# Experimental study of plagioclase growth, nucleation rates, and shape evolution during cooling of an anhydrous basaltic andesite

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## 1. Introduction

Data on the nucleation and growth rates of plagioclase are underrepresented in the experimental dataset for **basaltic andesites. Moreover, previous** experiments were generally conducted on a **perfectly homogeneous glass** (without pre-existing crystals).

**We aim at constraining the nucleation (J) and growth (G) rates of plagioclase in a natural basaltic andesite.**

- **Experiments were performed at 1 atm, anhydrous and NNO conditions in a vertical furnace at ULiège**

## 2. Experimental Method

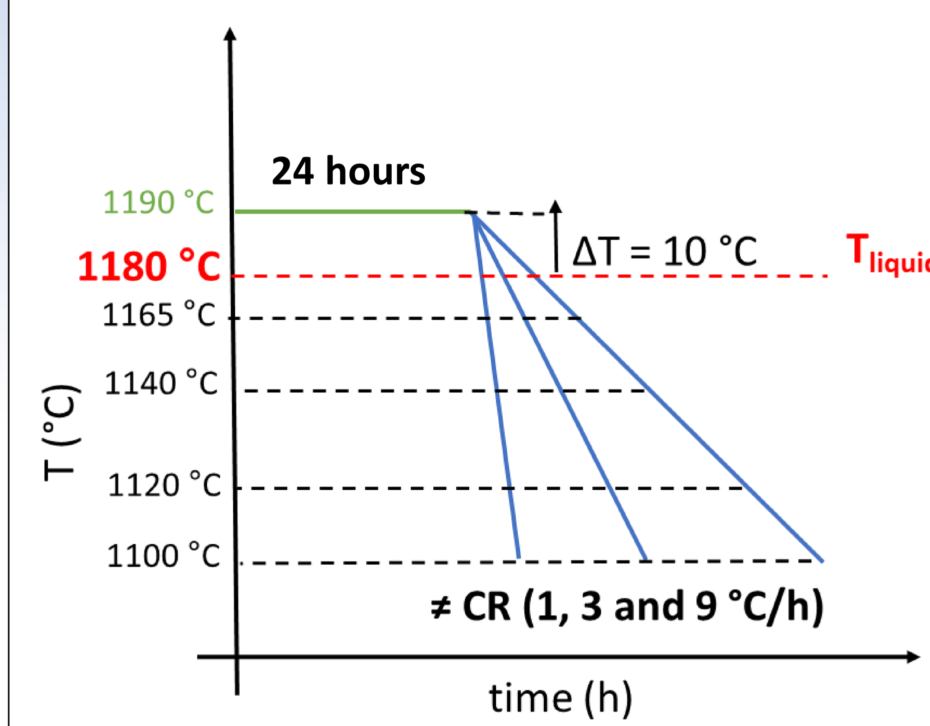


**Figure 1 : Multi-step cooling experiments quenched at a final temperature of 1100 °C.** Different cooling rates (CR) used after an initial dwell at 10 °C above the liquidus.

| | OS36 | 1190 °C |
|---|---|---|
| | Basaltic andesite | Run |
| $SiO_2$ | 56,94 | 57,65 |
| $TiO_2$ | 1,30 | 1,28 |
| $Al_2O_3$ | 16,27 | 16,64 |
| FeO | 9,56 | 9,53 |
| MnO | 0,18 | 0,19 |
| MgO | 2,79 | 3,13 |
| CaO | 6,39 | 6,63 |
| $Na_2O$ | 4,32 | 4,14 |
| $K_2O$ | 0,91 | 0,89 |
| $P_2O_5$ | 0,26 | 0,3 |

**Table 1 : Composition of the starting material (OS36)** analysed by XRF (*Bechon et al., 2022*) and by electron microprobe (experimental run held 10 °C above the liquidus for 24 hours). Platinum loops were pre-saturated in order to prevent FeO loss.

- **Starting composition :** powdered basaltic andesite (Osorno volcano, Chile: Table 1) heated in a muffle furnace on platinum loops at 1000 °C to remove volatiles and a certain proportion of initial crystals.
- Experiments contained some **pre-existing crystals of Plg** (not homogeneous glass).
- Different cooling rates were used (Fig. 1). BSE images acquired for each experimental run were treated with GIMP and FIJI.
- 3D shape of plagioclase estimated using **ShapeCalc** spreadsheet (*Mangler et al. 2022*).

## 3. Textural observations

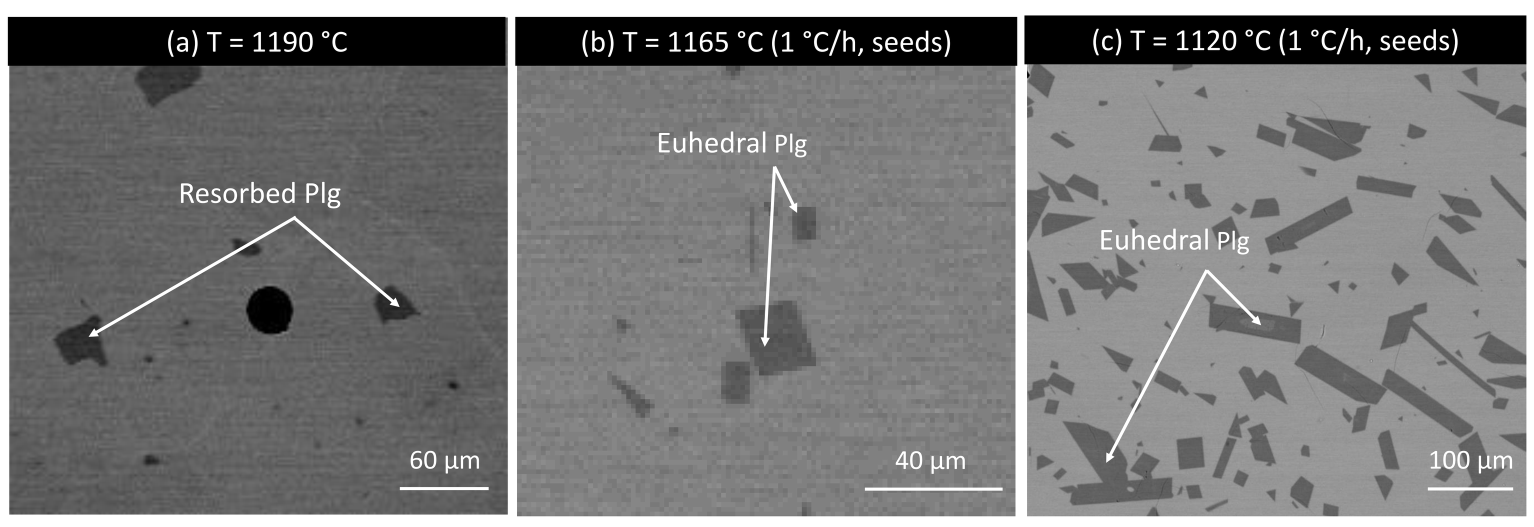


**Figure 2 : Plagioclase textural evolution.**
(a) 10 °C above the liquidus (end of the initial step; Fig. 1).
(b-c) 15 °C and 60 °C below the liquidus

- ➢ Close to the liquidus → partial resorption of pre-existing plagioclase (Fig. 2a)
- ➢ favored nucleation around the Pt wire and bubbles (not shown here)

- ➢ Plagioclase texture: from equant (1165 °C) to tabular shape (1120 °C, Fig. 2b-c).
- ➢ High proportion of largest crystals (> 50 µm) → Tabular shape is dominant (Fig. 3)
- ➢ Large variation of 2D aspect ratio (from equant to tabular, Fig. 3)

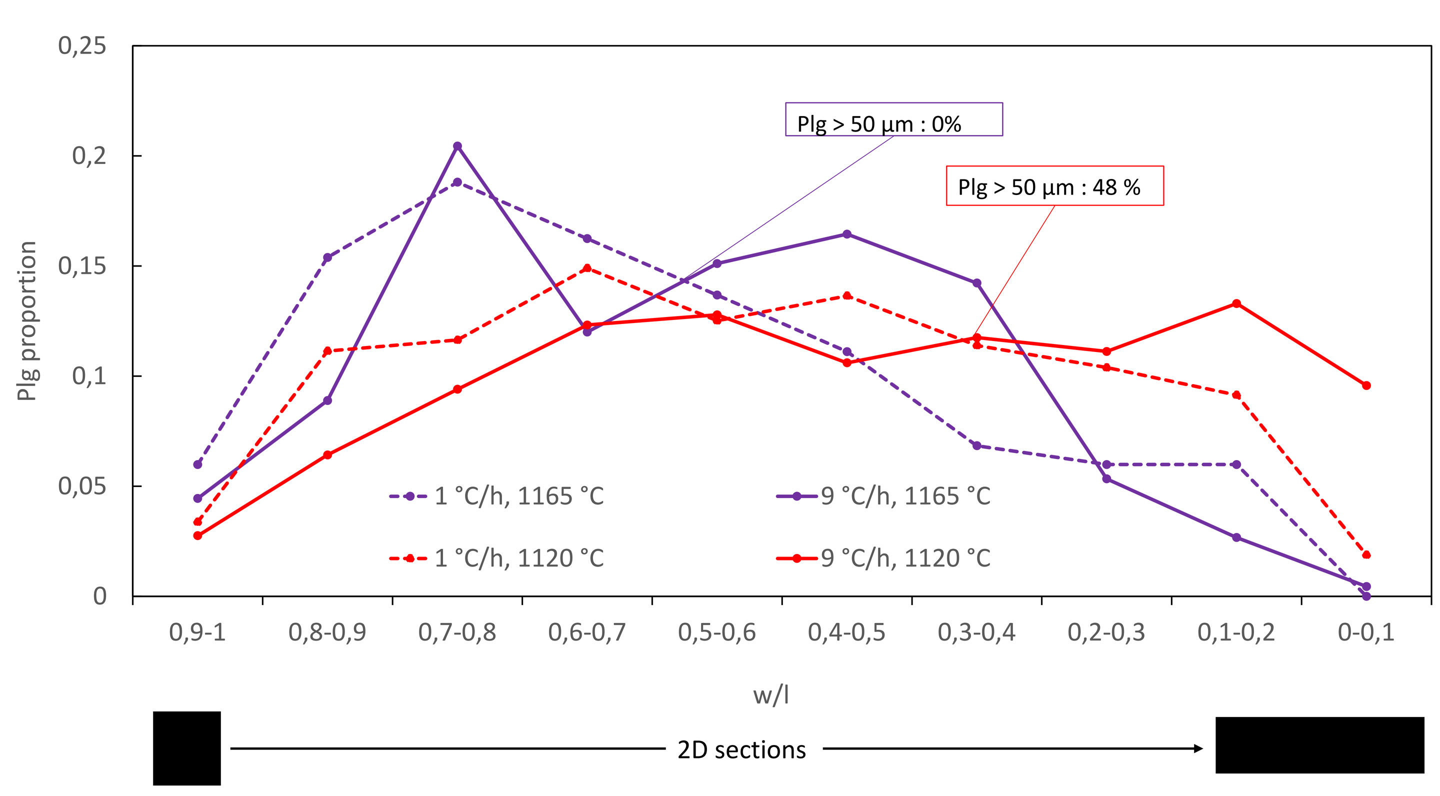


**Figure 3 : Evolution of the w/l 2D shape factor**. w and l are the 2D minor and major axis of each crystal.

## 4. CSDs

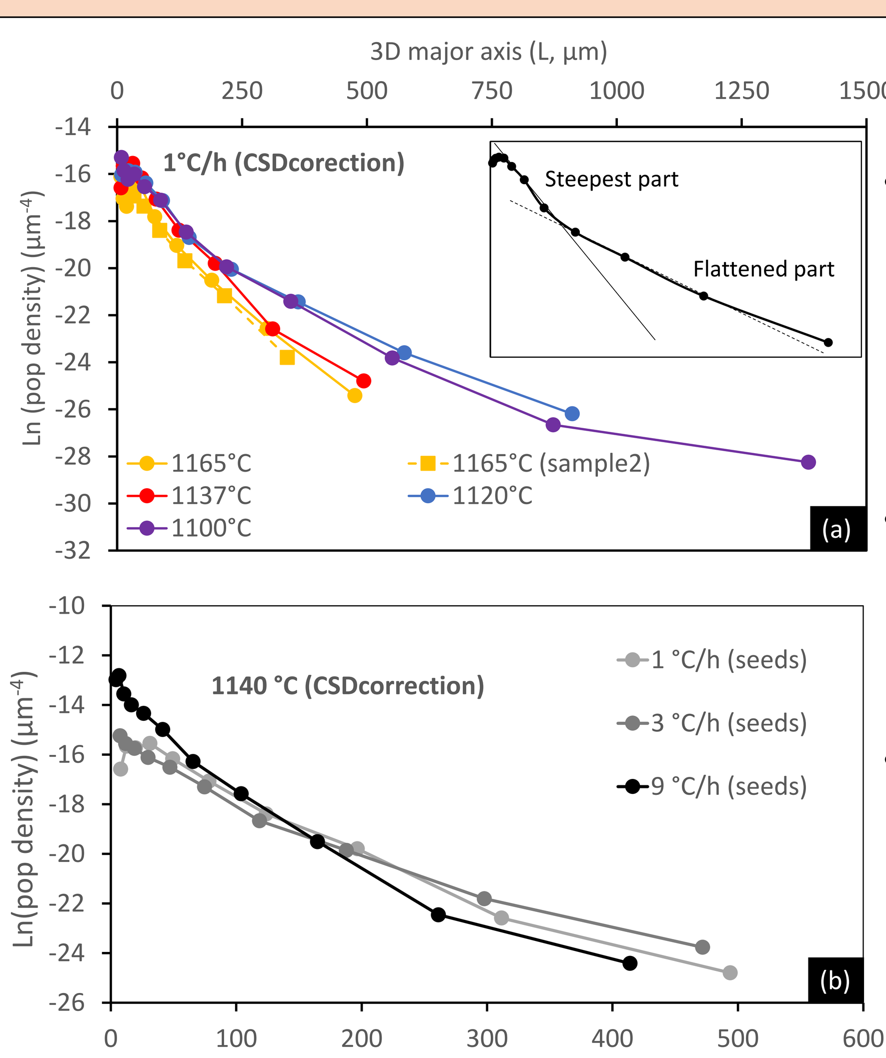


**Figure 4 : CSDs obtained with the CSDcorrection plugin from Higgins (2000).**
a) CSDs evolution with increasing ΔT.
b) CSDs at several cooling rates

- CSDs in three parts :
  - ➢ Neck part : the smallest crystals
  - ➢ Prominent log-linear section
  - ➢ Flattened part : the largest crystals
- With increasing ΔT (Fig. 4a):
  - ➢ Slope decrease
  - ➢ Increase in the flattened part
- With increasing cooling rate (Fig. 4b):
  - ➢ Increase in the initial density of crystals ($n_0$).
  - ➢ Slope increase

## 5. Growth rates

$$G_{max} = \frac{lmax}{2t} \qquad J_{Batch} = \frac{N_V}{t}$$

$$G_{Batch} = \frac{Sn}{2t} \qquad J_{CSD} = n_0 * G$$

$$G_{CSD} = \frac{-1}{2*(slope*t)}$$

**Equations : Calculation of nucleation (J) and growth (G) rates.** Sn corresponds to the mean size of crystals (Batch method), and $N_v$ to the volume density.

- Nucleation and growth rates are calculated by various methods (lmax, Batch, and CSD method; Equations).
- Strong variation between the different methods (Fig. 5a).
- Increase in growth rate with cooling rate (Fig. 5b)
  - ➢ Great increase at 9 °C/h

**Different cooling rates (Gmax values; Fig 5b)**
- ➢ 1 °C/h : 2.7. $10^{-8}$ to 5.6. $10^{-8}$ cm/s
- ➢ 3 °C/h : 5.6. $10^{-8}$ to 7.8. $10^{-8}$ cm/s
- ➢ 9 °C/h : 1,1. $10^{-7}$ to 2.8. $10^{-7}$ cm/s

G values in agreement with other studies (cf. compilation of *Moschini et al., 2023*) : **$10^{-9}$ cm/s** (Gbatch) to **$10^{-8}$-$10^{-7}$ cm/s** (Gmax)

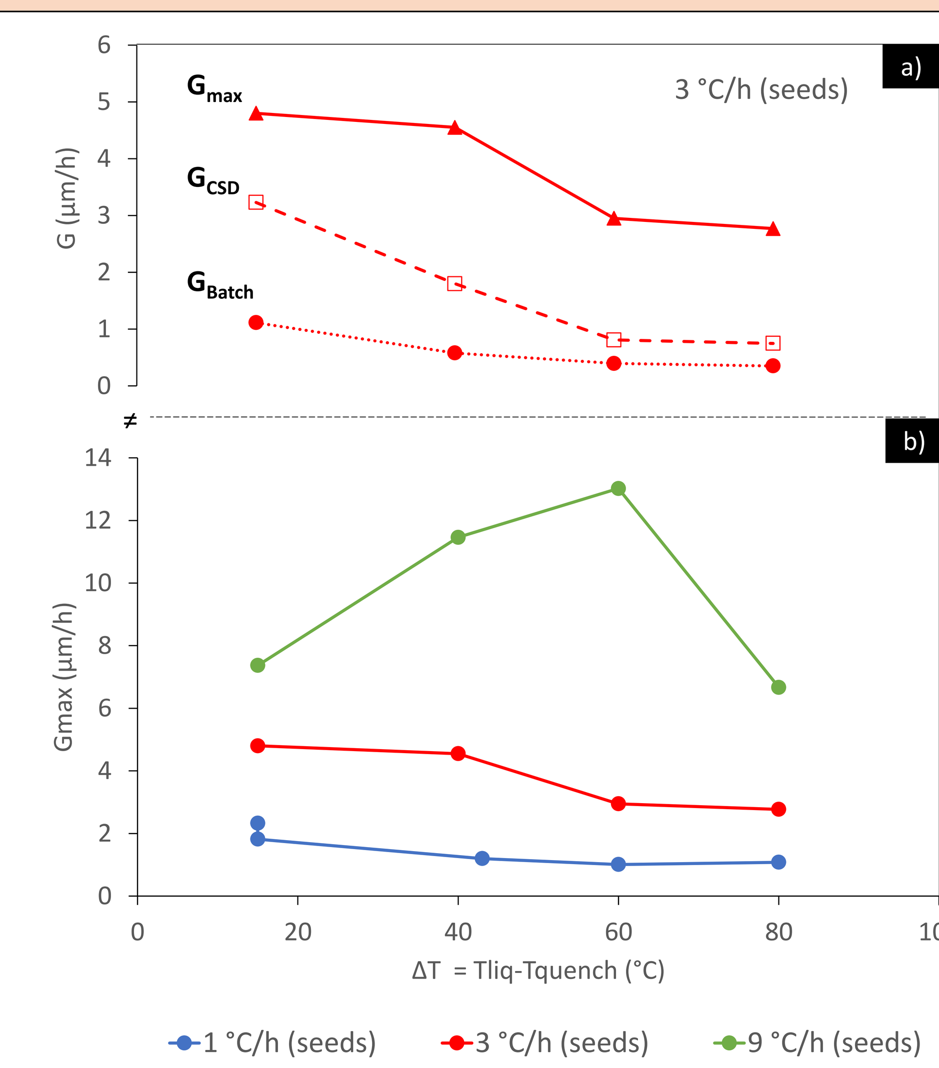


**Figure 5 : Variation of plagioclase growth rate during the cooling.** a) Gmax values (lmax : average on the 10 biggest crystals).
b) Comparison between G values obtained by lmax, CSD, and Batch methods.

## 6. Nucleation rates

- $J_{CSD}$ are lower than $J_{Batch}$ by a factor 10 (Fig. 6a)
  - ➢ Batch method based on point counting
  - ➢ CSD : several crystals generations (with size variations)

**Cooling history :**

- Nucleation rate increases with cooling rate (Fig. 7b)
- 3 °C/h : high variability of the nucleation rate at **1165 °C (ΔT = 15°C)**.
  - ➢ Variable nucleation near the liquidus.

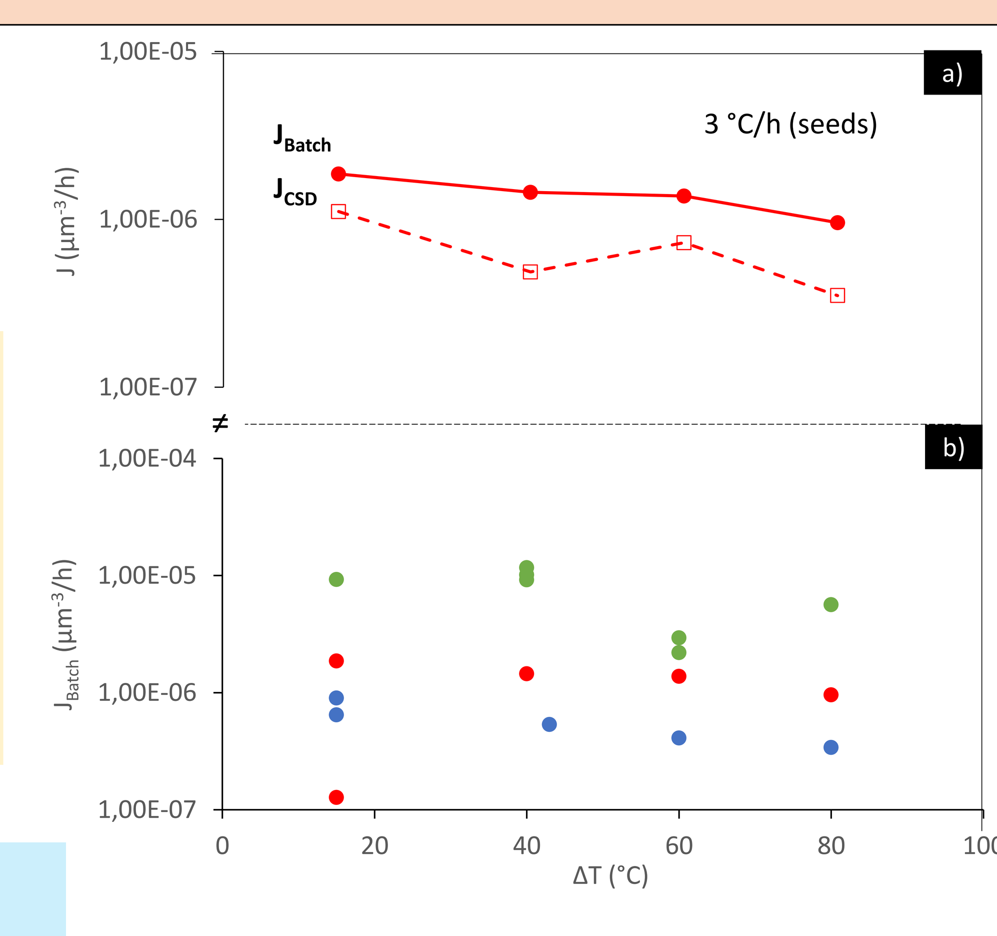


**Figure 6 →: Variation of plagioclase nucleation rate with increasing ΔT**
a) Comparison between JCSD and JBatch methods.
b) $J_{Batch}$ at different cooling rates.

## References

- Bechon T et al. (2022): Petrology of the magmatic system beneath Osorno volcano (Central Southern Volcanic Zone, Chile). *Lithos, V.426-427.*
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