Experimental constraints on magma mixing: case studies from Phlegrean Fields and Montserrat

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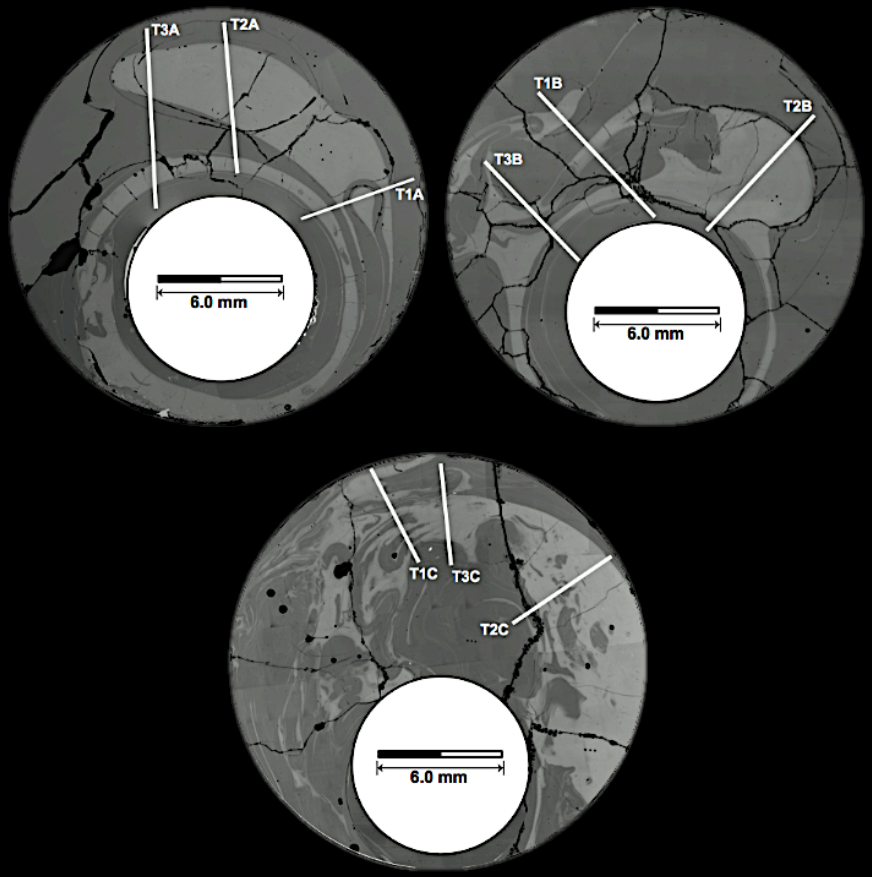

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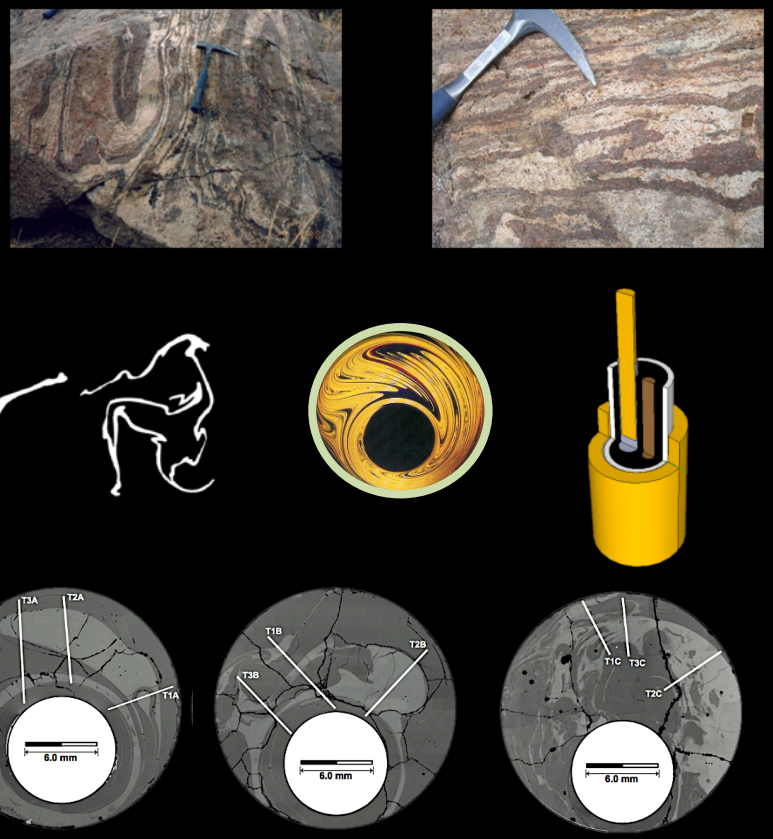
VUELCO

Presentation outline

- *Introduction*
  - Magma mixing
  - Chaotic mixing in magmas
- *Methodology*
  - Chaotic mixing
  - Chaotic mixing setup
- *Results*
  - Optical analysis
  - Geochemical analysis
- *Future Work*
  - Campi Flegrei
  - Montserrat



Aims

Experimentally study the physical and chemical interplays between mafic and felsic natural melts to:

1) **provide time scale of mixing** under controlled chaotic dynamics, using melts with high-viscosity contrast at high temperature

2) Constrain **the mobility of major and trace elements** using concentration variance decay in time

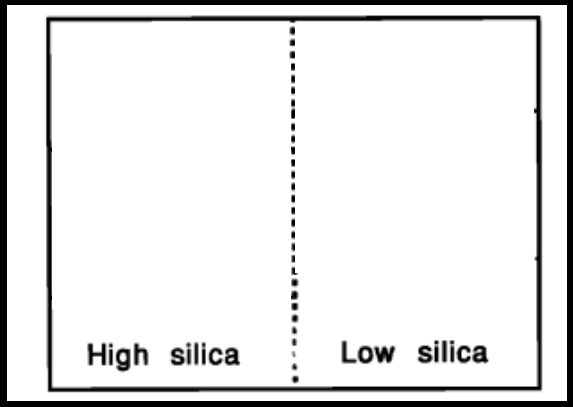
Background

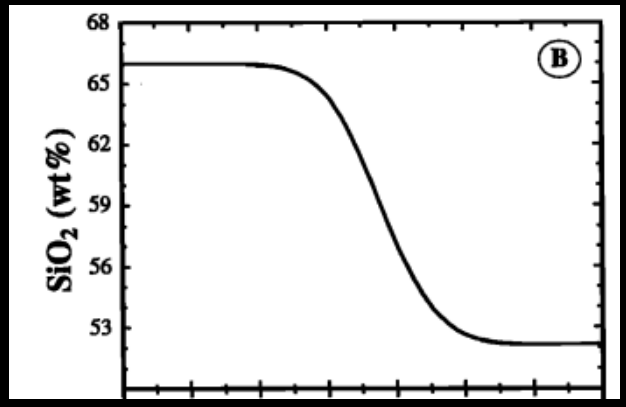
Magma Mixing

is a major differentiation process and one of the most important eruption trigger

the mechanisms acting to promote melt interaction, both from the physical and chemical point of view are still poorly understood

magma mixing has been mostly addressed using **STATIC** chemical diffusion experiments (e.g., Watson 1979; Baker 1991)





In nature magmas interact through more complex geometries and dynamics

Magma mixing structures


J. Pritchard
2011

Fractal structures

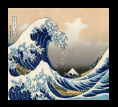

Morgavi
2012

Observed on <u>different scales</u>
Through:
variable structural and textural patterns and filament-like structures

Chaotic Mixing


Perugini
2004

Chaotic Mixing
(Predictable Random Motion)

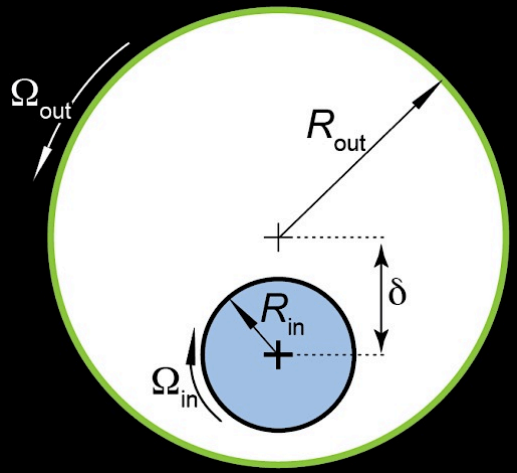


"Chaotic mixing" is the repeated "stretching and folding" of fluids

Time evolution

To create chaotic mixing structure Swanson and Ottino in 1990 use the Journal Bearing Flow (JBF) apparatus,

the mixing is triggered by alternate rotation of two eccentric cylinders.

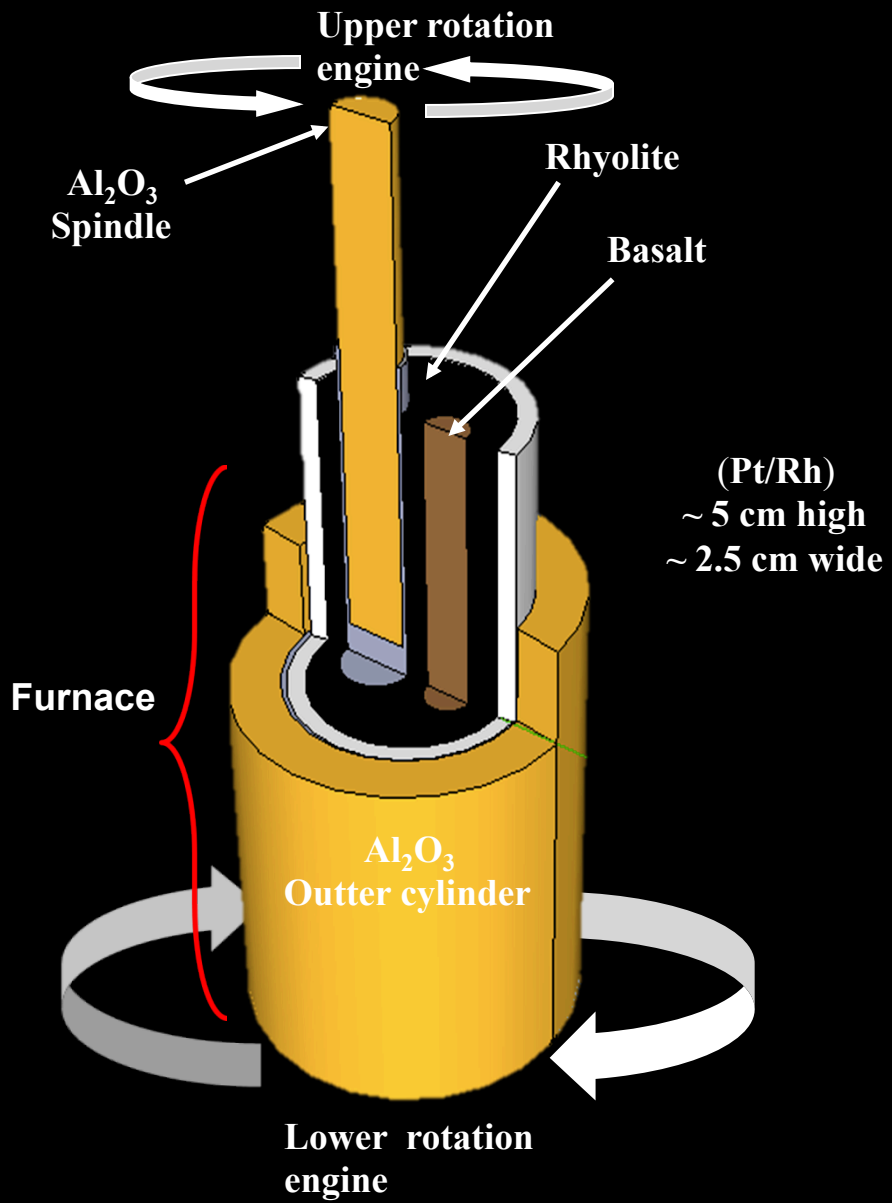


Chaotic Mixing High Temp. Exp. Setup

- high temperature and high viscosities Experiments

Re-melted glass composition

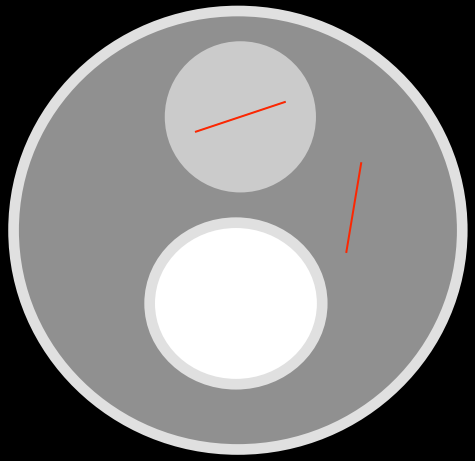
2.5 cm



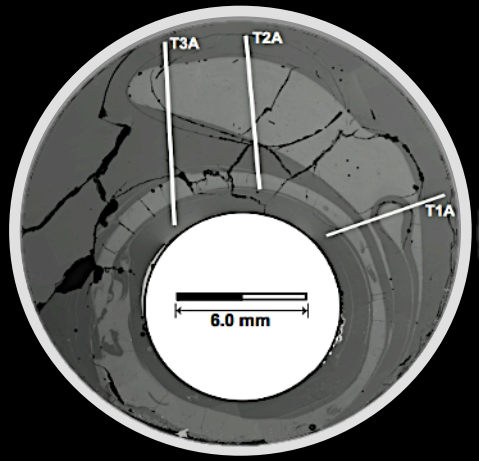
Optical results

Chaotic Mixing experiment 1350 °C

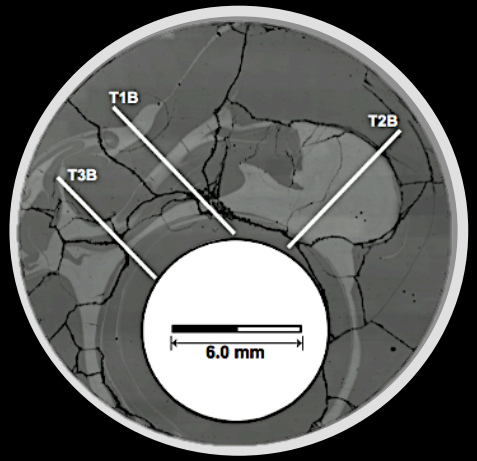
Time=0



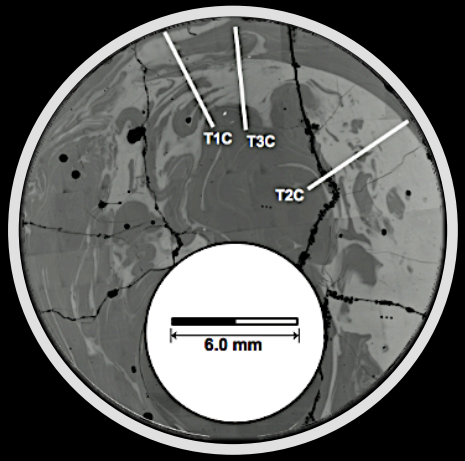
Time=1h
(1 Protocol)



Time=2h
(2 Protocols)



Time=4h
(4 Protocols)



The mafic liquid was dispersed within the felsic liquid

Protocol	Numbers of Rotations	Speed	Time	
	2 rotations	0.05 Rpm	40 min.	Outer cylinder
	6 ratations	0.33 Rpm	20 min.	spindle

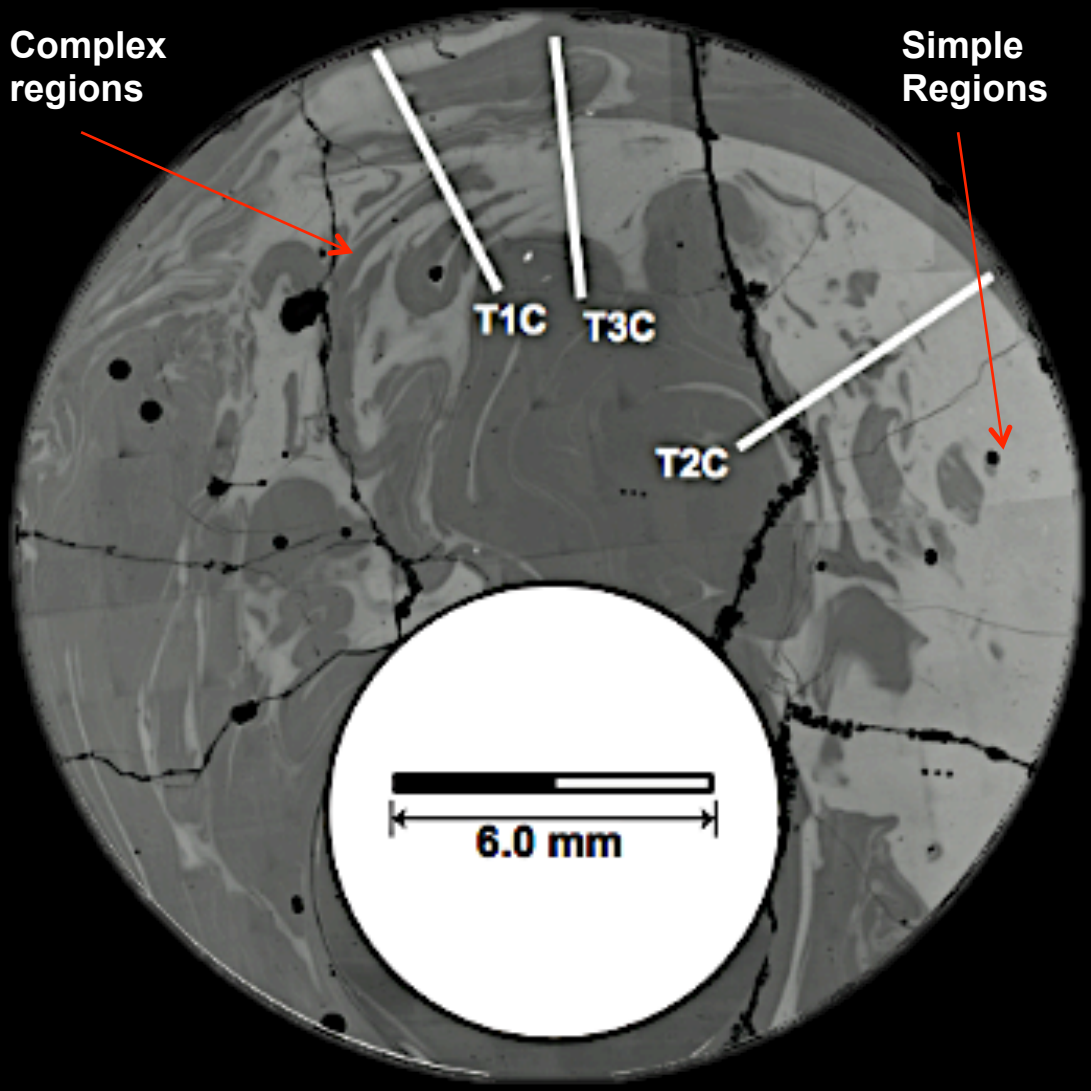
- Exp. at 1350°C for 1, 2 and 4 hrs
- For each experiment 3 transects of 100 points each were selected for geochemical analyses

BSE Image
1350 °C 4 hours

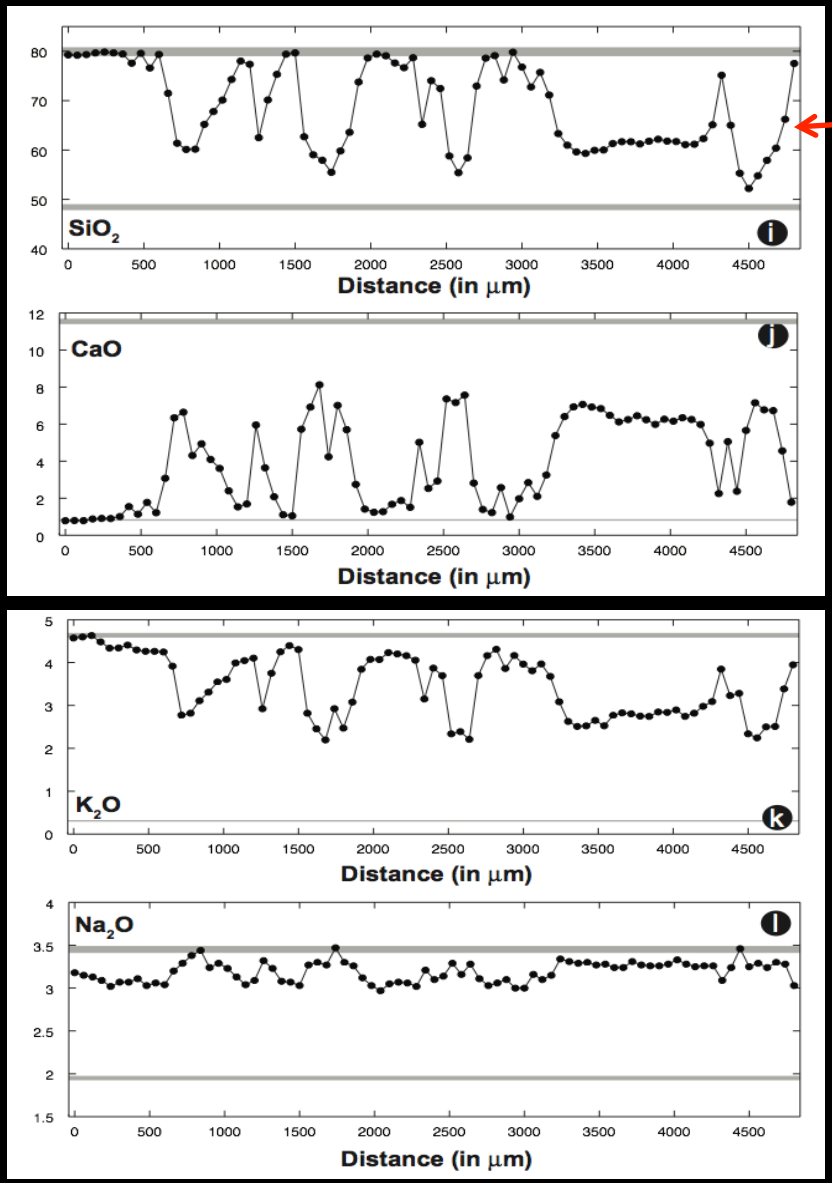
Our experiments:

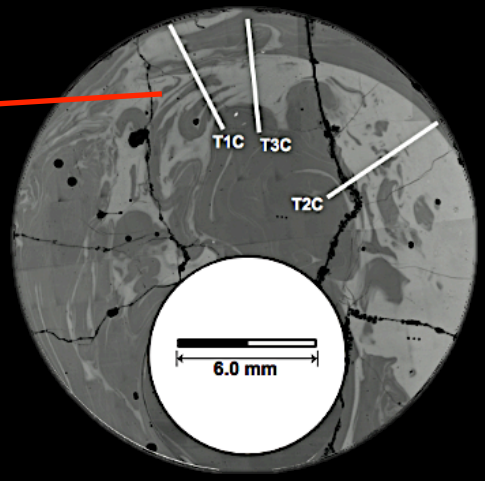
- Produced a strong modulation of mixing pattern
- Formation of very complex fluid structure and developing of complex and simple regions

We have produce an exponential increase of contact area



Filament Transect 1350 °C 4h

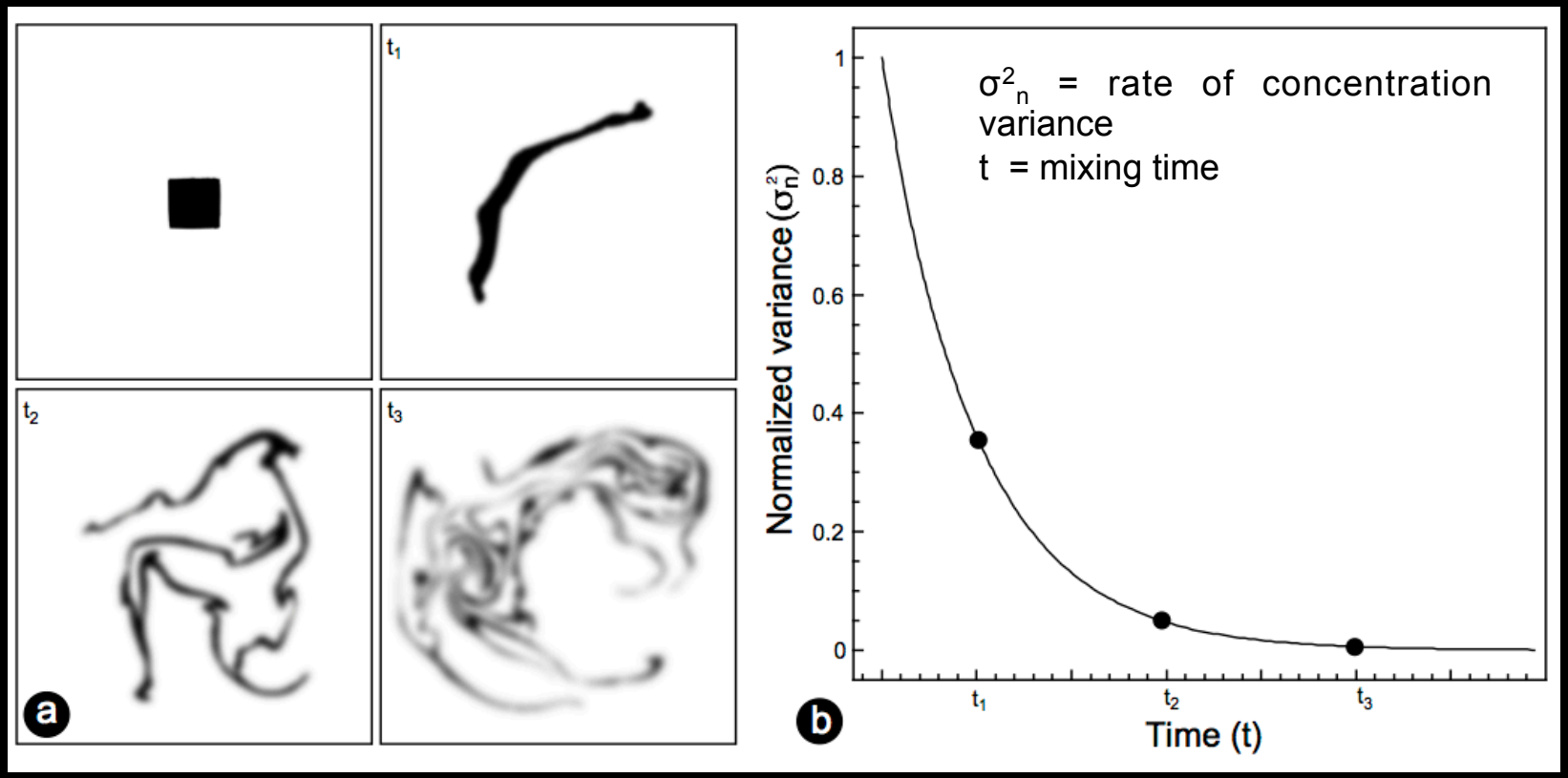




Elements variability exhibits oscillatory patterns with compositional “highs and lows” evidencing the transition of the two melts

larger number of filaments with a small thickness display a larger shift to the hybrid composition relative to filaments with a larger size.

Concentration variance
(one value for all system)

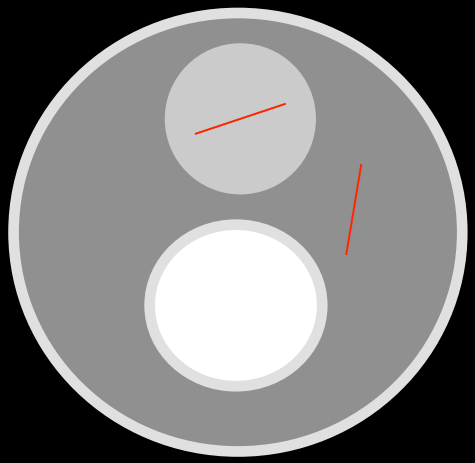


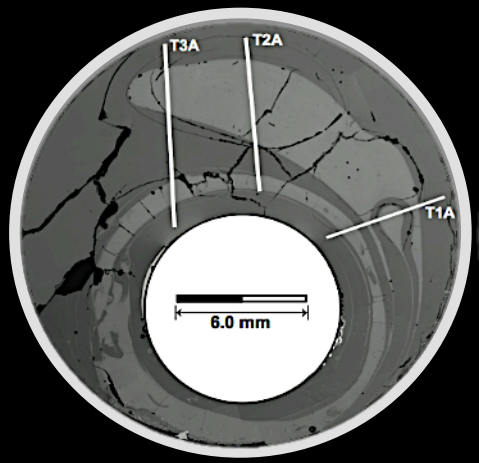
The concentration variance measures the homogenity of the system therefore during chaotic mixing and it is expected to decay in time.

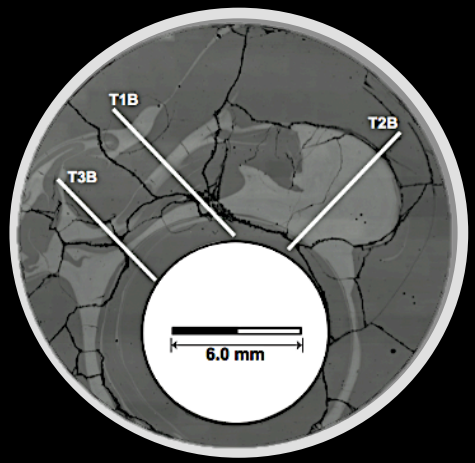
The mobility of each chemical element was quantified via: the variation of concentration variance.

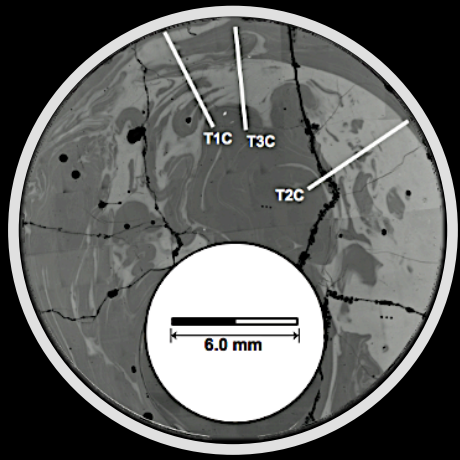
Concentration variance Analysis

Time 0 | Time 1 | Time 2 | Time 4









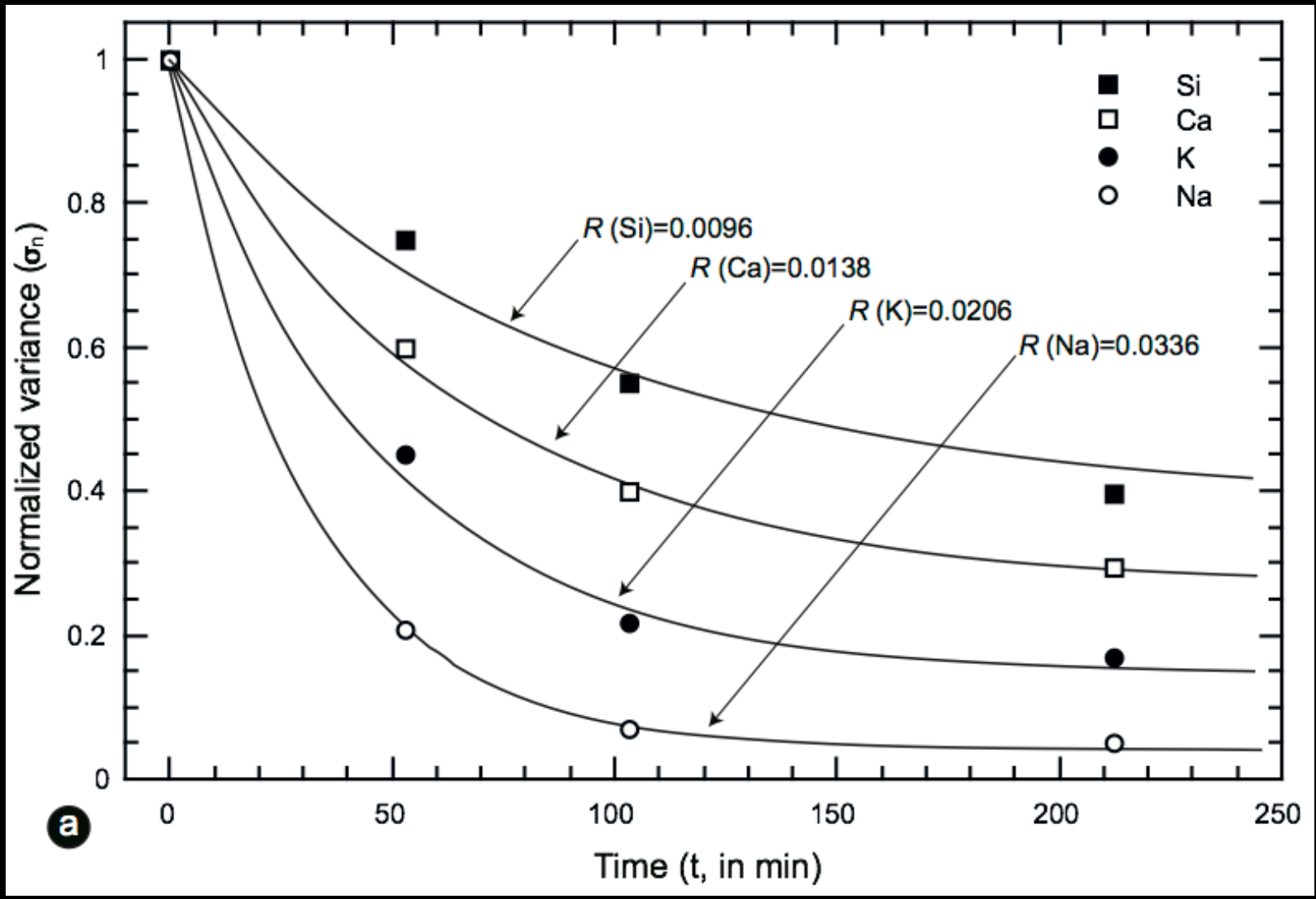
- For each transect we calculate the concentration variance (normalized to the initial variance) and took the average on the three transects.

$$\sigma_n^2 = \frac{\sigma^2(C_i)_t}{\sigma^2(C_i)_{t=0}}$$

- σ^2_n = 1 no mixing (starting end member)
- σ^2_n = 0 full mixing (hybrid composition)

	Time 0	Time 1	Time 2	Time 4
Na_2O	1	0.22	0.1	0.06
K_2O	1	0.28	0.14	0.10
CaO	1	0.38	0.21	0.17
MgO	1	0.39	0.22	0.18
SiO_2	1	0.42	0.24	0.20
Al_2O_3	1	0.44	0.26	0.22
TiO_2	1	0.47	0.27	0.22
$FeO_{(Tot)}$	1	0.60	0.31	0.29

The degree of Homogenization for major elements



Vuelco

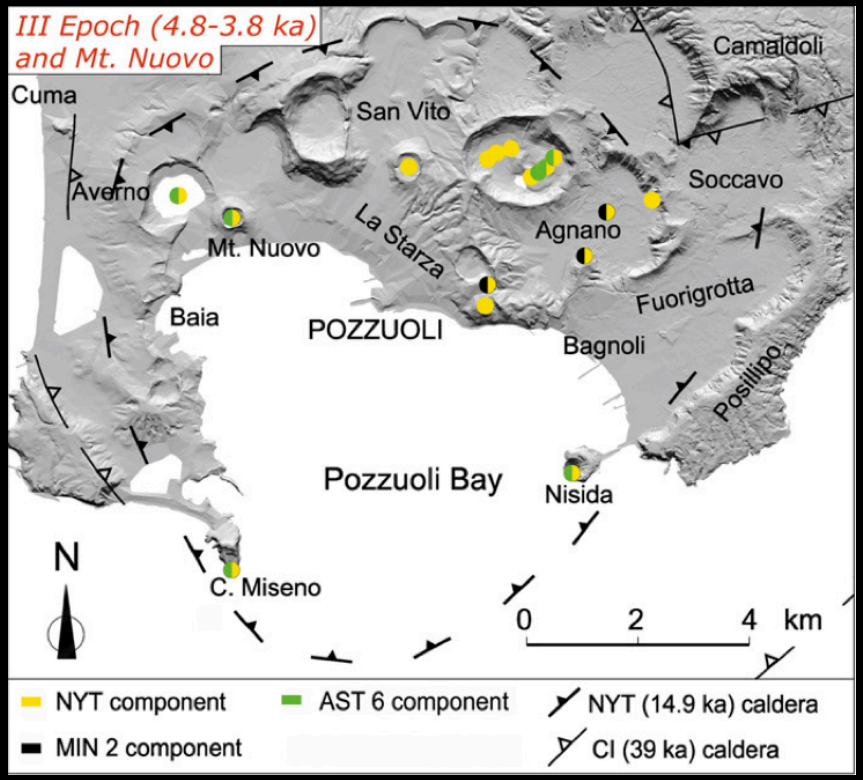
- Results from this study will be applied to natural outcrops for a variety of purpose

Estimate the time-scale of magma mixing

- The impact of chaotic mixing processes in the petrological study of the compositional variability of natural rock samples.

Campi Flegrei **Montserrat**

Campi Flegrei



Different colours identify the dominant isotopically distinct magmatic components, or in case of mixing, the two components involved (Arienzo et al 2011)

Compared with previous studies on mixing

Provide time scale of mixing under controlled chaotic dynamics

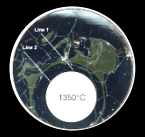
Di Renzo et al, 2011

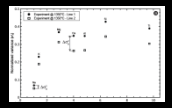
Understanding if mixing could be a possible explanation for geochemical differentiation of the volcanic products

Montserrat


First year


Second Year


Third Year


FUTURE WORK

Remobilization of Andesite Magma by Intrusion of Mafic Magma

Mafic inclusions in andesite lava block. Hammer (37 cm) for scale.