Report of Transnational Access Projects

(Note: the information here will be publicly disclosed in the Geo-INQUIRE website, do not include sensitive information)

Project ID: *C3_TA3-83-4_3*

Principal investigator: *Martín Miranda-Muruzábal, University of Geneva*

Project team (if applicable):

- *Luca Caricchi, University of Geneva*
- *Rosa Anna Corsaro, INGV - Etna Observatory*

Project title: ***DE**ciphering **C**ycles of **A**ctivity over **D**ecades at Mt. **E**tna*

Project acronym: ***DECADE***

Hosting installation: *Eastern Sicily – Lithotheque (TA3-83-4)*

Hosting team: *Letizia Spampinato (INGV - Etna Observatory, Italy)*

Period of access: *24/10/2025 (arrival of the samples in Geneva)*

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Report of activities:

Between July 2001 and January 2003, two major events in the recent history of Mt Etna occurred: the well-known 2001 and 2002–03 eruptions. These two flank eruptions displayed both highly explosive and effusive behaviour, generating significant impacts on the surrounding villages and tourist facilities (e.g., Clocchiatti et al. 2004). To investigate why these events occurred in such close succession, the GEO-INQUIRE Eastern Sicily Lithotheque installation provided access to samples from subsequent eruptions, whose products are now inaccessible or difficult to sample in the field. These samples span the period from 2004 to 2013 and will be compared with samples from the 2001 and 2002–03 eruptions.

Clinopyroxene has been shown to crystallise throughout Mt Etna's plumbing system (e.g., Armienti et al. 2007; MacDonald et al. 2024), and experimental studies indicate that it is a liquidus phase at both high and intermediate crustal depths (Perinelli et al. 2018; Mollo et al. 2010). This makes clinopyroxene crystals excellent candidates for recording the architecture of Mt Etna's plumbing system and the magmatic processes occurring within it. Accordingly, this project investigates the compositional variations among different chemical zones within clinopyroxenes from the 2001–2013 eruptions to understand the observed eruptive variability in terms of explosivity, magnitude, and eruptive behaviour. The sample set provided by the infrastructure, covering the 2004–2013 eruptions, was complemented by a sample collected during a field campaign in March 2025 from the products of the 2001 eruption, as well as by published data for the 2002–03 eruption (Ubide et al. 2019).

The provided samples were prepared as thin sections. Clinopyroxene and glass analyses, the latter performed only on tephra samples, were subsequently carried out using the JEOL JXA-iHP200F HyperProbe at the University of Geneva. Clinopyroxene analyses were collected along core-to-rim transects at a step size of 10 µm when all concentric crystal zones were exposed and available for analysis. Individual spot analyses were instead performed on complexly zoned or incomplete crystals and on crystals within glomerocrysts. In addition, five matrix-glass analyses were acquired from each tephra sample.

As previous studies have reported (Ubide et al. 2019; MacDonald et al. 2024), Etnean clinopyroxenes typically consist of a Na-rich, resorbed core followed by an overgrowth characterised by high Cr_2O_3 contents and Mg# values. This overgrowth is followed by a mantle displaying sector and oscillatory zoning. In some cases, the crystals terminate in a thin rim enriched in Na_2O and Al_2O_3. Some of the clinopyroxene crystals analysed in this study display additional core textures that have not yet been reported in the literature, including patchy, replacement, and cold cores.

Preliminary results show that, whereas the high-Na cores display relatively constant compositions, the mantles exhibit coupled variations in Na_2O, Cr_2O_3, and Mg# (Figure 1). Starting with low Na_2O, and high Cr_2O_3 and Mg# which progressively reverses after the 2004 eruption (Figure 1). This suggests a progressive variation of the pre-eruptive temperature or the input of mafic magma. This pattern may indicate progressive changes in pre-eruptive temperature, variations in the input of mafic magma, or a combination of both processes. Further investigation is required to fully understand these fluctuations. Nevertheless, these preliminary results demonstrate the ability of clinopyroxene to record temporal variations in pre-eruptive storage conditions and the magmatic processes operating within Mt Etna's plumbing system.

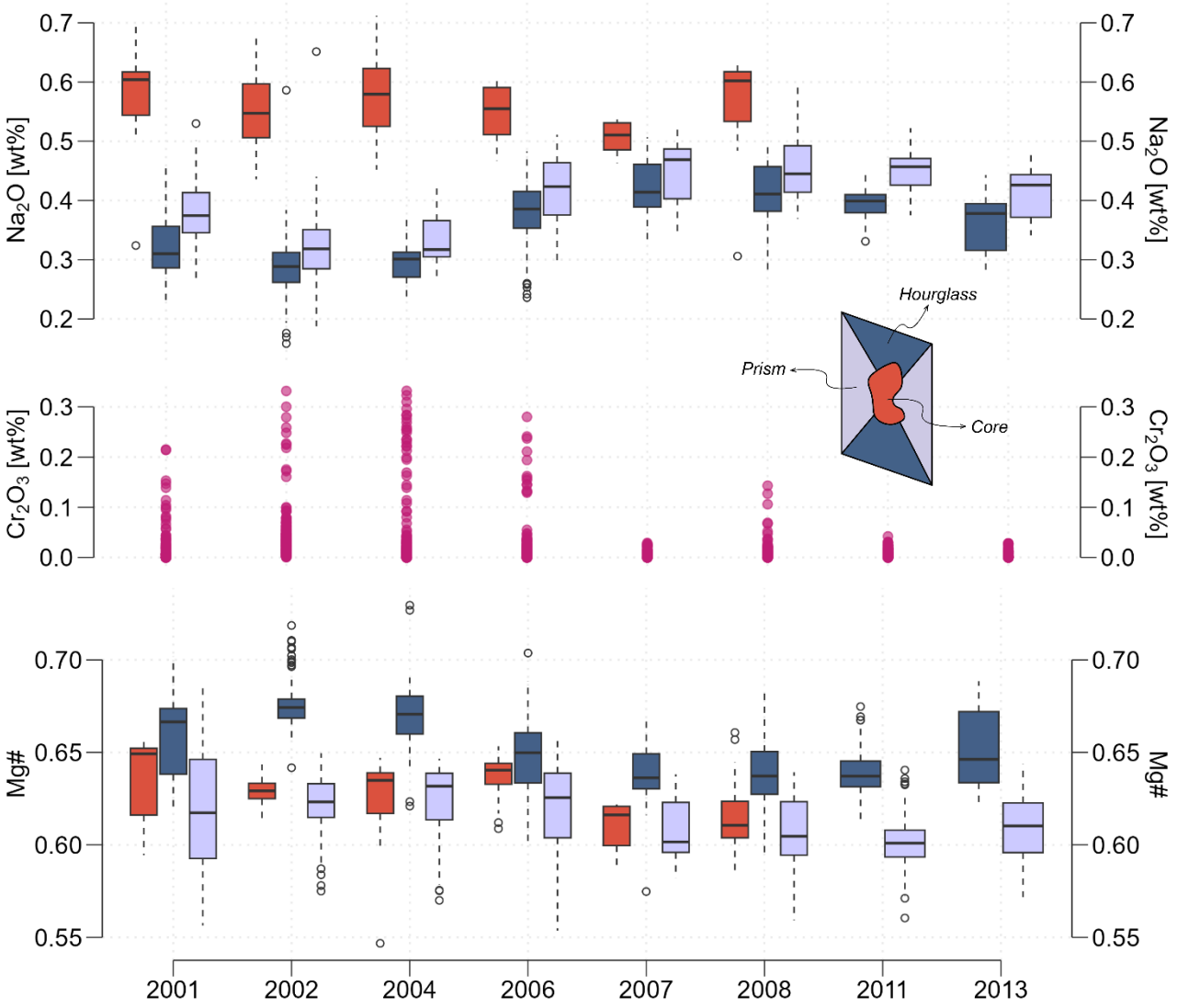

Figure 1 – *Boxplots showing the compositional evolution of high-Na cores and mantles from clinopyroxenes from 2001 to 2013. One sample per year. Samples from 2004 to 2013 from the TA3-83-4 GEO-Inquire infrastructure (see supplementary file for more information about the samples). 2001 sample collected in a field campaign in March 2025 and 2002 data from Ubide et al. (2019). Mg# calculated with FeO (total).*

References

Armienti, P., Tonarini, S., Innocenti, F., & D'Orazio, M. (2007). Mount Etna pyroxene as tracer of petrogenetic processes and dynamics of the feeding system.

Clocchiatti, R., Condomines, M., Guénot, N., & Tanguy, J. C. (2004). Magma changes at Mount Etna: the 2001 and 2002–2003 eruptions. Earth and Planetary Science Letters, 226(3-4), 397-414.

MacDonald, A., Ubide, T., Mollo, S., & Taddeucci, J. (2024). Spatial and temporal mush heterogeneity during eruptions recorded in clinopyroxene from the 2021 paroxysms at Mt. Etna, Italy. Contributions to Mineralogy and Petrology, 179(11), 99.

Mollo, S., Del Gaudio, P., Ventura, G., Iezzi, G., & Scarlato, P. (2010). Dependence of clinopyroxene composition on cooling rate in basaltic magmas: implications for thermobarometry. Lithos, 118(3-4), 302-312.

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Perinelli, C., Mollo, S., Gaeta, M., De Cristofaro, S. P., Palladino, D. M., & Scarlato, P. (2018). Impulsive supply of volatile-rich magmas in the shallow plumbing system of Mt. Etna Volcano. Minerals, 8(11), 482.

Ubide, T., Mollo, S., Zhao, J. X., Nazzari, M., & Scarlato, P. (2019). Sector-zoned clinopyroxene as a recorder of magma history, eruption triggers, and ascent rates. Geochimica et Cosmochimica Acta, 251, 265-283.

Project outcomes:

EPMA data:

https://doi.org/10.5281/zenodo.21716432

Conference presentation:

Miranda-Muruzabal, M., Corsaro, R. A., & Caricchi, L. (2026, July). Mt. Etna eruptive patterns from a clinopyroxene perspective. In Goldschmidt 2026 Conference. GOLDSCHMIDT.