VOLUMETRIC CHANGES OF MUD ON MARS: EVIDENCE FROM LABORATORY SIMULATIONS.

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Abstract: Here we present results of mud experiments performed inside a low-pressure chamber to investigate whether the volume of mud changes once exposed to the reduced atmospheric pressure of Mars. Our results show that mud extruded onto the surface under martian environmental conditions increases its volume and hence behaves differently than on Earth. The low atmospheric pressure causes instability of the water present in the mud mixture, leading to the formation of bubbles, which increase the volume of the mud. This mechanism is somewhat similar to volumetric changes associated with degassing of some terrestrial lavas or mud volcano eruptions.

Introduction: The behavior and the rheology of mud during the emplacement of terrestrial sedimentary volcanism has been previously investigated (e.g., [1,2]). In contrast, this is not the case for Mars nor for other planetary bodies within the Solar System for which sedimentary volcanism has been proposed [e.g., 3]. The propagation behavior of low viscosity mud in a low-pressure chamber that partly simulated the environment of Mars was firstly experimentally studied by [4,5]. Their work revealed that low viscosity mud flows could propagate over cold (<273 K) and warm (>273 K) surfaces at martian atmospheric pressure, however, the mechanism of such propagation is different to that observed on Earth. On Mars, mud propagating over cold surfaces should rapidly freeze due to evaporative cooling [6] forming an icy-crust leading to propagation in a similar manner to pahoehoe lava flows on Earth [4]. In contrast, mud propagating over the warm surface boils and levitates above the surface. The viscosity of ascending mud varies depending on its water content, and the bahviour of high viscosity mud under martian pressures remains unexplored.

Experimental setup: We used the Mars Simulation Chamber at the Open University (UK) into which we inserted a 0.9 × 0.4 m plastic box filled with a ~10 cm thick layer of natural sand (ø ~200 µm) mixed with water to limit the infiltration of mud into the sand and to better maintain the temperature below 0°C. Inside was placed a container to accommodate 600 ml of mud (Fig. 1). The infilled box was cooled to a temperature of ~-20°C. The temperature of the mud when inserted into the container was 1-3°C and 20-22°C respectively. Two different viscosities were tested – the first mix contained 50 wt% clay (a bentonite composed of 76% montmorillonite, 23% illite and 1% kaolinite) and water (i.e. 1:1 mix). The other was prepared by mixing 75 wt% clay with 25 wt% water (3:1). The pressure was gradually reduced from 1 bar to 6 mbar within a timeframe of minutes (rapid) or in >hour (slow). Each experimental run was triplicated to confirm reproducibility.

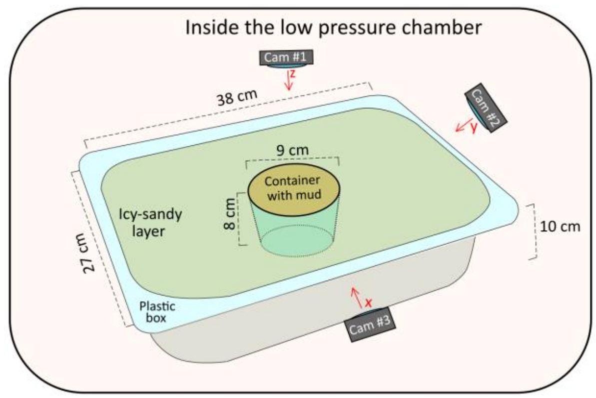

Fig. 1: Experimental setup.

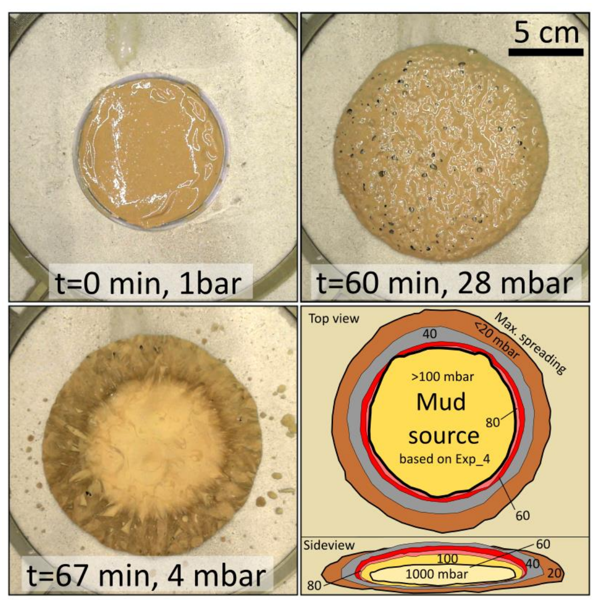

Figure 2: A sequence of images capturing the volumetric change of 1:1 mud at T=1°C depending on the pressure value. The simplified sketch shows the extent of such changes indicated with different colors.

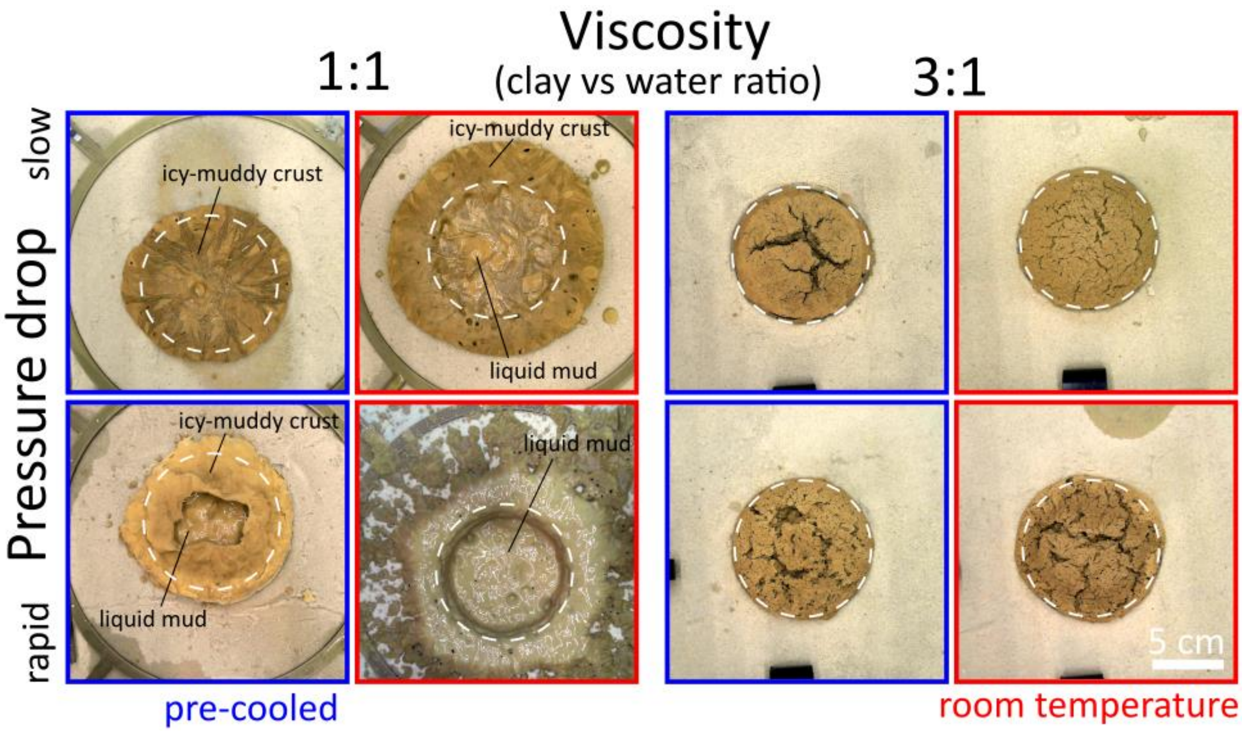

Figure 3: Examples of morphologies resulting from inflation of the mud induced by low pressure conditions. The blue and red boxes mark different temperatures of the mud. Morphologies of 3:1 mud are relatively uniform, in contrast a wider variety exists for less viscous 1:1 mud. The white dashed lines denote the position of 9 cm large container.

Observations: With the 1:1 mixture, once the atmospheric pressure was reduced, the mud started to boil (Figure 2). In the case of mud at room temperature and a rapid pressure drop, significant boiling caused an ejection of muddy droplets from the container into the surroundings. Such behavior was not observed for other experiments and mud was extruded due to the volumetric increase. Once the pressure dropped below 7 mbar, freezing occurred leading to the formation of an icy-muddy crust. Once this crust covered the entire mud surface, additional boiling and volumetric increase was limited. However, when crust broke, gasses were capable to run away and the deflation was observed.

For the 3:1 mixture vigorous boiling was not observed during the pressure drop. Instead, as the pressure decreased, the mud volume increased and sets of cracks developed on the surface of the mud. Regardless of the tested parameters, the volumetric increase was observed during all experiments as bubbles within the mud developed and increased their volume. In addition, we also observed a partial collapse of the newly formed foamy edifice as the gas trapped inside the mud escaped. This inflation and deflation of the mud often repeated and the magnitude of volumetric change leads to different morphologies (Figure 3).

Discussion and conclusion: The volumetric increase is caused by the formation of small water vapor bubbles which are trapped within the mud. The buoyancy of the bubbles is not sufficient to overcome the drag force within the viscous material and rise to the surface. Hence, these bubbles remain trapped and gradually grow up to centimeter scale sizes. During their growth they push the mud out of the container resulting in horizontal and vertical inflation of the mud surface over cm- scales (e.g., see outlines in Figure 2). This behavior is not observed at terrestrial mud flows. Our experimental approach hence shows that viscous mud exposed to reduced atmospheric pressure behaves differently to on Earth.

In the next step, we will quantify the observed volumetric changes using semi-manual or automatized processing of selected images using the PIV (Particle Image Velocimetry) and/or photogrammetry methods.

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References: [1] O'Brien and Julien (1988), Journal of Hydraulic Engineering 114 [2] Laigle and Coussot (1997), J. Hydraul. Eng., 123 [3] Ruesch et al. (2019) Nature Geoscience 12 [4] Brož et al. (2020), Nature Geoscience [5] Brož et al. (2020), EPSL 545 [6] Bargery et al. (2010), Icarus 210(1).