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Volumetric changes of extruded mud on Mars: Report from laboratory simulations

Ondřej Krýza[1,2], Petr Brož[1,2], Susan Conway[3], Adriano Mazzini[4], Ernst Hauber[5], Matthew Sylvest[2], and Manish Patel[2,6]

[1]Institute of Geophysics of the CAS, Prague 4, Czechia (kryza@ig.cas.cz)
[2]School of Physical Science, STEM, The Open University, Milton Keynes, United Kingdom
[3]CNRS UMR-6112 LPG Nantes, France
[4]Centre for Earth Evolution and Dynamics (CEED), University of Oslo, Norway
[5]Institute of Planetary Research, DLR, Berlin, Germany
[6]Space Science and Technology Department, STFC Rutherford Appleton Laboratory, Oxford, UK

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 could flow over cold (<273 K) and warm (>273 K) surfaces at martian atmospheric pressure, however, the mechanism of such propagation would be very different from that observed on Earth. On Mars, mud flowing over cold surfaces would rapidly freeze due to evaporative cooling [6] forming an icy-crust leading to the behavior of some of the mud flows in a similar manner to pahoehoe lava on Earth [4]. In contrast, the mud propagating over the warm surface boils and levitates above the surface. However, as the viscosity of ascending mud can vary, depending on water content, it remains unclear how this affects the mud behavior.

To investigate the behavior of muds more viscous than that studied by [4,5] in low pressure conditions, we used the Mars Simulation Chamber at the Open University (UK). In a set of experiments, we tested how the volume of mud (water-bentonite mixture) changed depending on different depressurization rates, mud initial viscosity and initial temperature. These experiments were performed in plastic boxes infilled with frozen (wet) sand (to simulate the martian surface). In the center of these boxes we placed a container filled with a mud volume, then we decreased the pressure to 7 mbar. Experiments were documented by system of video cameras situated around the model box. Quantification of the volumetric changes used semi-manual and automatized image analyses using the PIV (Particle Image Velocimetry) and photogrammetry methods.

Results revealed a significant volume increase during the experiments with slow depressurization, higher mud viscosity and low initial mud temperature. The volumetric change occurs due to the formation of water vapor bubbles, which are temporarily trapped within the mud. This phenomenon occurs since the bubble buoyancy is insufficient to overcome the drag force within the viscous material. Hence, these bubbles remain trapped in the mud allowing their gradual growth up to centimeter-scale sizes. During their volume increase, they push the mud out from the container resulting in horizontal and vertical propagation of the mud over cm-scales. In those experiments where the mud bulge freezes due to the evaporative cooling, the internal structure is kept in (or beneath) the icy crust. Our experimental approach hence shows that when mud with identical characteristics is extruded on Earth and Mars, different morphologies would result.

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