Mechanisms controlling explosive-effusive transition of Teide-Pico Viejo complex dome eruptions

O. Dorado[a], J. Andújar[b], J. Martí[a], A. Geyer[a]

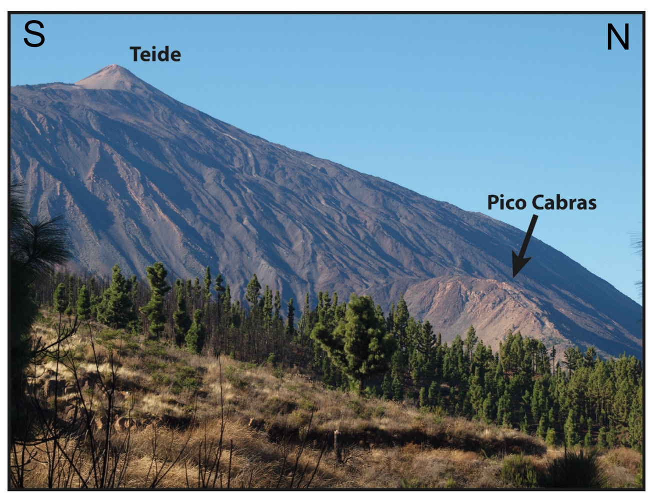
[a] Institute of Earth Sciences Jaume Almera, ICTJA-CSIC, Group of Volcanology, SIMGEO (UB-CSIC), Lluís Solé i Sabarís s/n, 08028 Barcelona, Spain.
[b] ISTO, CNRS-Université d'Orléans-BRGM, 1[a] rue de la Férollerie, Orléans 45071, France.

INTRODUCTION AND OBJECTIVES

- The **geological record** allows us to evaluate the eruptive sequences and the eruptions' explosivity index.

↓

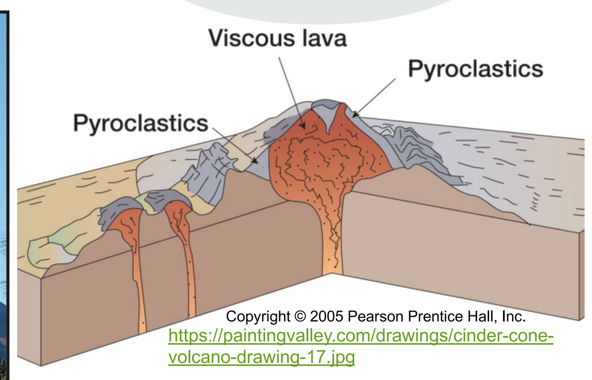
- This is vital for a correct hazard assessment, especially in volcanic systems with high return period.



DOME ERUPTIONS

Which are the driving forces of the **abrupt transitions** between **explosive and effusive** activity during an eruption?

Volatile zonation?
Degassing?
Magma ascent rate?
Pre-eruptive conditions changes?
New magma influx?

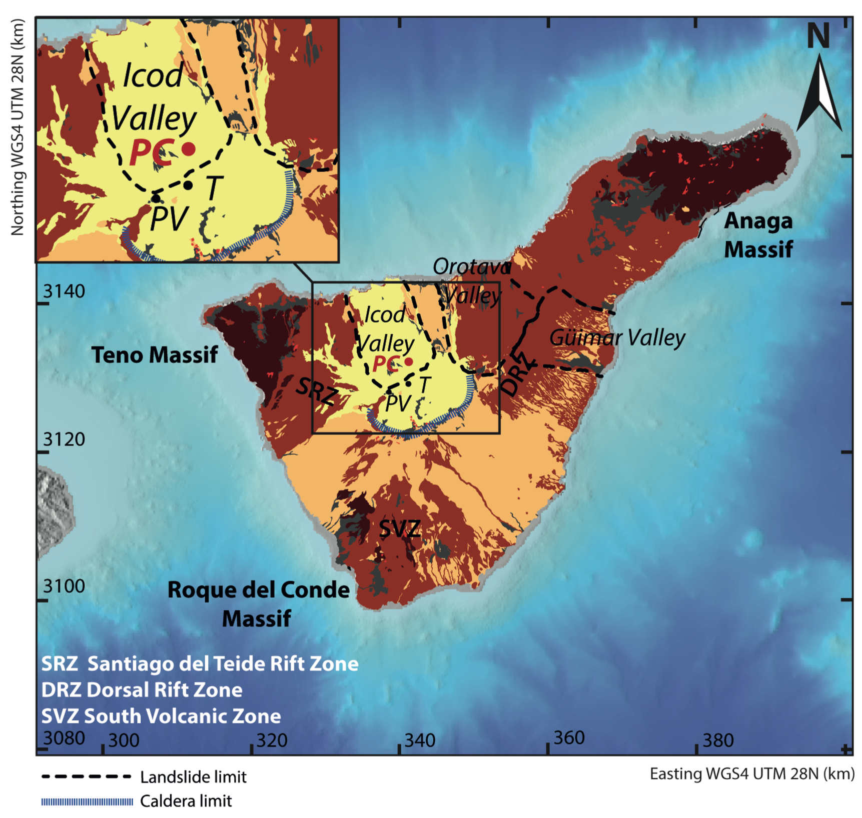


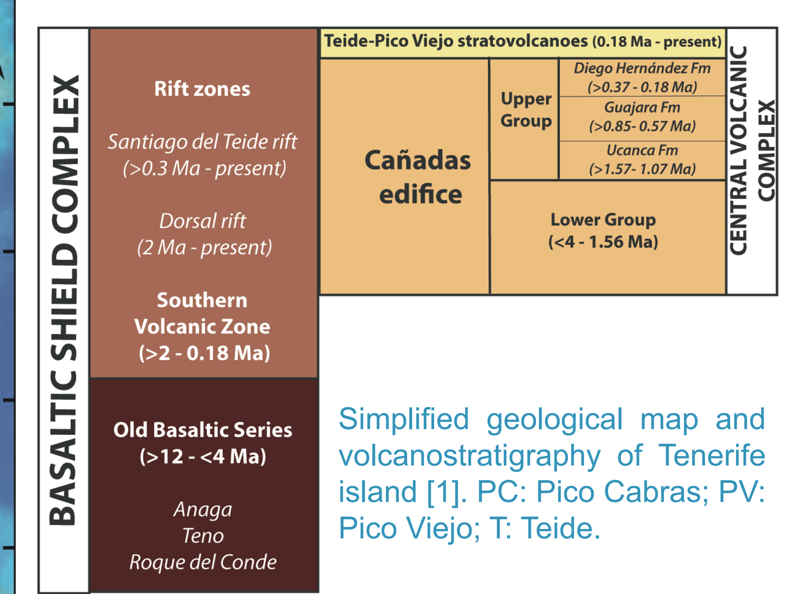
Pico Cabras dome's photography (left) and dome's squeme (above).

Objectives

- Identify the **pre-eruptive parameters** that control the explosive-effusive transitions in Tenerife dome eruptions.
- Evaluate the presence of halogen volatiles in Tenerife felsic magmas.

GEOLOGICAL CONTEXT





Simplified geological map and volcanostratigraphy of Tenerife island [1]. PC: Pico Cabras; PV: Pico Viejo; T: Teide.

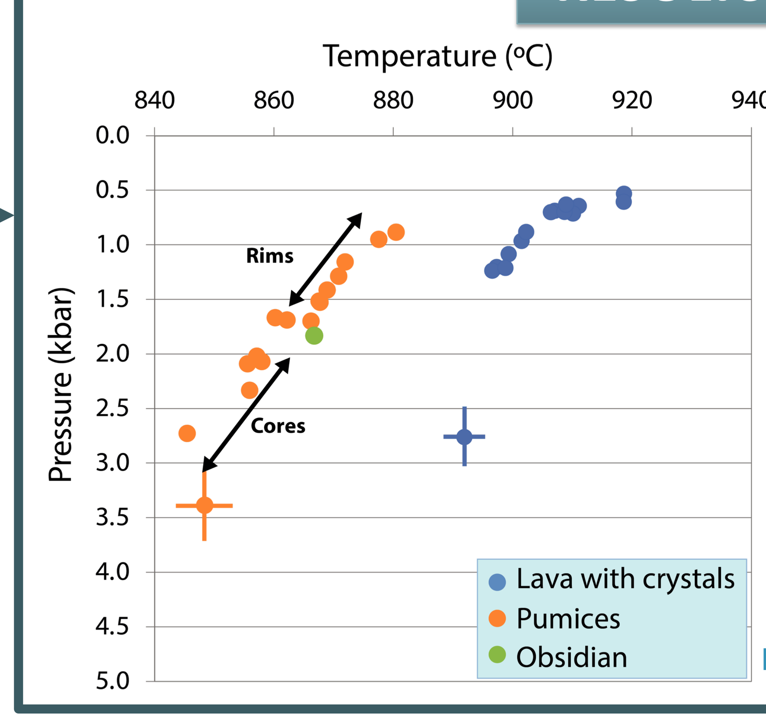
The Upper Group of the Central Volcanic Complex comprise the products of 3 volcanic cycles that end with a caldera collapse. Teide-Pico Viejo Complex is the result of the beginning of the 4th cycle.

Tenerife island vulcanism is **bimodal**: basaltic magmas (high recurrence and low magnitude), and phonolitic (low recurrence and high magnitud). The later is only found in T-PV complex, in central and lateral (**domes**) vents.

METHODOLOGY

1) **Petrographic** characterization of samples from the **effusive** (lava flows) and the **explosive** (pumice) phases of Pico Cabras dome eruption, using both petrographic and scanning electron microscopes.
2) **Geochemical** analysis using an electron microprobe (major elements) and micro-X-ray fluorescence (for Br quantification).
3) **Pre-eruptive parameters**: geothermobarometer [2] and geohygrometer [3]. These use the chemical composition of minerals (clinopyroxene and feldspar, respectively) and the magma in **equilibrium**.
4) Comparison with **experimental petrology** data: [4-6].

RESULTS: PRE-ERUPTIVE PARAMETERS (P, T H_2O)



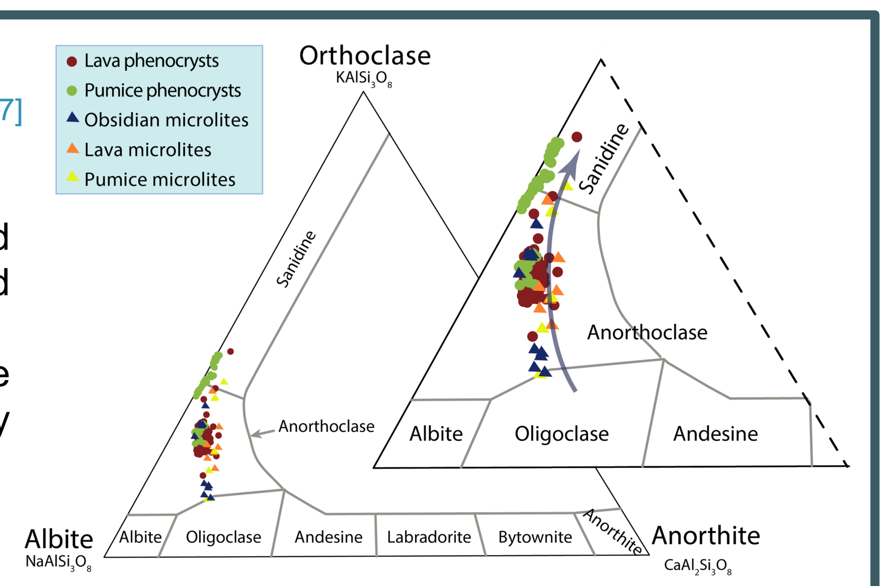
P-T diagram with data calculated using the geothermobarometer.

- P-T: significant contrast in temperature results.
- H_2O: inverse relationship between dissolved water content and %An in feldspar. Some analysis do not pass the equilibrium test based in the K_D.
  - Effusive phase: average of 3.4 wt% H_2O.
  - Explosive phase: average of 5.4 wt% H_2O.
- High H_2O content calculations (>5.5 wt%) are **above water-saturation limit** in phonolitic magmas [10] → Is this geohygrometer poorly calibrated for phonolitic magmas?

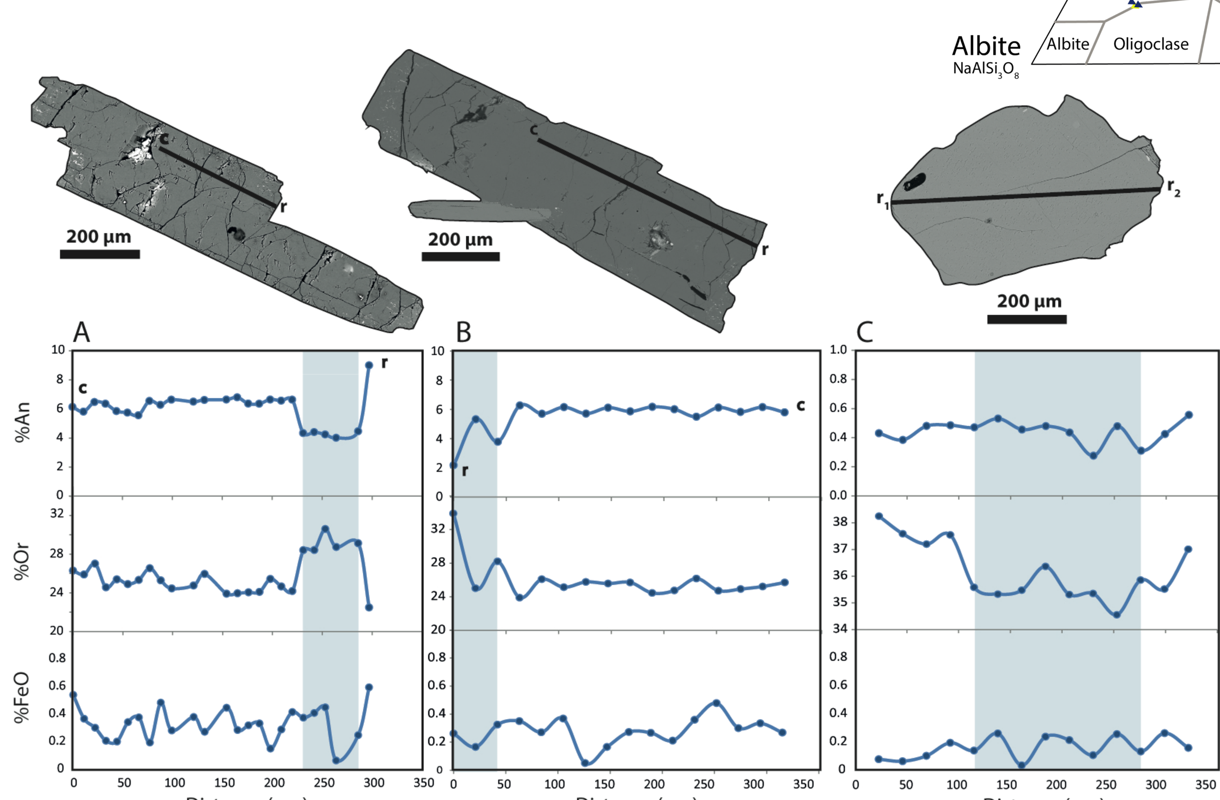
RESULTS: GEOCHEMISTRY

Feldspar

Feldspar classification diagram [7]



- Continuous **evolution** from oligoclase (less evolved magmas) to sanidine compositions (more evolved magmas).
- **Less fractionated** feldspars (low or negative fractionation index "log(or/An)") are also slightly **enriched in iron.**



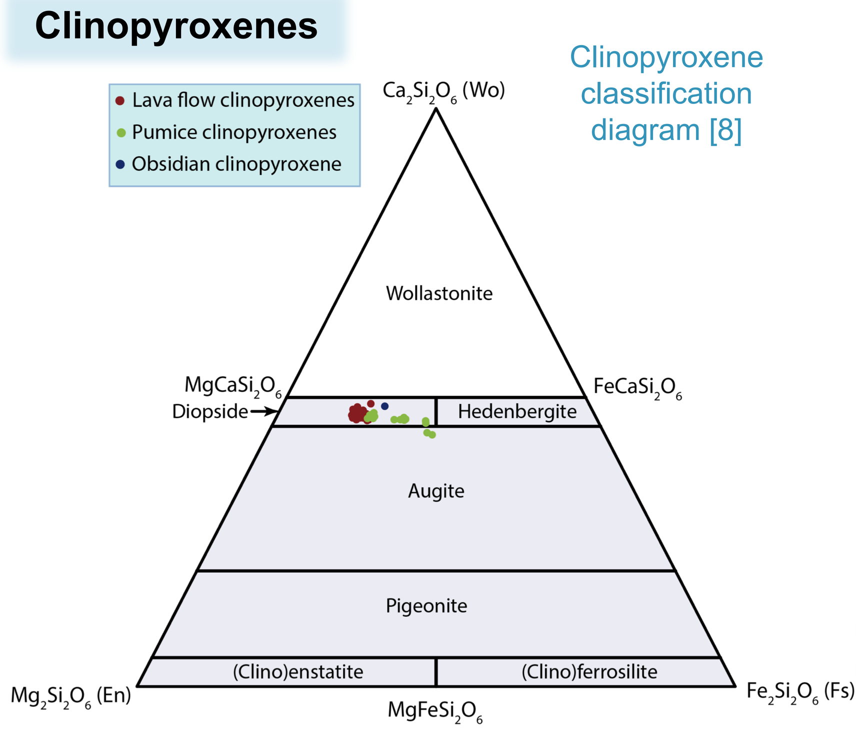
Feldspar **zonations**:

- **Effusive phase** (lava flow): rims both enriched and depleted in anorthite.
- **Explosive phase** (pumices): two poblations of feldspar, one equivalent to the lava's poblation and other more evolved.
- Small variations inside the crystals.

Representative feldspar phenocrysts zonations.

Clinopyroxenes

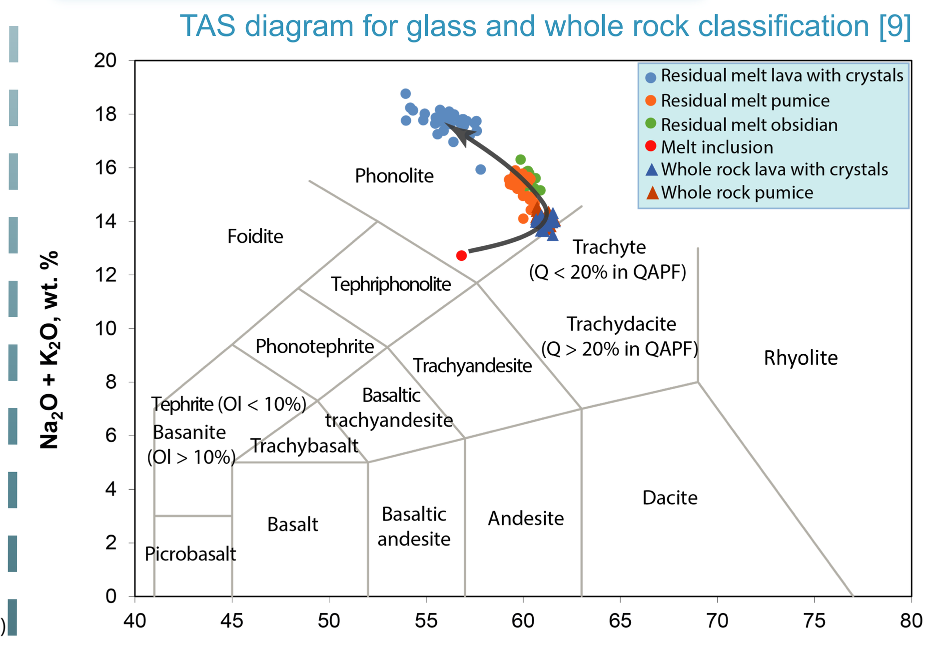
Clinopyroxene classification diagram [8]



- Ca-rich clinopyroxenes: **diopsides** and some augites.
- Zonations have only been found in the explosive phase, with cores enriched in Fe, na and Mn.
- Typically associated with **Fe-Ti oxides**: magnetite and ilmenite.

Whole rock, glass and volatiles

TAS diagram for glass and whole rock classification [9]

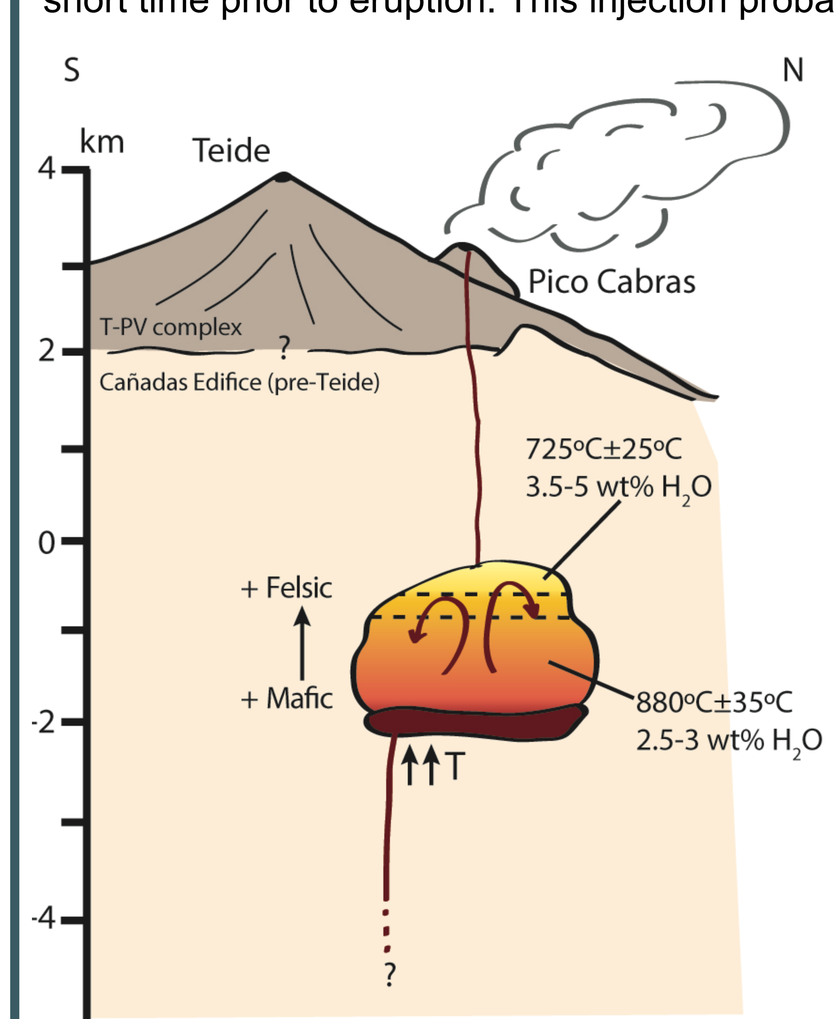


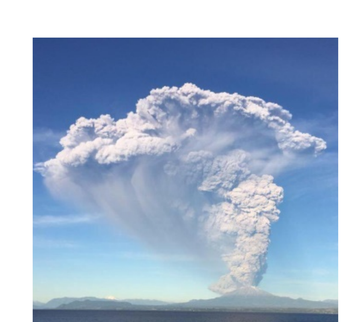
- Whole rock and glass: continuous evolution from glass inclusión to residual melt in lavas.
- Cl in melt from 0.2 to 0.6 wt% and Br from 10 to 15 ppm measured in the explosive phase.
- **Sodalite**: indicator mineral of the presence of halogen gases in the fluid phase: **6.4-7.1 wt% Cl and 130 ppm de Br.**

DISCUSSION AND CONCLUSIONS

P-T: **low accuracy** due to the difficulty obtaining the exact composition of the magma in equilibrium. → Comparison with the experimental mineral assemblage obtained by **experimental petrology.**

Model: magma chamber at 1kbar, chemical and thermally **zoned**. Zoning in minerals indicate **self-mixing** processes. Ca-rich rims in feldspars suggest **underplating** and **injection of a mafic magma** short time prior to eruption. This injection probably triggered the eruption.





1st phase: Explosive (pumices). Related to the upper cupola of the chamber with less temperature and higher volatile content. It was triggered by an increase in temperature and energy after a mafic injection.

Collapse of the eruptive column because of energy loss and formation of a PDC into the Icod Valley.

2nd phase: Effusive (lava flow). Related to the magma stored in the main body of the magma chamber.

Schematic model of Pico Cabras eruption's magma chamber. Pre-eruptive conditions within the magma chamber calculated in this work have been indicated. Scheme not to scale.

From Cl and Br measured in the explosive phase and the distribution coefficient between magma and fluid phase we estimate **244.6 Tm of Cl and 9.9 Tm of Br** released to the **atmosphere** in this eruption.

CONCLUSIONS

- Pico Cabras eruption: magma chamber at 1 ±0.5 kbar chemical and thermally zoned.
- The pre-eruptive parameters that controls the explosive-effusive transition are the temperature and the volatile content.
- The release of high amounts of Cl and especially, Br, may lead to a local destruction of the stratospheric ozone layer.
- Phonolitic dome eruptions in Tenerife should be taken into account for improving the hazard assessment of the island, with special focus on Icod valley.

BIBLIOGRAPHY

1. Martí *et al.* (2011). *Journal of Volcanology and Geothermal Research*, 178(3), 529–542.
2. Masotta *et al.* (2013). *Contributions to Mineralogy and Petrology*, 166(6), 1545–1561.
3. Mollo *et al.* (2015). *Chemical Geology*, 392, 1–8.
4. Andujar *et al.* (2008). *Chemical Geology*, 257(3–4), 173–191.
5. Andujar *et al.* (2013). *Journal of Volcanology and Geothermal Research*, 260, 62–79.
6. Andujar y Scaillet (2012). *Journal of Petrology*, 53(9), 1777–1806.
7. Deer *et al.* (1972). *Journal of Geophysical Research: Atmospheres*, 104(D19), 23871-23880.
8. Morimoto (1988). *Mineralogy and Petrology*, 39(1), 55-76.
9. Le Bas *et al.* (1986). *Journal of Petrology*, 27(3), 745–750.
10. Schmidt y Behrens (2008). *Chemical Geology*, 256(3–4), 259–268.

I would like to thank my tutors Joan Andújar, Joan Martí and Adelina Geyer for their helpfull advices in the realization of this work. Also the ISTO-CNRS in Orleans, for giving me the opportunity of working there and provide me with all the analytical resources, and specially to Bruno Scaillet and María Jiménez for their advices. Finally, thank to the CSIC for my JAE Intro 2018 fellowship (JAEINT_18_00808).