Modeling Crystal Residence Times Recorded in Plagioclase, Láscar Volcano, Central Andes Volcanic Zone

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Introduction

- Láscar Volcano (Figure 1) is considered the most active volcano in the Andean Central Volcanic Zone with at least 27 eruptions since 1848 and nearly continuous active degassing in the crater (Matthews *et al.*, 1999).
- Since 1984, Láscar has displayed cyclic activity with the repetition of dome formation, crater collapse, and vulcanian to plinian eruptions, with the largest occurring in April 1993 (Figures 2, 3, & 4).
- We use plagioclase hosted in pumice from the April 1993 plinian eruption to create preliminary diffusion timescale models.
- These data will allow for the analysis of diffusion timescales prior to the explosive April 1993 plinian eruption and for the identification of changes within the magma bodies underlying Láscar by using eruptive units as a proxy.

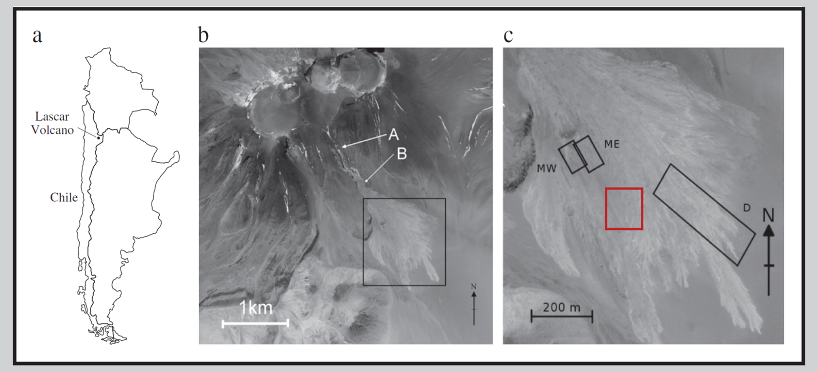

Figure 1 (above): (a) Map of Láscar Volcano. **(b)** Location of pyroclastic fan. **(c)** Red box indicates location where samples were sourced. Modified from Jessop *et al.* (2012).

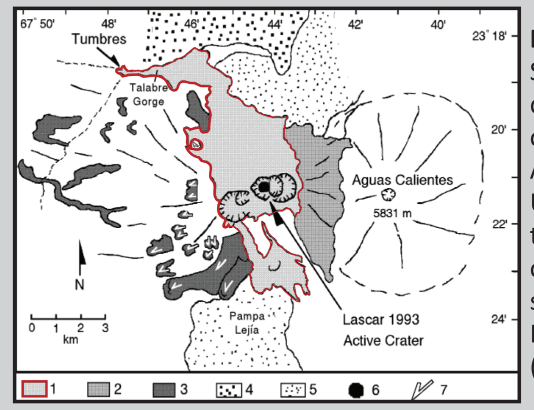

Figure 2 (left): Schematic map of the distribution of pyroclastic flows from the April 1993 eruption. Unit outlined in red is the pumaceous pyroclastic flow deposit sampled in this study. Modified from Venzke (1993).

Figure 3 (left): Picture of the April 1993 plinian eruption pyroclastic fan spilling over the underlying Tumbres-Talabre lava. Picture courtesy of Gary Michelfelder.

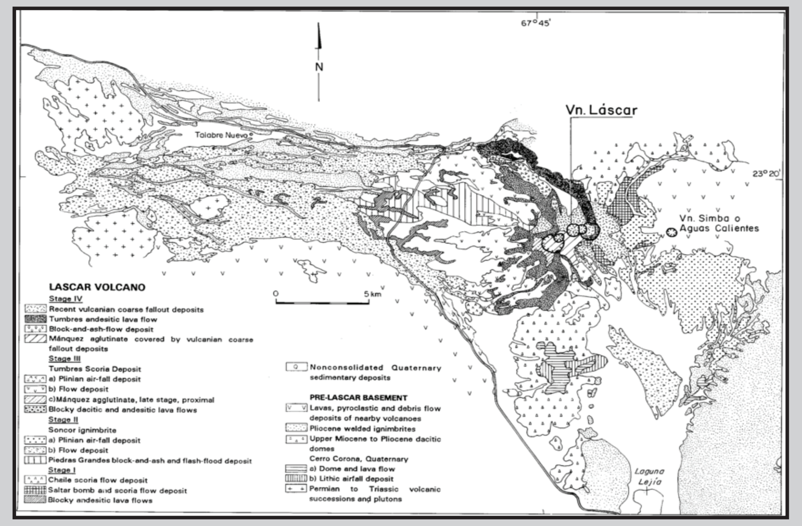

Figure 4 (above): Geologic map of the extent of eruptive units sourced from the four eruptive stages of Láscar Volcano. After Gardeweg *et al.* (1998).

Methods

- 16 plagioclase crystals (hosted in pumice) were selected on 2 corresponding pre-existing thin section mounts representing the banded and non-banded pumice clasts of the April 1993 plinian eruption.
- Trace element data was collected through the use of the ESI NWR 193 laser ablation system (Figure 5) paired with the Thermo Icap Q ICP-MS at the University of Arkansas. Major element data was collected using the JEOL JXA-8230 Superprobe electron probe micro analyzer (EPMA; Figure 6) at the University of Iowa.
- Line transects and accompanying EPMA spot analyses were plotted across each of the plagioclase crystals from core to rim, with one EPMA spot per distinct zone composition (Figure 7). Depending on the size of the crystal, up to two transects were plotted per crystal, oriented along different crystallographic axes.
- Data was reduced within the Iolite 4 software to remove outliers and reduce error.
- Sr trace element data was combined with An major element data in open-source Python script developed by Jordan Lubbers to create the resulting model shown (Figures 8 and 9; Lubbers *et al.,* 2022).

Figure 5: ESI NWR 193 laser ablation system

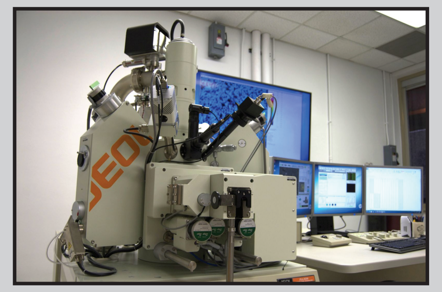

Figure 6: JEOL JXA-8230 Superprobe EPMA

Results

April 1993 Non-Banded Pumice (P03)

April 1993 Banded Pumice (P03A)

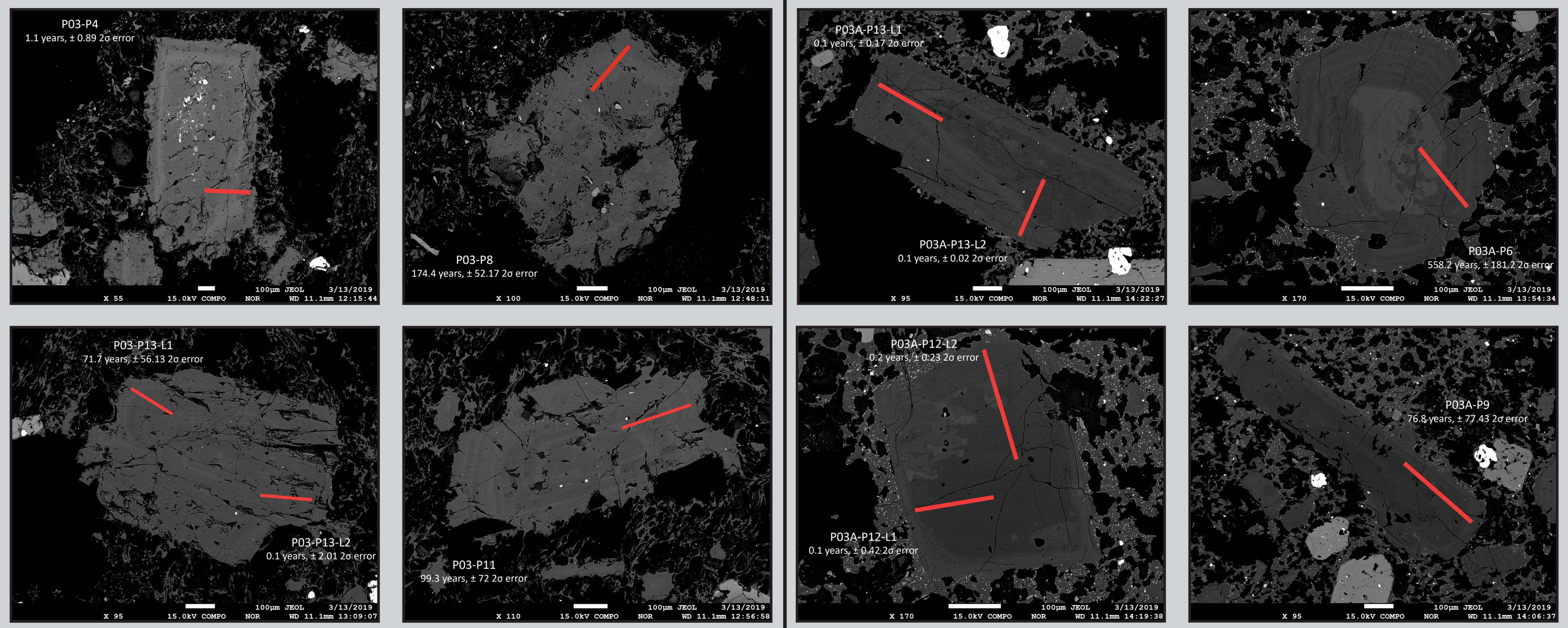

Figure 7: Backscatter electron images of modeled plagioclase phenocrysts with annotated diffusion timescales and error. Locations of LA-ICP-MS transects have been overlain in red.

Preliminary Diffusion Timescale Models

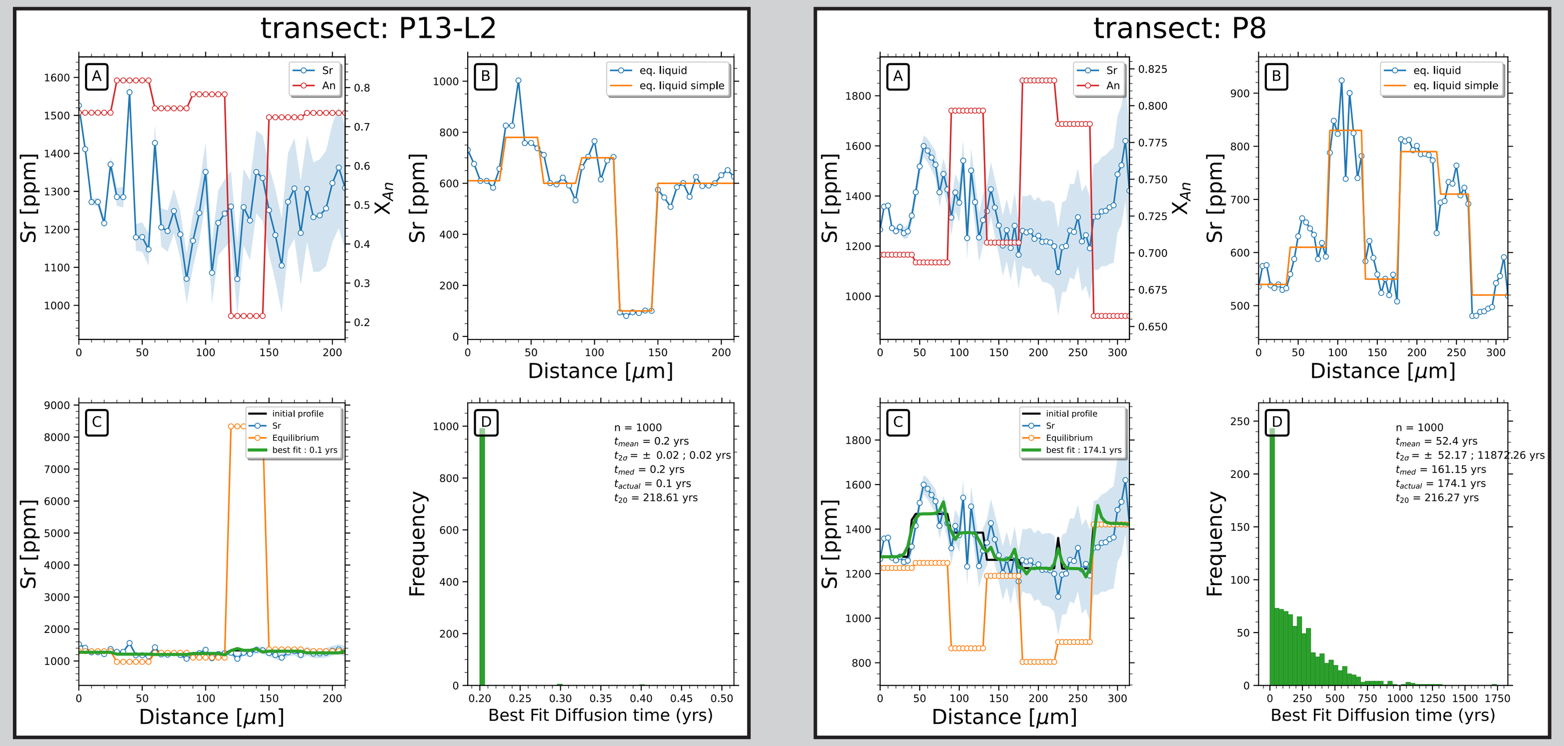

Figure 8: Example diffusion timescale models from plagioclase of the two pumices. **(A)** Strontium and anorthite content (X_{An}) plotted against distance. **(B)** Equilibrium liquid profile compared to a simplified profile utilized in modeling. **(C)** Initial profile and best fit from model plotted on observed data. **(D)** Results from the Monte Carlo Simulation. Diffusion methodology used is Bindeman *et al.* (1998) from Lubbers *et al.* (2022).

Figure 10 (above): Example of a banded pumice clast from Sample P03A.

Preliminary Interpretations

1) Initial results suggest the presence of two distinct crystal populations shared between the banded (Figure 10) and non-banded pumices. An older (between 29.3 to 558.2 years before eruption; ± 8.27 to ± 338.66 2σ error) and a younger (0.1 to 1.1 years before eruption; ± 0.02 to ± 2.01 2σ error). Populations are separated by a gap centered upon approximately 10 years before the April 1993 plinian eruption.

2) This gap can be interpreted as a mixing event that occurred prior to the historical eruption. Provides a possible explanation for the large discrepancy in diffusion timescales between the two populations.

3) Two populations can be interpreted to represent antecrystic/xenocrystic crystals and crystals that grew and began diffusion following the mixing event.

4) Assuming relative accuracy of the diffusion timescale model, this means that crystals in the younger population had approximately anywhere between 3 and 33 days to diffuse towards equilibrium with the surrounding magma in the magmatic system beneath Láscar Volcano prior to the beginning of the explosive April 1993 eruption.

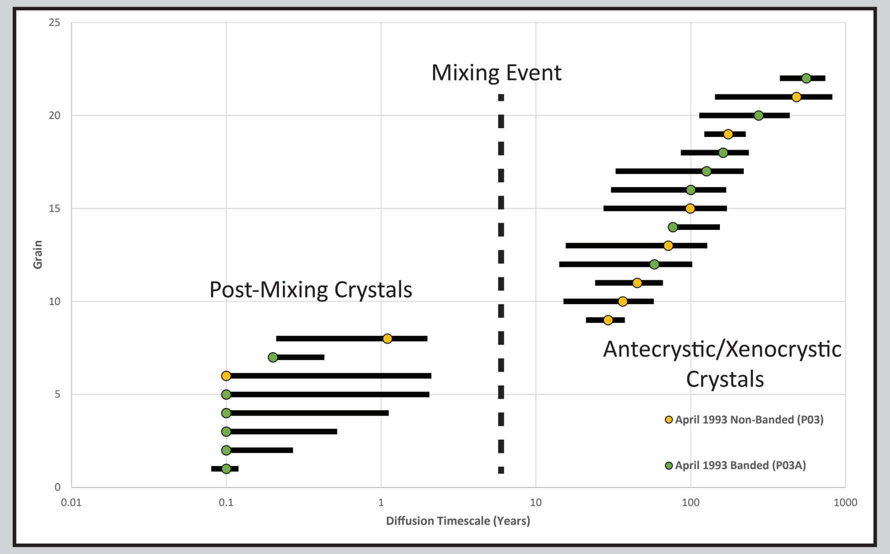

Figure 9: Preliminary diffusion timescale model for plagioclase crystals from the April 1993 Plinian eruption. Modeled grains are first ordered in ascending best-fit timescale and then by 2σ error (shown by error bars).

Future Work

- Individual diffusion models for the crystals and transects will continue to be iterated upon in order to improve the fit of the simple-liquid line by adjusting values used in the script's step function (Figure 8b).
- Additional diffiusion models will be created for Mg and Ba to determine if there is a element best suited for modeling diffusion in Láscar's plagioclase phenocrysts.
- Initial conditions used in modeling will be improved in order to provide more accurate timescales.
- Further diffusion methodologies will be used (Nielson *et al.,* 2017; Tepley *et al.,* 2010) alongside Bindeman *et al.* (1998) to compare and contrast resulting timescales when possible.

Acknowledgments

I would like to thank the National Science Foundation (EAR-2006374: RUI: Tracking magma accumulation and evolution in the Andean Central Volcanic Zone), the Missouri Space Grant Consortium (NASA-Missouri Space Grant Consortium Cooperative Agreement #80NSSC20M0100), and the Missouri State University Graduate College for providing the funding for this project. I would also like to thank Jordan Lubbers for his continued asssistance in iterating and improving the diffusion timescale models. Additional thanks is extended to Barry Shaulis and Kenny Horkley as well as my fellow MSU grad students for assistance with data collection and reduction.

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