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Rheology of Icelandic lava flows as analogues for Mars: comparison between morphometric and experimental determinations

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The rheological properties and emplacement parameters of extra-terrestrial lava flows (effusion rate, yield strength, viscosity), such as those on the Moon and Mars, are commonly derived from their morphology through simple physical models (1). Since observations are mostly limited to remote sensing data (images and topography) with no possible ground-truth evaluations of the results, a critical assessment of these methods is required. In experimental volcanology, the temperature-dependence of liquid viscosity and the effect of crystals on the viscosity of a suspension can be investigated. The purpose of this study is to compare the viscosity obtained from morphometric analysis on terrestrial lava flows to that can be measured in the laboratory (by using samples taken from the same flows). Two postglacial lava flows from the Western Volcanic Zone in Iceland were selected for their similarity with some basaltic lava flows on Mars. The geometrical parameters are estimated from high-resolution Digital Elevation Models obtained with the HRSC-AX camera, which is an airborne version of the High Resolution Stereo Camera on board of ESA‘s Mars Express spacecraft. Laboratory techniques are applied to samples collected along the lava flow. The viscosity of the pure liquid lava is measured with the concentric cylinder between 1500°C and 1250° C. The crystallisation sequence during the cooling of the magma during ascent and emplacement at the surface is described from hand samples and is thermodynamically modelled with MELTS (2). The apparent lava viscosity of the magma (residual liquid + crystals) is calculated as a function of temperature from the residual liquid composition (using the GRD model, 3) and characteristics of the solid fraction (using the fit parameters from 4). When the lava erupts, its viscosity is slightly higher than a pure liquid (due to the presence of phenocrysts) and then strongly increases as the groundmass crystallises. Assuming a Newtonian behaviour, the highest viscosity that is reached at the maximum packing of the plagioclase laths (corresponding to viscosity of 6.64 to 7.44 log Pa s at T=1131°C) is comparable to the viscosity value obtained from morphometry (6.24 $\pm$ 0.5 log Pa s). However the consideration of a non-Newtonian flow law (strain-rate dependent) will promote flowing with higher crystals content at lower temperature. The viscosity of lava is changing through emplacement and depends strongly on the crystallization sequence. We show that although the viscosity recorded in the morphology gives an idea of the general rheological behaviour it doesn't represent the viscosity at which the lava is flowing. We also suggest that more than the bulk silica content the variations in viscosity observed on Mars throughout its history could be due to the difference of crystallization sequence.

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