Reconstruction Of Pre-Eruptive Magmas from Láscar Volcano (NE Chile) Using Apatite as Compositional Proxy

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Background

- The Central Andean Volcanic zone (CVZ) is a section of the Andean volcanic arc that has exhibited strong and consistent activity since the Pleistocene.
- Láscar volcano is the most active among the 44 stratovolcanoes present in the CVZ. Its eruptive history comprises four stages:
  - **Stage I (< 43 ka):** Effusion of andesitic lava flows. Construction of Láscar's 1st stratocone. Explosive events registered as pyroclastic flow deposits (Chaile & Saltar Units).
  - **Stage II (26.5 ka):** Growth and collapse of andesitic lava domes (Piedras Grandes unit), followed by Plinian events (Soncor ignimbrite).
  - **Stage III (9.2 ka):** Emission of andesitic lava flows followed by explosive events registered as pumice fall deposits (Tumbres-Talabre pumice).
  - **Stage IV (7.1 ka):** Emission of lava flows, setting of the current stratocone configuration.
  - **Historic activity (1848 - today):** Cyclic behavior of dome growth and collapse, followed by vulcanian-to-Plinian eruptions until the Plinian eruption of April 1993.
- Currently, there are no comprehensive models that explain the architecture and dynamics of Láscar's plumbing system.

What magma dynamics lead to explosive events in Láscar?

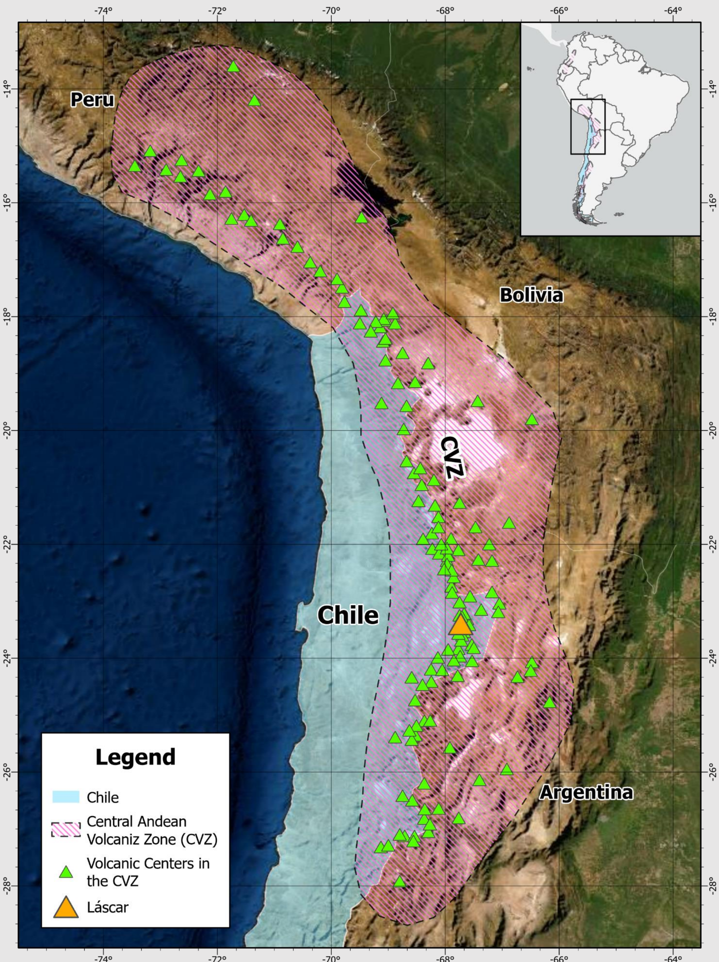
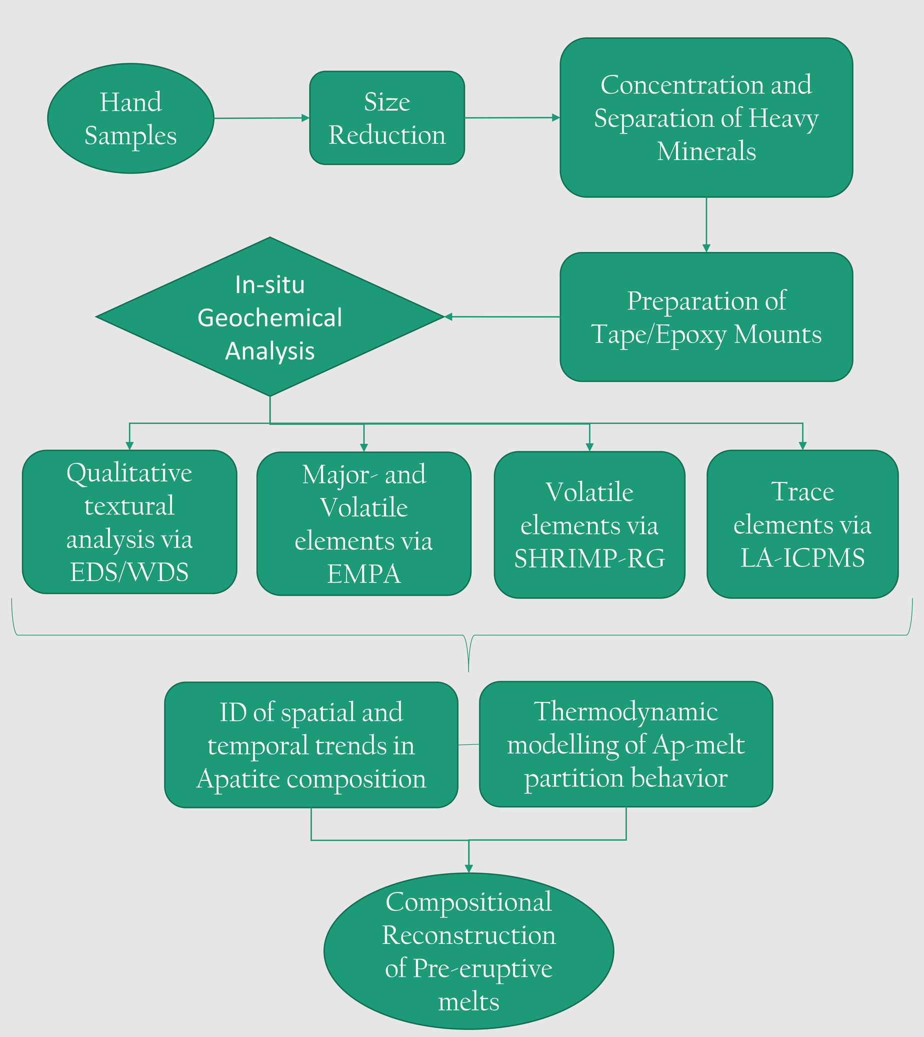


Figure 1. Location of Láscar in the Central Andes

Hypothesis

Mass transfer processes modify the volatile budget of pre-eruptive magmas in Láscar. These variations are significant over time and can be correlated to explosive events in its Holocene eruptive history.

Methodology



Sample	Type	Eruptive Event	Ar-Ar Age [ka]	SiO_2 [%wt.]
P01	Pumice	Soncor Ignimbrite	26.5	60.7
P02	Pumice	Tumbres-Talabre Eruption	9.2	59.93
P03	Banded Pumice - Bulk	1993 Eruption	-	61.44
P03A	Banded Pumice - Dark Bands	1993 Eruption	-	58.97

Table 1. Samples involved in this project, previously studied by Stearn (2020).

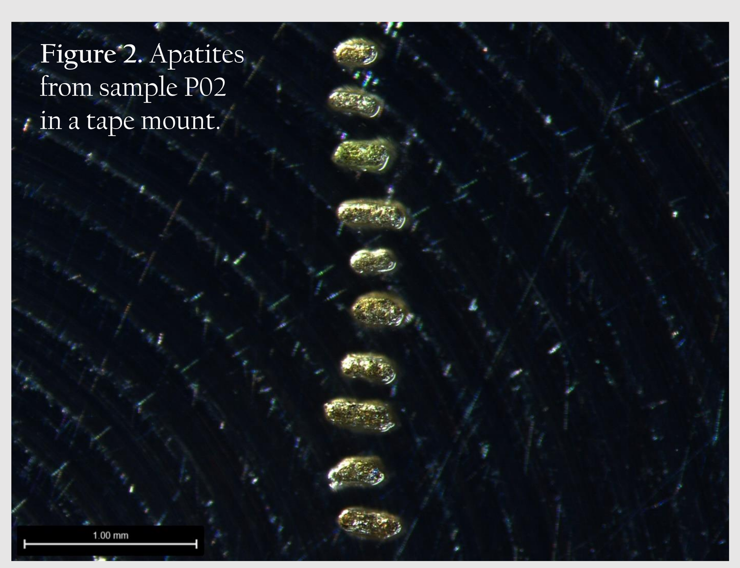


Figure 2. Apatites from sample P02 in a tape mount.

Results

Systematic Classification

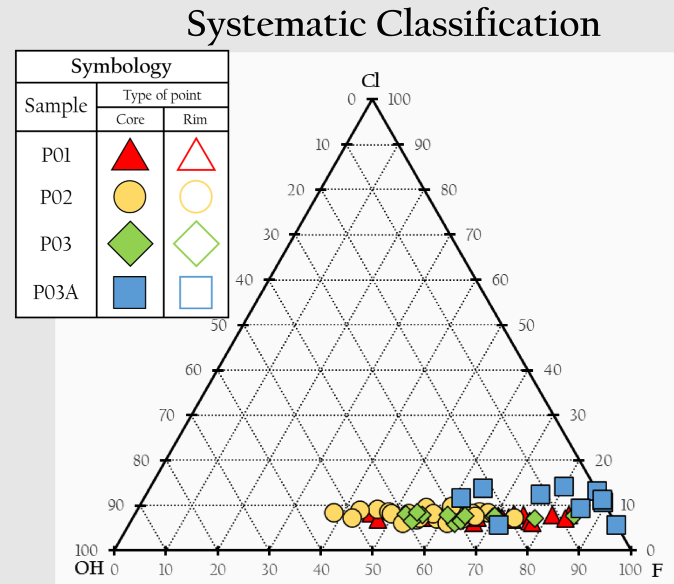


Figure 3. Ternary classification of Láscar apatites. Structural formula calculations follow Ketcham (2015).

Textural Analysis via Electron Microscopy (EDS/WDS)

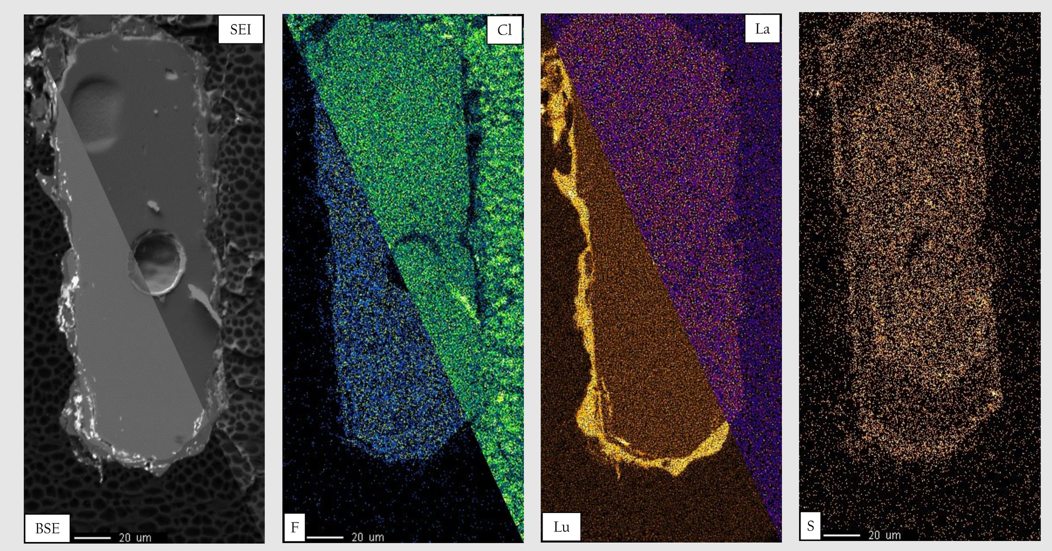
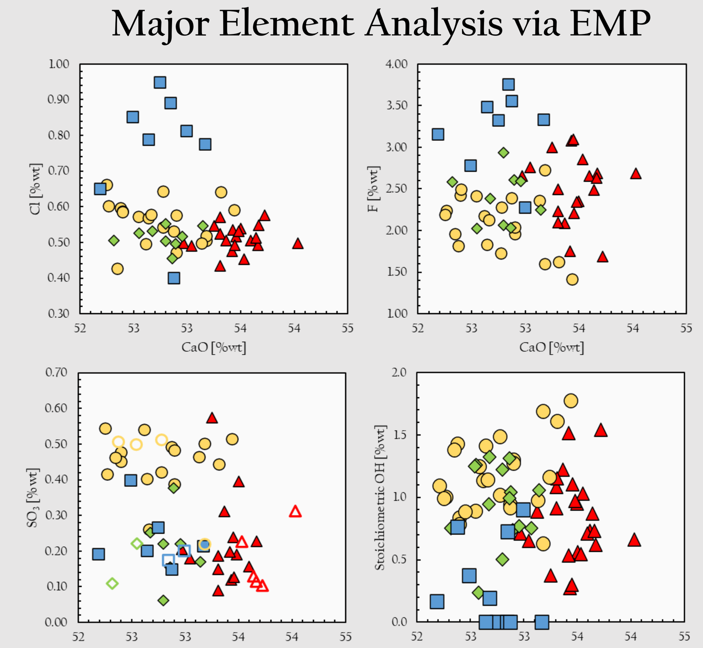
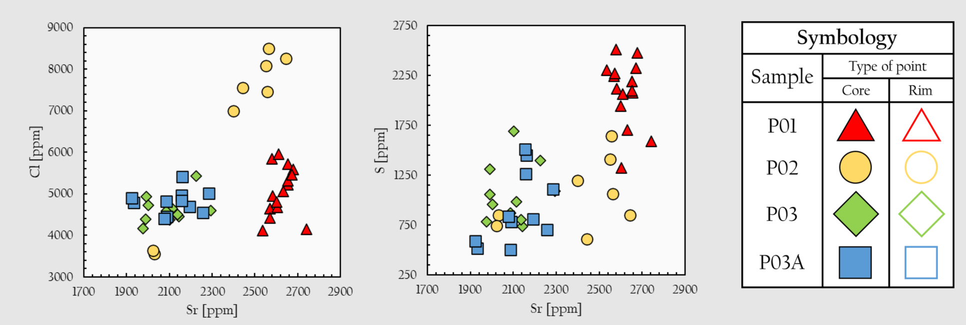


Figure 4. Electron microscopy images and compositional maps of a crystal from sample P01.

Major Element Analysis via EMP

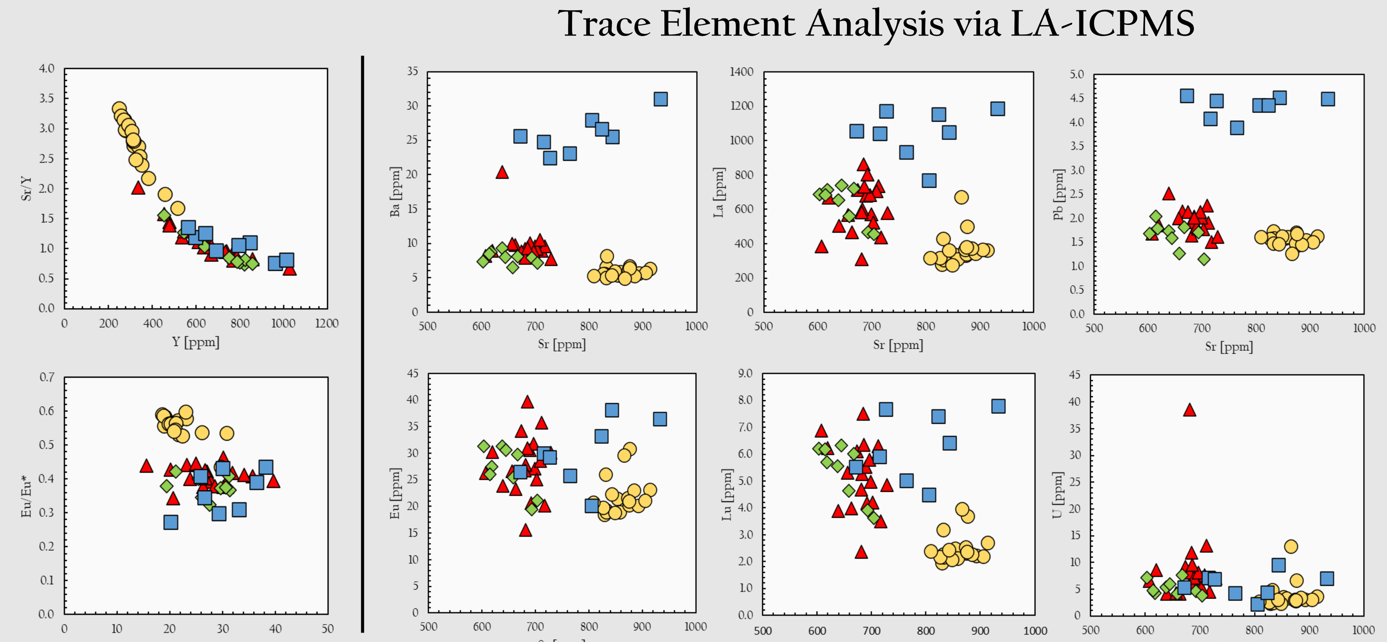


Volatile Element Analysis via SHRIMP-RG



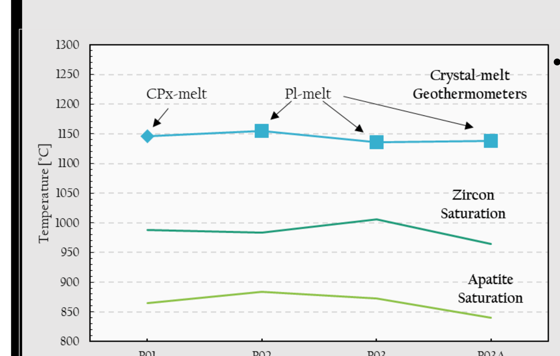
- **Figure 5 (Left).** Harker diagrams for major elements and stoichiometrically determined water-in-apatite. Calcium concentration [%wt] in the X-axis.
- **Figure 6 (Above).** Harker diagrams for Cl- and S- in-apatite gathered through SHRIMP-RG. Strontium concentration [ppm] in the X-axis.

Trace Element Analysis via LA-ICPMS



- **Figure 7 (Far left).** Sr/Y and Eu/Eu* ratios in apatite. Yttrium and Europium concentrations [ppm] as X-axis, respectively.
- **Figure 8 (Left).** Harker diagrams for trace elements in apatite. Strontium concentrations in the X-axis

Thermodynamic Modelling of Water-in-Melt Contents



- **Figure 9.** Crystal-melt crystallization temperatures (Putirka, 2008), Zircon saturation temperatures (Boehnke et al., 2013), and apatite saturation temperatures (Piccoli & Candela, 2002) for Láscar whole-rock samples.

Sample	Avg. Melt H_2O (calculated w/ Cl) [%wt]	Avg. Melt H_2O (calculated w/ F) [%wt]
P01	3.34	5.67
P02	5.33	7.60
P03	4.21	7.63
P03A	2.07	3.90

Table 2. Water-in-melt estimations for Láscar samples. Model by Li & Costa (2020).

Preliminary Interpretations

- Zonation patterns in Ap crystals, along with low AST indicate small residence times and inheritance. Apatite records late evolutionary stages of magma.
- Triangular trends are evidence for the strong influence of magma mixing between three different sources in Láscar samples.
- REE ratios suggests that plagioclase crystallization strongly controls the composition of samples.
- REE signatures also suggest a certain degree of participation of crustal assimilation.
- Volatiles concentrations in pre-eruptive melt are controlled by the same phenomena that controls concentration of other elements.

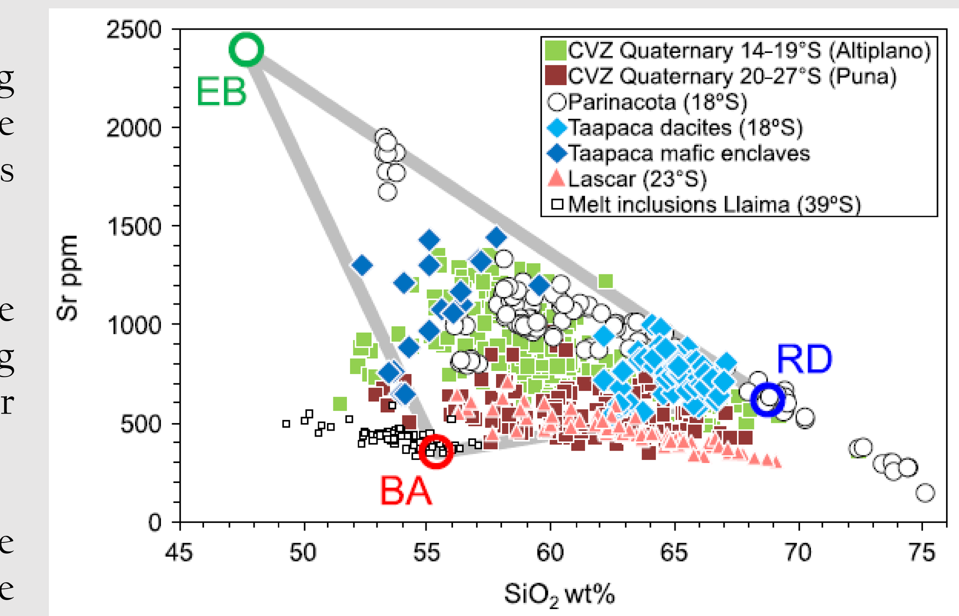


Figure 10. Sr vs. SiO_2, with proposed compositional end-members (enriched basalt, EB; rhyodacite, RD; basaltic andesite, BA) compared to whole-rock and melt inclusion samples from different volcanoes in the CVZ by Blum-Oeste & Wörner (2016).

Apatite composition attests pre-eruptive compositions of magma, and their configuration is a response to re-equilibration from a mafic composition to an intermediate composition caused by mixing.

Future Work

- Obtain, process and interpret Sr and Nd isotopic signatures (i.e., $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios) from whole-rock samples to quantify the influence of crustal assimilation and fractional crystallization in the composition of Láscar pre-eruptive melts.
- Compare the whole-rock isotopic information of current samples to that of effusive samples from Láscar to quantify the extent and influence of magmatic mass transfer processes in defining eruptive style.
- Integrate current information from whole-rock and apatite geochemistry to that of other mineral phases (plagioclase, pyroxene) in a comprehensive model for the plumbing system of Láscar.

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