FRICTION EXPERIMENTS ON ANORTHOSITE-BEARING GOUGES AND IMPLICATIONS FOR THE MECHANISM OF THE LIGHT MANTLE AVALANCHE IN TAURUS-LITTROW VALLEY. G. Magnarini[1], T. M. Mitchell[2], S. Aretusini[3], G. Pennacchioni[4], G. Di Toro[3,4], and H. H. Schmitt[5], [1]Natural History Museum, London, U.K. (corresponding author giulia.magnarini@nhm.ac.uk) [2]Department of Earth Sciences, University College London, U.K., [3]Istituto Nazionale di Geofisica e Vulcanologia, INGV, Rome, Italy, [4]Dipartimento di Geoscienze, Università degli Studi di Padova, Italy, [5]Department of Engineering Physics, University of Wisconsin Madison, Madison, WI, USA.

Introduction: Friction weakening mechanisms are important in facilitating the runout of large terrestrial landslides [1][2]. The similarity of mechanisms operating in terrestrial long runout landslides and high-slip-rate seismic faulting has been suggested in the light of the role of frictional heating in triggering a series of physical and chemical reactions responsible for friction weakening mechanisms [e.g., 3]. Motivated by the experimental work conducted in the field of fault mechanics, experimental work has been used to investigate friction-weakening mechanisms in terrestrial long runout landslides [e.g., 4]. However, none of these experiments have been conducted on non-terrestrial analogue materials to investigate the long runout mechanisms in extraterrestrial environments.

Evidence for the presence of long runout landslides on the Moon opened important implications for mechanisms of reduction of friction on planetary bodies in the absence of an atmosphere and water availability. The Light Mantle is a lunar long runout landslide deposit in Taurus-Littrow Valley, the landing site of the Apollo 17. The landslide deposit extends for about 5 km on the valley floor (Figure 1). Either triggered by impact [5][6] or by seismic shaking [7], the origin of the hypermobility of the Light Mantle landslide remains unresolved.

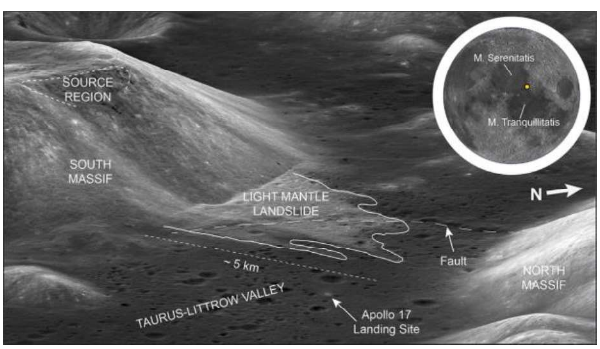

Figure 1: The Light Mantle avalanche in Taurus-Littrow Valley *(*NASA/GSFC/Arizona State University*)*.

Howard [5] suggests that dry fluidization involving regolith particle interactions is the most likely process during the emplacement of the Light Mantle landslide. Instead, Schmitt et al. [7] speculate that gas fluidization is the principal mechanism, through the release of regolith-implanted solar wind volatiles during the flow. Finally, Kokelaar et al. [8] propose that the incorporation of erodible regolith during the flow is likely to be implicated in enhancing the Light Mantle mobility. Moreover, also acoustic fluidization remains a theoretically viable mechanism [9].

We conducted friction experiments using a rotary shear apparatus (SHIVA; at INGV, Rome) in order to determine the viability of dynamic weakening mechanisms in anorthosite-bearing gouges that could explain the exceptional runout of the lunar Light Mantle landslide. We present the results of the friction experiments, XRD analysis and microstructural observations. Finally, we comment on the implications for the emplacement mechanism of the Light Mantle landslide.

Methods: We used Proterozoic anorthosites of the Scandinavian Shield, provided by the European Space Agency Sample Analogue Curation Facility (ESA SAFC). These Proterozoic anorthosites are used as analogue of the composition of the South Massif and from which we prepared the experimental gouges (< 250 µm). The experimental parameters were chosen so to simulate the sliding conditions of material along a surface inclined with an angle of 30º. This angle corresponds to a slightly higher angle than the current NE-facing slope of the South Massif. Under lunar gravity, ~ 1.6 m s^{-2}, the material would be subjected to an acceleration of 0.8 m s^{-2} (i.e., $g_{MOON} * \sin(30^{o})$). We chose the normal stresses to apply so that they would correspond to the load applied by slides of various thicknesses constituted of material with a density of 2500 kg m^{-3}, under lunar gravity (i.e., 2 MPa = 500 m; 5 MPa = 1250 m; 10 MPa = 2500 m).

We analyzed the thin sections of sheared gouges (orthogonal to the slip surface and tangential to the slip vector) using a TESCAN Field Emission Scanning Electron Microscope (FESEM).

Friction Experiments and XRD Analysis: A total of six experiments were performed at a constant normal stress of 2 MPa, 5 MPa, 10 MPa, and both at room humidity and in high vacuum (< $5e^{-4}$ mbar) to simulate the absence of a lunar atmosphere.

A small reduction of friction of ~ 0.1 occurs at the highest normal stress experiments, both at room humidity and high vacuum conditions. However, considering the high slip rate applied (1 m s^{-1}) and the tested slip displacement (up to 5 m), overall the friction coefficient remains high (~ 0.6), independently of the applied normal stress (2, 5, and 10 MPa) and environmental conditions (room humidity and high vacuum) (Figure 2). We do not observe dynamic weakening at conditions where it is seen for many other gouge compositions.

We conducted XRD analysis of the the original gouge sample and the gouges after the friction experiments. We do not observe the presence of new phases in the sheared gouges.

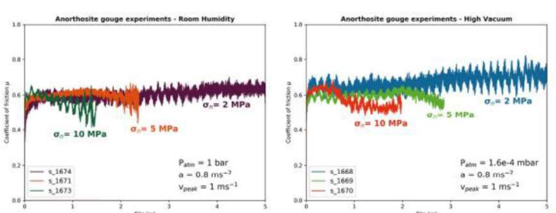

Figure 2: Results of the friction experiments conducted on anorthosite-bearing gouges.

Microstructural Observations: We selected FESEM images of the s_1668 experiment sample (2 MPa normal stress; 5 m displacement; high vacuum conditions) to investigate the microstructures, as its conditions were the most relevant to the study of the Light Mantle landslide.

From the analysis of the sample, we observed strain localization close to the slip zone. Moving away from the slip zone, we identified three distinct microstructural zones, as described in Figure 3:

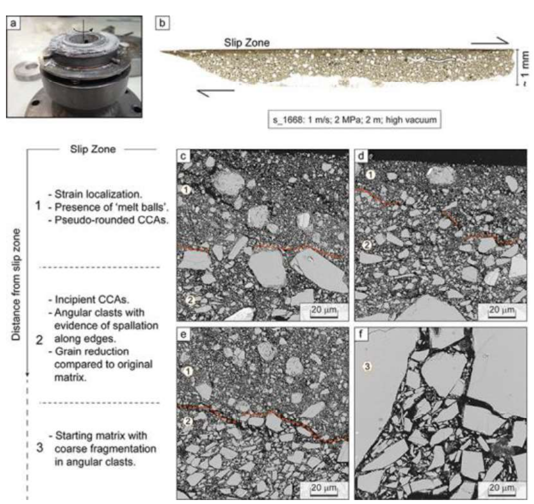

Figure 3: Microstructural zones identified within the gouge sample of the experiment s_1668.

Implications for the mechanism of the Light Mantle avalanche: Given that we do not record dynamic weakening at conditions that already overestimate some variables involved in the emplacement of the Light Mantle (i.e., thickness and slope angle), we conclude that dynamic weakening mechanisms did not take place during this mass-wasting event. Although the results from our experimental work do not provide new insights on the actual operating mechanism during the Light Mantle emplacement, they allow us to rule out dynamic friction weakening mechanisms. Therefore, that leaves dry fluidization [5], gas fluidization [7], acoustic fluidization [9], and regolith entrainment [8] available for consideration.

Clast-cortex aggregates (CCAs) have been described in the basal slip zone of large landslides [e.g. 10]. Rempe et al. [11] studied CCAs in calcite-bearing gouges and show that CCAs form at low normal stresses (< 5 MPa); in room-dry or vacuum conditions; and they better develop with increasing displacement (up to 5 m). Although anorthosite-bearing material appears to have a high dynamic shear strength, our results show that CCAs are developed at similar low-strain and dry conditions. This may suggest that CCAs may have formed during the Light Mantle landslide emplacement and that they may have been possibly preserved within the final deposit, as shown for the larger Heart Mountain landslide by [7].

Conclusions: Our results suggest that friction weakening mechanisms did not take place during the initiation of the Light Mantle landslide, therefore other mechanisms must have dominated the landslide emplacement and be responsible for its excessive runout distance. It is possible that the observed microstructures, such as clast-cortex aggregates, formed during the emplacement of the Light Mantle landslide. Our experimental work could be used as reference during the analysis of the microstructures of the core samples (73001-73002) extracted from the landslide deposit by the Apollo 17 astronauts.

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