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Supplemental Material

Text.

TABLE S1. SAMPLE LOCATION AND ORIENTATION

TABLE S2. MEAN SITE AMS DATA

Supplementary document for

Emplacement dynamics of a crystal rich, highly viscous trachyte flow of the Sancy stratovolcano (France)

by

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TEMPERATURE ESTIMATES BASED ON DIFFERENT GEOTHERMOMETERS

Thermometer reference	Phase equilibrium	Temperature (°C)	SEE* (°C)
Powell and Powell (1977)	Plagioclase-liquid	816†	N.A.
Drake and Weill (1975)	Magnetite-ilmenite	880†	N.A.
Putirka (2008) equation 23	Plagioclase-liquid	970	± 43
Putirka (2008) equation 24a	Plagioclase-liquid	912	± 36
Putirka (2008) equation 26	Plagioclase-liquid saturation	960	± 37
Putirka (2008) equation 24b	Alkali feldspar-liquid	847	± 23
Putirka (2008) equation 24c	Alkali feldspar-liquid saturation	819	N.A.
Putirka (2008) equation 27a	Two feldspars	813	± 30
Putirka (2008) equation 27b	Two feldspars	807	± 30
Ghiorso and Evans (2008)	Magnetite-ilmenite	869	N.A.

*Standard Error of Estimate values from Putirka (2008), corresponding to a 1 σ standard deviation.

†Estimates from Gourgaud (1985).

ESTIMATION OF LAVA VISCOSITY FROM THE PETROLOGICAL ANALYSES

The lava viscosity (η_{lava}) of a mixture of crystals in a liquid phase can be defined by:

$$\eta_{lava} = \eta_{liq} \cdot \eta_r \qquad (1)$$

where the melt viscosity (η_{liq}) is Newtonian and depends on temperature (T) and composition, the relative viscosity (η_r) depends on the volumetric abundance (ϕ) and the particles aspect ratio (r). The melt viscosity was estimated using the model of Giordano et al. (2008):

$$\log \eta_{melt} = A + \frac{B}{T-C} \qquad (2)$$

where A is a constant representing the lower limit of the silicate melt viscosity at high temperature (-4.55); and B and C are adjustment parameters depending on the chemical composition (Giordano et al., 2008). For the estimates we used a spreadsheet available online (*https://www.eoas.ubc.ca/~krussell/VISCOSITY/grdViscosity.html*) in which we input the composition matrix composition from Gourgaud (1985):

	Mesostase 13 from Gourgaud (1985)
SiO_2	68.47
Al_2O_3	0.12
FeO tot	14.85
MgO	0.48
CaO	0.09
Na_2O	0.05
K_2O	0.43
TiO_2	4.48
MnO	6.50
P_2O_5	0.00

This gives the following parameters for use in Equation (2):

B = 11281 and C = 300.5.

We also consider a low dissolved water content (0.1 wt.% H_2O) which gives the following parameters:

B = 11272.4 and C = 269.5

To consider the effect of crystals, we determined their amount and shape. To do this, two thin sections and a hand sample were scanned (Fig. A1). Images were processed to discriminate between the phenocrysts (white) and the groundmass (black). The minimum phenocryst content was then computed as the ratio between the crystal area and the total area of the section. Crystal aspect ratio was then determined as the ratio of the large and short axis of an equivalent ellipsoid.

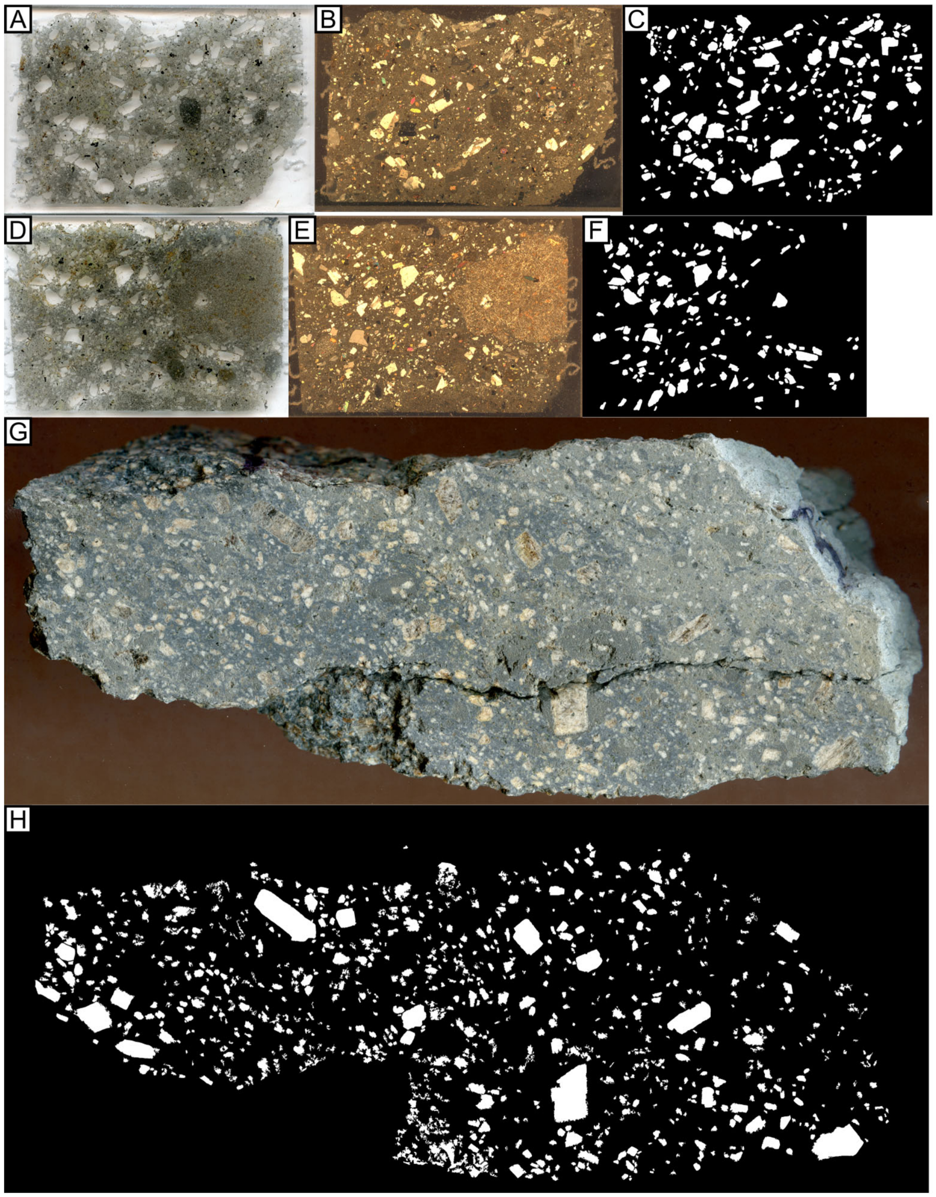

Figure A1. *(A) Thin section (~4.2 cm across) of the Grande Cascade plug under natural light. (B) Same section under polarized light. (C) Corresponding binary image used for crystal content estimation. (D) Thin section (~4 cm across) of the Grande Cascade plug under natural light, showing a basic enclave on the upper-right. (E) Same section under polarized light. (F) Corresponding binary image used for crystal content estimation. (G) Scan of a Grande Cascade plug slab (~25 cm across). (H) Corresponding binary image used for crystal content estimation.*

Results indicate a minimum crystal content of 25 % with an average aspect ratio of 1.5

We then used Krieger-Dougherty (1959) to estimate the relative viscosity (η_r) due to the effect of crystals:

$$\eta_r = \left(1 - \frac{\phi}{\phi_m}\right)^{-B\phi_m} \qquad (3)$$

in which ϕ is the crystal fraction, ϕ_m is the maximum packing, and B is the Einstein coefficient. Here we consider ϕ_m and B for a given crystal aspect ratio via the equations given by Mueller et al (2010). Given that the aspect ratio of the phenocrysts has an average of 1.5, we obtained:

$\phi_m =$ 0.542 and B =3.77 .

For crystal crystal content of 35% the relative viscosity is therefore 8.34.

SUMMARY OF VISCOSITY ESTIMATES AS A FUNCTION OF TEMPERATURE

Lava temperature (°C)	η_{liq} (dry) (Pa s)	η_{lava} (dry) (Pa s)	η_{liq} (0.1 wt% H_2O) (Pa s)	η_{lava} (0.1 wt% H_2O) (Pa s)
800	1.1×10^{10}	9.4×10^{10}*	3.0×10^{9}	2.5×10^{10}
850	1.4×10^{9}	1.2×10^{10}	4.5×10^{8}	3.7×10^{9}
970	2.6×10^{7}	2.2×10^{8}	1.1×10^{7}	8.9×10^{7}

Finally, we also estimated the viscosity of a basic enclave using the bulk rock chemical composition given by Gourgaud (1985) and the Giordano et al. (2008) model.

	Mesostase 1 from Gourgaud (1985)
SiO_2	56.75
Al_2O_3	1.00
FeO tot	19.63
MgO	3.21
CaO	0.10
Na_2O	1.30
K_2O	4.55
TiO_2	5.34
MnO	5.02
P_2O_5	0.00

Using this composition we obtained the following parameters

B = 8602.7 and C = 422.1

This gives a viscosity of 3.6×10^5 Pa s at 1000 °C.

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