluca, can reawaken from multi-millennial dormancy and produce large eruptions within years
- Maximum size of future eruptions can be constrained by combined zircon and thermal modelling