



## Influence of non-Newtonian rheology on magma degassing

Thibaut Divoux, Valérie Vidal, Maurizio Ripepe, Jean-Christophe G eminard

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## SUPPLEMENTARY ONLINE MATERIAL

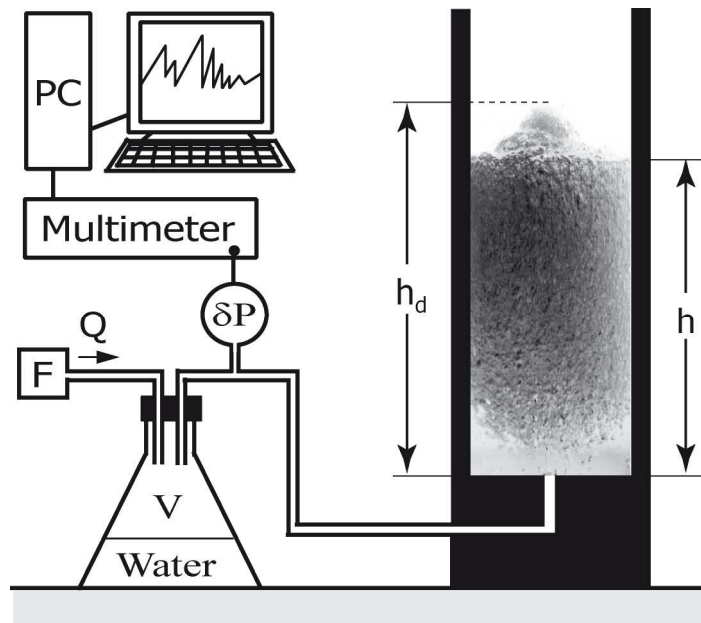
### **Influence of non-Newtonian rheology on magma degassing**

T. Divoux, V. Vidal, M. Ripepe, and J.-C. Géminard

#### **1. Experimental setup**

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The experimental setup is the same than the one described in Divoux et al. [2009]. For sake of clarity, we report it below:



**Figure 1: Sketch of the experimental setup. The fluid column is a real picture from experiments. Note the presence of a vertical gradient of small bubbles trapped in the fluid, as well as a dome at the fluid surface.**

The experimental cell has an inner diameter of 74 mm, and a total height of 270 mm. Air is injected at constant flow-rate  $Q$  at the bottom of a non-Newtonian fluid column, via a chamber of volume  $V$ , through a nozzle of 2 mm diameter. We measure the overpressure variations  $\delta P$  in the chamber through time.

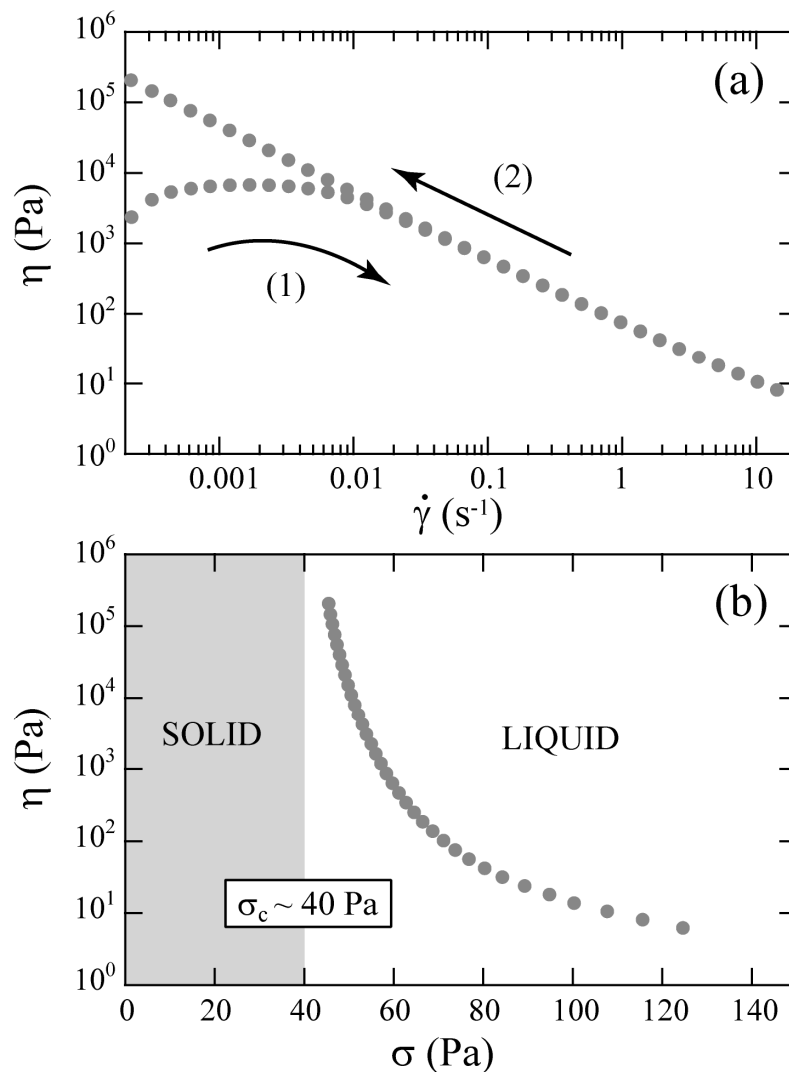
We note  $h_0$  the initial fluid height, at the beginning of the experiment. After some time, the bubble column fills up with small bubbles trapped due to the fluid yield stress. This vertical bubble gradient is well visible on the picture above. As the void fraction increases, the fluid column height  $h$  increases. For a certain range of air flow rate  $Q$ , we observe the formation of a dome of height  $\Delta h = h_d - h$ .

## 2. Fluid rheology

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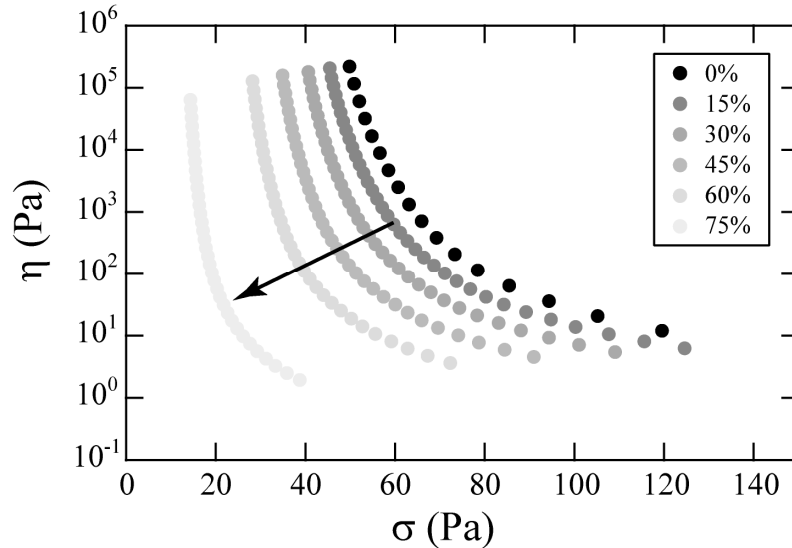
In the experiment presented in this article, we used, as a non-Newtonian fluid, a diluted solution (15% in mass of distilled water) of a commercial hair-dressing gel (*Gel coiffant, fixation extra forte* Auchan). If preserved from drying, this gel has stable characteristics through time.

The rheological measurements presented here are performed with a rheometer Bohlin Instruments, C-VOR 150, equipped with parallel plates (PP-60, gap 1000  $\mu\text{m}$ ). In order to prevent any sliding of the fluid at the walls, sand paper was glued to the plates. All the measurements are performed at constant temperature  $T = 25^\circ\text{C}$ .



**Figure 2:** (a) Viscosity as a function of the applied shear rate. (1) and (2) indicate the measurement cycle (first increasing, then decreasing the shear rate). (b) Viscosity as a function of shear stress for the gel 15%. The gray region indicates the shear stress for which the gel behaves as an elastic solid (for  $\sigma < \sigma_c$ , where  $\sigma_c$  is the yield stress, it does not flow). Only the downward series is represented.

In Figure 2 are displayed the rheology measurements for the fluid used in this work. The fluid is strongly shear-thinning for shear rates higher than  $10^{-2} \text{ s}^{-1}$  (Fig.2a) and presents a yield stress  $\sigma_c \sim 40 \text{ Pa}$  (Fig.2b). In a previous work [Divoux et al., 2009], we mainly used a 10% gel mixture. The graph below presents the change in rheology when varying the gel concentration.



**Figure 3: Viscosity as a function of shear stress for different gel concentration (the percentage indicated here is the % of water in weight in the mixture). The black arrow indicates the evolution when diluting the gel.**

In Figure 3, we present the evolution of the fluid viscosity as a function of shear stress, for different gel-water mixtures. Note the continuous evolution of the rheological curves. In a previous study, we presented the evolution of such curves for the 10% gel, when the void fraction (number of small bubbles trapped in the fluid) increases (see Divoux et al. [2009], Fig.11). The evolution is similar, indicating that the presence of bubbles strongly influences the fluid rheology.

## References

Divoux, T., E. Bertin, V. Vidal & J.-C. G eminard, Intermittent outgassing through a non-Newtonian fluid, *Phys. Rev. E* **79**, 056204 (2009).