PHYSICAL PROPERTIES OF LUNAR MAGMAS AT HIGH-PRESSURE AND HIGH-TEMPERATURE

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Comprehensive models of significant aspects of lunar evolution are hampered by a lack of quantitative constrains on the physical properties of lunar magma at high pressures (P) and temperatures (T). This lack of data plagues the accuracy of models of the physical and thermodynamic properties and resulting dynamics of the lunar interior. For example, the plagioclase-rich crust of the Moon exposed in the highland terranes is widely believed to have formed due to flotation of plagioclase in a global, crystallizing lunar magma ocean. However, dynamic models of this flotation suffer from scarcity of data on the density and viscosity of lunar melts (which determine in part the upward velocity of rising crystals), at lunar high pressure-temperature conditions. The accumulation of dense oxide minerals as they crystallize from magma, likewise critically depends on their settling velocity (v) in less dense silicate melt. The higher the settling velocity, the further the minerals can fall before the melt solidifies, and the more chance they have to accumulate. Viscosity (η) and density (ρ) are critically important physical properties of magma, governing the efficiency, rate and nature of melt transport and affecting the rates of physicochemical processes such as magma crystallization and differentiation. Such melt properties are a consequence of atomic-scale transport processes, and therefore directly related to the structure and thermodynamic properties of magma.

Prediction of variations in viscosity and density as a function of pressure, temperature and composition is still highly challenging. In this case, experimental determination of melt properties at high pressure and high temperature conditions relevant to the lunar interiors, through in situ synchrotron X-ray absorption, and in situ viscometry experiments conducted on lunar compositions provide us with the much needed density and viscosity measurements for lunar melts. Constraints from recent experimental measurements of density and viscosity [1,2] for synthetic equivalents of three end-member compositions bracketing the unusually broad range of titanium contents in Apollo samples: Apollo 15C green glass (low titanium content of 0.23 wt% TiO2), Apollo 17 orange glass (intermediate titanium content of 8.8 wt% TiO2) and Apollo 14 black glass (high titanium content of 16.4 wt% TiO2), effect of chemical composition, pressure and temperature on these properties, and its implications as input parameters for an integrated model of the dynamic evolution of the lunar magma ocean will be discussed.

References: [1] Rai N, Perrillat J-P, Mezouar M., Petitgirard S, Colin A, van Westrenen W. (2019). *In-situ* viscometry of lunar magmas at high pressure and high temperature. Frontiers in Earth Science 7, 94. [2] van Kan Parker M, Sanloup C, Sator N, Guilot B, Tronche EJ, Perrillat J-P, Mezouar M, Rai N, van Westrenen W (2012). Neutral buoyancy of titanium-rich melts in the deep lunar interior. Nature Geoscience doi:10.1038/ngeo1402.