Evidence of Recent Slope Deformation and the Lasting Effect of Local Subsurface Geometry in the Taurus-Littrow Valley, Apollo 17 Landing Site.

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Introduction: The Taurus-Littrow Valley (TLV), location of the Apollo 17 landing site, hosts recent, late-Copernican geomorphological landforms and tectonic structures, namely the Light Mantle (LM) avalanche deposit and the Lee-Lincoln (LL) lobate scarp. The LM deposit represents a unique case of a hypermobile avalanche on the Moon [1][2]. Suggested to have been triggered by the Tycho impact event 110 Ma, the Light Mantle has recently been interpreted as being made of two distinct units, based on albedo variations [2][3]. The Lee-Lincoln lobate scarp is the surface expression of a recent thrust fault [4], which is considered to be the source of strong seismic shaking throughout TLV [5][6], and potentially still active [7].

The LM deposit represents a geomorphological marker. Surface change superposed on the Light Mantle deposit, and on the slope from which it was generated (the NE-facing slope of the South Massif), must post-date the landslide event. As the absolute age of the deposit is known thanks to the Apollo 17 returned samples, such surface changes demonstrate that recent processes have occurred at this location during the last 70-110 Ma. For example, small scale grabens (10-20 m wide) associated with the Lee-Lincoln lobate scarp are found superposed on the young LM unit [4]. These troughs likely formed less than 50 Ma ago [8] and are thought to be generated by the flexural bending of the hanging wall [4][8].

Here, we extend the body of evidence of surface changes that have affected the South Massif since the emplacement of the LM deposit (Fig.1).

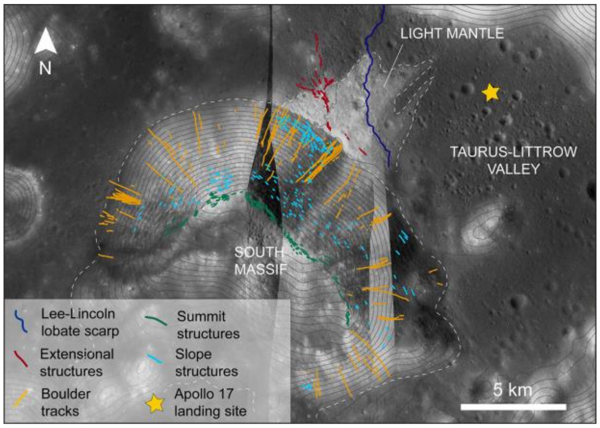

Figure 1. *LROC NAC orthophoto mosaic of the South Massif and Taurus-Littrow Valley (NASA/PDS). Different types of surface features are mapped.*

Boulder Tracks and Regolith Disturbance: We have identified 64 boulders with associated boulder tracks, in addition to the 54 identified by [9] using a neural network and deep learning approach. We observed cross-cutting relationships between boulder tracks, which provide evidence for relative timing boulder falls, although not allowing to infer the time span between the events.

Regolith disturbance from downslope creep is thought to be the expression of recent seismic activity [7] or to be the product of continuous downslope creep under the effect of gravity (e.g., [10]). We observed widespread disturbed regolith on the slopes of the South Massif. The disturbed regolith appears in patches that are characterized by a crenulated pattern. The downhill movement of regolith effectively modifies the existing morphology, such as by contributing to filling craters or by obliterating boulder tracks (Fig.2).

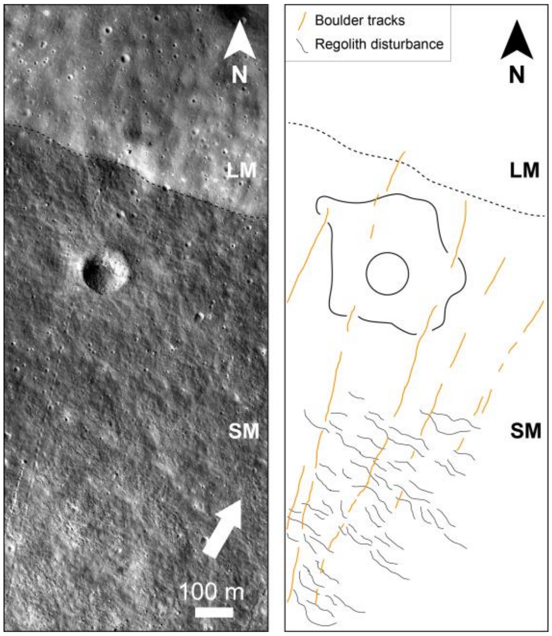

Figure 2. *Examples of the modification of boulder tracks by regolith disturbance and impact cratering. Left: top view of the lower part of the NE-slope of the South Massif (SM) and the Light Mantle deposit (LM); the white arrow represents the slope direction. Right: sketch of the structures observed: boulder tracks (yellow lines); areas of disturbed regolith (thinner black lines).*

Summit Structures: At the summit of the NE-facing slope, we observe structures that resemble terrestrial crestal grabens (Fig. 3). In this location, the uphill-facing surfaces are about 1 m high. The origin of crestal graben is associated with gravitational slope deformation.

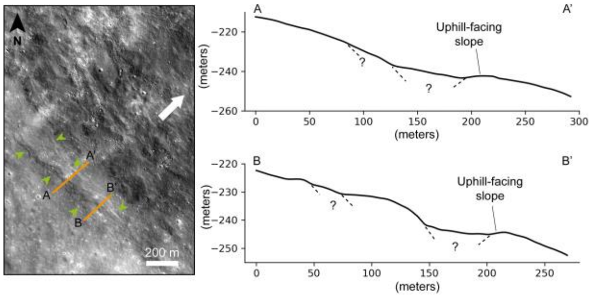

Figure 3. *Structures observed at the summit of the NE-facing slope of the South Massif resemble crestal grabens (light green arrowheads).*

Linear Slope Structures: The upper part of the South Massif slope is characterized by linear structures that are parallel to contour lines. Some of them produce slope benches, about 20 m long (in the downslope direction), which correspond to breaks in slope (Fig. 4a). On the lower part of the NE-facing slope, the linear structures appear to be at an angle (~30º) with the contour lines.

Discussion and Conclusions: We discuss the relationships between the mapped structures to reconstruct the deformation history of the South Massif, and the driving forces that generated the slope structures since the emplacement of the Light Mantle.

The overlapping relationships between the boulder tracks and regolith disturbance suggests that continuous slope deformation has been affecting the NE-facing slope. We attribute the efficiency of the process to repeated ground-shaking perturbation, which maintains the slope in a perpetually unstable state.

We suggest that the linear structures on the lower part of the slope may be the expression of backthrust faults that form in association with thrust faults. Similarly, we suggest that the formation of the Nansen Moat (NM) and the through that is present all along the contact between the young LM unit and the base of the South Massif is also link with backthrust faults, which are re-activating the buried fault that bounds TLV.

We attribute the formation of crestal graben and linear slope structures parallel to contour lines to gravitational deformation, as a result of the state of disequilibrium that affects the slope due to the development of backthrust faults linked to the LL scarp.

We conclude that the NE-facing slope of the South Massif has been recently and continuously affected by slope deformation processes. We suggest that the efficiency of these processes is the product of lasting, and perhaps ongoing, effects of activity of the LL scarp, coupled with the influence of the subsurface geometry of the valley inherited from the impact basin formation.

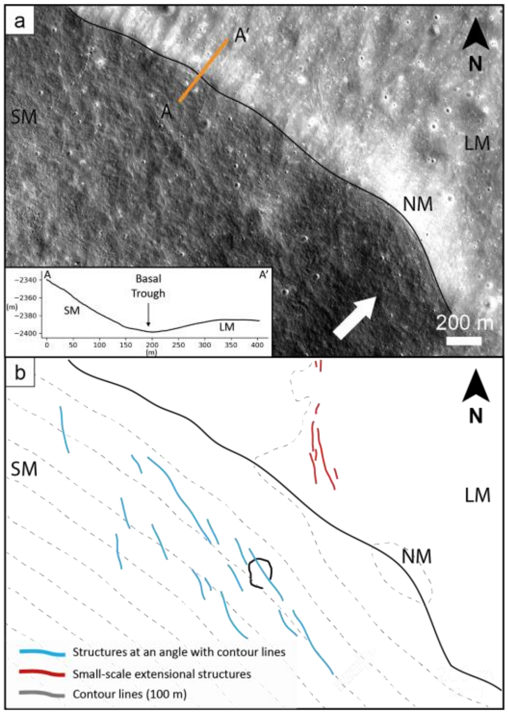

Figure 4. *Linear slope structures observed at the base of the NE-facing slope of the South Massif (light blue lines). The Lee-Lincoln lobate scarp is located about 2 km to the East (outside the frame of the image). Light grey lines represent 100 m contour lines.*

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