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Rheology of the Andean domes as an analog for lunar silicic constructs

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The Andean volcanoes in the Atacama Desert offer a unique environment to perform remote sensing investigations as these bare surfaces are well exposed and well preserved due to their relatively young (quaternary) ages, and to hyper-arid environmental conditions. The Atacama Desert is, in fact, the driest non-polar desert on Earth, and for this reason, it has already been previously studied as a Moon and Mars analog environment (e.g., Flahaut et al., 2017). In the present study, we compare dacitic domes from the Altiplano-Puna Volcanic Complex (APVC) of the Atacama desert with volcanic edifices which have been previously reported as possible silicic domes on the Moon.

Five Atacama domes were studied from orbit, and three of them were sampled to obtain ground truth. These features formed by monogenetic eruptions and comprise high-K dacitic to rhyodacitic compositions with SiO_2 contents ranging from 66 to 68 wt%. The dome dimensions measured from ASTER DEM indicate diameters between 1.5 to 6.2 km and heights between 250 and 700 m. Similar measurements were performed on various lunar domes with the LOLA DEM and show diameters ranging from a few km to 30 km, with slopes up to 9°. To the first order, dome eruptions can be considered as the extrusion of a Bingham fluid (the cooling magma) characterized by a yield strength τ and a plastic viscosity η (e.g., Hulme, 1974). Using the dome 3D dimensions as inputs into a rheological model, we estimate apparent viscosity to be in the order of 10^9-10^{11} Pa.s for both the Atacama domes and the lunar silicic domes.

In parallel, the non-Arrhenian Newton silicate melt viscosity is calculated using the Atacama dome bulk composition and the model of Giordano et al. (2008). Resulting liquid viscosities range from 4.5 to 8 x 10^6 Pa.s. The difference between the apparent and actual liquid viscosity was further used to calculate the packing fraction with the Einstein-Roscoe equation, which was found to be around 0.70-0.73 for all domes.

Dacitic domes in the APVC have aspect ratios, yield strengths and apparent viscosities similar to the Gruithuisen and Mairan lunar edifices, where elevated silica contents were previously reported

(Glotch et al., 2011). We thus argue that the studied domes may be good analogs for these lunar domes, which are likely made of felsic rocks. However, when comparing viscosity estimates obtained from remote sensing data (apparent viscosity) and sample analyses (liquid viscosity) for the domes, we found that they differ by several orders of magnitude. Plausible explanations, which include a high amount of crystals in the mush (suggested by the high packing fraction values) will be discussed at the conference time.

References: Flahaut J. et al. (2017), Icarus, 282, 152-173; Giordano D. et al. (2008), EPSL 271,123–134; Glotch, T. D. et al. (2011), GRL, 38, L21204; Hulme G. (1974), Geophys. Journal International, 39 (2), 361–383.