GOING WITH THE (DEBRIS) FLOW: YOUNG MASS WASTING ON THE MOON. L. R. Ostrach and N. E. Petro, NASA Goddard Space Flight Center, Greenbelt, MD. (lillian.r.ostrach@nasa.gov)

Introduction: Mass wasting, which is the downslope movement of rocks and soil, has long been recognized to be an extensive degradational process acting on the lunar surface and can be indicative of relatively youthful activity [e.g., 1]. Investigations based on Apollo [e.g., 1,2] and Lunar Orbiter [3] photographs identified gradational features such as talus slopes, regolith creep, boulder tracks, avalanches, debris flows, crater wall slumps, and gully-like landslides. However, these investigations were restricted to the available surface coverage and limited resolution of the images, and thus provided primarily qualitative descriptions of the morphology for a small sample of lunar features (e.g., three gully-like landslides were identified by Bart [3]). New data from recent lunar missions have enabled detailed lunar surface investigations. Xiao et al. [4] conducted a global investigation to characterize the spatial distribution, morphology, and ages, of mass wasting features identified in LROC NAC images. Similarly, Kumar et al. [5] investigated gullies and landslides, identified in LROC NAC and Chrandryaan-1 Terrain Mapping Camera images, within a 7 km diameter crater in Schrödinger basin to characterize morphology and formation mechanism.

Motivation: The high resolution and detail of LROC NAC images reveal evidence of recent erosion on the Moon, particularly within crater interiors. The steep walls of young, fresh craters (as steep as 36° from horizontal, [6]) are susceptible to gravity-driven mass wasting events typically triggered by nearby moonquakes or impact events [e.g., 4,5], whereas the walls of older craters are shallower and exhibit fewer mass wasting features [4]. Thus, the mass wasting landforms observed in young craters must therefore be young – but how young?

Cataloging Mass Wasting: Investigating the range of observed mass wasting features with LROC NAC observations provides a unique opportunity to investigate degradation observed within young lunar craters of different sizes. The catalog compiled by Xiao et al. [4] is limited to the low- to mid-latitudes and the lunar nearside; we are compiling a global catalog of mass wasting features contained within lunar craters ≥10 km in diameter, emphasizing the features observed within Copernican- and Eratosthenian-aged craters. These measurements have the capability to provide insight into the dominant controls of active landform modification. Furthermore, repeat LROC NAC observations of a location at different times and under similar illumination conditions provide an opportunity to examine temporal changes [7], and it may be possible to observe surface changes within crater interiors. We also utilize additional datasets, including the LROC WAC GLD100 and LOLA topography for slope measurements and Diviner derived rock abundances to identify blocky locations.

Mass Wasting Examples–Debris Flows, Gullies: In the absence of liquid water on the Moon, debris flows result from granular material movement downslope in a fluid-like manner [e.g., 8]. Debris flows are found in many young impact craters and often form a smooth, fluid-like texture that may be mistaken for impact-generated melt. Detailed morphology of debris flows are striking in LROC NAC images, where some examples are composed of low-reflectance material relative to the crater walls [**Fig. 1,2**], finer-grained (smooth texture) fingers superposing coarser-grained (rougher texture) [**Fig. 1,2**], and meandering flows interweaved with one another, forming braided channels [**Fig. 1,2**]. Some debris flows originate from high on the crater wall near the rim, with a poorly defined source region. Other debris flows are sourced in erosional troughs or alcoves [**Fig. 3**] and may form gully-like features consisting of an alcove-channel-fan morphology [e.g., 3,5]. Few craters are observed superposed on debris flows, indicating that the flows are geologically young, but determining the absolute age of the flow is difficult because it could have formed yesterday or 100 million years ago [**Fig. 1**]. Crater degradation models [9], coupled with topographic information, potentially could provide estimates of the debris flow ages. However, temporal changes to the debris flow, if observed in repeat LROC NAC images, have the potential to provide measures on the current rates of activity through crater erasure, advancement of the flow terminus down the crater walls, as well as changes in flow morphology (e.g., braided channels).

Implications: Assessing the global distribution of mass wasting features located within young impact craters with new data is key to understanding the current rate of landform modification on the Moon. Compiling a catalog of mass wasting features within crater interiors has the potential to identify, and perhaps constrain, present-day activity occurring on the lunar surface through observed temporal changes. For instance, comprehensive assessments of the spatial distribution, morphology, and morphometry, of debris flows that are commonly observed within young craters provide critical information about how debris flow form and their occurrence across the lunar landscape. These fresh, youthful surfaces also represent excellent sites for future exploration as they represent not only freshly exposed material, but also a section of stratigraphy that would not be sampled within the regolith.

References: [1] Pike, R.J. (1971) NASA SP-232, 14–20. [2] Howard, K.A. (1973) Science 180, 1052–1055. [3] Bart, G.D. (2007) Icarus 187, 417–421. [4] Xiao, Z., et al. (2013) EPSL 376, 1–11. [5] Kumar, P.S., et al. (2013) J. Geophys. Res. Planets 118, 206–223. [6] Wagner, R.V., et al. (2013) Lunar Planet. Sci. 44, abstract 2924. [7] Speyerer, E.J., et al. (2015) Lunar Planet. Sci. 46, abstract 2325. [8] Highland, L.M. and Bobrowsky, P. (2008) U.S. Geol. Surv. Circular 1325. [9] Fassett, C.I. and Thomson, B.J. (2014) J. Geophys. Res. Planets 119, 2255–2271.

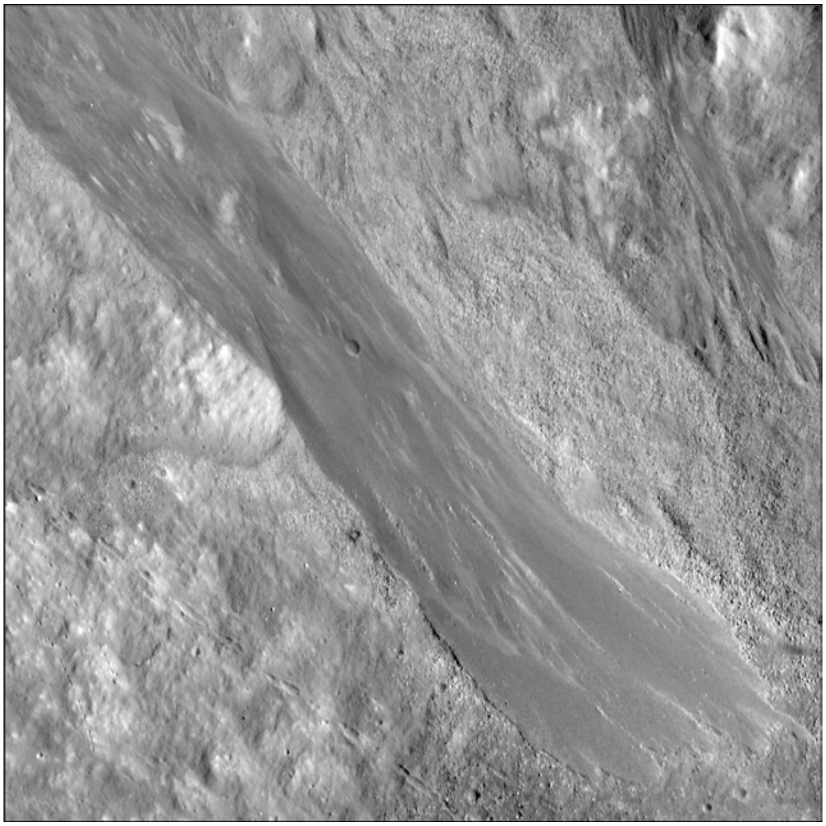

Fig. 1. (left) Debris flow on the wall of a crater superposed on the rim of Clavius E (51.51°S, 347.28°E, ~15 km diameter). The flow has braided, meandering channels that coalesce downslope into larger lobes of talus. The presence of a superposed crater (center, ~13 m diameter) suggests that while youthful, the flow may not be currently active. LROC NAC M185961505L, downslope to lower right, north is down, image width is ~696 m.

Fig. 2. (below) Debris flows in Stevinus A (31.75°S, 51.55°E, 8 km diameter). The flows are composed of low albedo material relative to the crater wall. Two types of material are observed: “rough” with resolved rocks and “smooth” with braided flows. A 7 m diameter boulder impedes the debris flow (right). Repeat observations could reveal present-day debris movement around the boulder. LROC NAC M154893929R, downslope to the right, image width is 500 m.

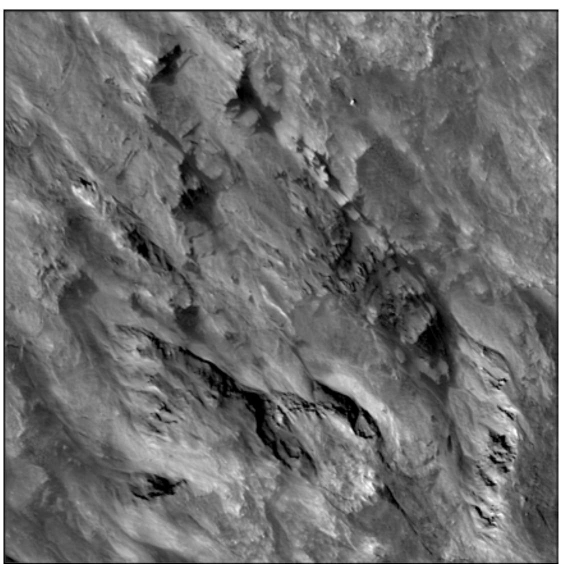

Fig. 3. Alcoves incised in a crater wall near the rim, providing source material for flows into the crater interior. Southeastern wall of an unnamed crater (15.80°N, 177.39°E, ~12 km diameter) that impacted into the eastern wall of Virtanen crater. LROC NAC M169398317R, illumination from the bottom/bottom left, image width is 600 m.