NATURE OF THE TAURUS-LITTROW REGOLITH AT THE BASE OF THE NORTH MASSIF – DRIVE TUBE CORE 76001/2. H. H. Schmitt[1], [1] Dept. Eng. Phys., Univ. Wisconsin-Madison, P.O. Box 90730, Albuquerque, NM, 87199, hhschmitt@earthlink.net

Introduction: Regolith from the apron at the base of the North Massif sampled by Apollo 17 (76500) has provided insights into pre-mare lithoclastic ash eruptions. [1] Drive tube core sample 76001 gives additional information into the processes of regolith formation in that location. Additionally, the identification of tracks in the regolith to sampled boulders at Stations 6 and 7 add limits to the rate of lateral migration of massif regolith.

North Massif (Station 6): A drive tube core (76001) into the regolith of the apron of material at the base of the North Massif provides insights into down-slope migration of impact-generated debris. Papike and Wyszynski's [2] study of this 31-32 cm core concluded that the material in the core developed largely by "slow accumulation by down-slope movement." They divide the sample into two units, a lower unit A (31-20 cm) and an upper unit B (20-0 cm) with the faint distinction between the two resting on clast type-frequency analysis in thin section and 2% more fine-grained material in unit B and ~1% more lithic clasts in unit A. In addition, visual observation of photographs given by Meyer [3] of the split core indicates a higher content of lithic clasts in unit A than in unit B.

On the other hand, Nagle [4] describes six units in the core, based on detailed binocular observation of particle characteristics and size- and type-frequency determinations during dissection. Nagle's units 1 and 2 and 3-6 appear roughly consistent with Papike and Wyszynski's units A and B, respectively. The change at 20 cm between units A and B may reflect a contribution from a small avalanche or ejecta blanket, as it apparently coincides with a major decrease in GCR track densities [5]. GCR track densities are high ($\sim10^9/cm^2$) and consistent throughout unit A, but drop to a minimum of $<10^8/cm^2$ in unit B between ~20 and 30 cm. This change suggests that more mature unit A material may have covered less mature unit B material.

Conversely, the core's maturity index ranges between 70 and 80 (except for a bump to 90 between 6 and 10 cm and a drop to 60 at 32 cm, and its FeO concentration decreases gradually from 12% to 10% from top to bottom. [6] Agglutinate content of the core is 43.2% (A) and 48.6% (B). Nagle also reports a paucity of glass particles in the core as a whole relative to other lunar regolith samples. These various factors indicate a much more consistent mixing environment and prolonged maturation than for the deep drill core materials [7]. Whether or not unit A was introduced in a single event, accumulation of all the core materials by slow, down-slope (~26º) migration of impact eroded melt-breccias, while continuously exposed to solar wind sputtering and micro-meteor impact, is strongly indicated by these characteristics. Impacts in the valley occasionally added basalt and orange and black pyroclastic ash to this mix, now accounting for 0-15% [2] and 1-4% [4] in various levels of the core. Over time, some of these introduced materials also would have been incorporated in agglutinates.

The content of ~3.5 Ga orange and black pyroclastic ash [8] in 76001, 2-4% in A and 1-5% in B) is about the same as the 4% present in sample 70181 at the deep drill core [9] about 4 km to the south. This similarity suggests that impact redistribution of regolith, allowing for varying surface exposure ages, is fairly uniform though out the valley and on the slopes of the massifs. Pyroclastic ash is 2-3% in South Massif sample 72501, 3-6% in light mantle avalanche samples, and ~6% in Sculptured Hills sample 78501, [9] supporting this conclusion.

In the initial period following the pyroclastic ash eruptions in Taurus-Littrow, based on resent studies of ash stratigraphy at Shorty Crater [8], ash covered the slopes and valley floor to at least a depth of ~1 m. Massif regolith near the base of the North Massif regolith apron above its intersection with the valley floor after ash eruptions ceased would have been covered as well. Down-slope movement of ash probably continued to dominate over that of indigenous massif regolith until essentially all initial ash on the massif slope had been removed. Ash from higher slopes would have mixed with and covered the original ash deposits at the base of the massifs, subsequently to be covered in turn by the gradual increase in indigenous massif regolith like that which currently forms the upper portions of the apron at the base of the North Massif and was sampled in core 76001. A significant concentration of orange and black pyroclastic ash, including both original ash deposits and ash particles transported down-slope, very likely lies beneath the existing regolith apron. Indeed, Schmitt, et al. [10] and Petro, et al. [11] have concluded that a large, uncovered debris flow of ash accumulated down slope from a pyroclastic fissure on the North Massif of that massif, north of Camelot Crater.

Boulder Track Longevity: The boulders sampled at Station 6 and 7 both have tracks in the North Massif regolith that lead to their sources on the slope behind them. [10] These tracks have led to the rough stratigraphic delineation of Crisium and Serenitatis melt-breccia ejecta units that make up the massif. On the other hand, no tracks have been identified behind the boulders sampled at South Massif Station 2 that could have rolled into place since the light mantle avalanche occurred between 75 and 100 million years ago. [10] Exposure ages measured for the North and South Massif boulders approximately define the longevity of tracks impressed on massif slopes of ~26º.

Exposure ages determined for surface samples of the Station 6 boulder (76015, 76215, 76315) indicate that its well-defined track in the slope regolith, ~ 1-2 m deep and ~8 m wide [12], formed 17–21 million years million years ago [13, 14]. The significantly fainter, ~ 0.1 m deep track behind the boulder at Station 7, identified only after LROC images were obtained [10] formed 25–32 million years million years ago (77075, 77135) [13, 14, 15, 16] on a significantly less steep slope. The absence of identifiable tracks behind boulder 1 sampled at Station 2, with an apparent maximum exposure age (72275) of ~53 million years [17], provides a rough upper limit for the longevity of tracks on ~26º lunar slopes. Regolith on slopes of this magnitude, therefore, migrates down-slope and laterally so as to fill depressions to a depth of ~1-2 m within less than ~50 Myr. As impacts and rolling boulders continuously form depressions on this scale, mixing of the regolith on steep slopes is more rapid and uniform than on more level surfaces. This in turn explains the relative absence of small craters on massif slopes versus the flat valley floor. Mixing would be the outcome of the combined influence of macro- and micro-meteor impact, down slope bias in particle migration, and occasional seismic shaking [10]. The near absence of even small-scale features in units A and B in drive tube core 76001 versus the large scale variations in the deep drill core [18], illustrate this aspect of regolith mixing on steep slopes.

Conclusions: Significant information about processes that create and modify lunar regolith exists in the synthesis of existing data on cores and other samples obtained by Apollo 17 as well as other Apollo missions. Such synthesis also identifies addition research avenues for the lunar community to pursue.

References: [1] Schmitt, H. H. (2016) *LEAG Ann. Mtg*. Abstract 5008. [2] Papike J. J. and Wyszynski J., (1980) *LPS XI*, 1609-1621. [3] Meyer C. (2012*) Lunar Sample Compendium* 76001. [4] Nagle, J. S. (1979) *LPS X*, 1385-1399. [5] Corzaz, G. (1980) *LPS XI*, 1453-1462. [6] Morris R.V. and Lauer H.V. (1979) *LPS XI Abstracts*, 861-862. [7] Morris R. V., et al. (1979) *LPS X*, 1141-1157. [8] Schmitt, H. H. (2017) *LPS XLIX* Abstract 1072. [9] Heiken G. H. and McKay D. S. (1974) *LPS V*, 843-860. [10] Schmitt, H. H., et al. (2017) *Icarus*, 298, 2-33. [11] Petro, N. E., et al. (2018) *SSERVI Forum,* Abstract NESF2018-036. [12] Wolfe, E. W., et al. (1983) *USGS Prof. Paper 1080*, 279 p. [13] Corzaz, G., et al. (1974) *LPS V*, 2475-2499. [14] Turner, G., and Cadogan, P.H. (1976) *LPS XII*, 2267- 2285. [15] Stettler, A., et al. (1978) *LPS IX Abstracts*, 1113-1115. [16] Eberhardt P., et al. (1974) *LPS V Abstracts*, 197-199. [17] Leich, D. A., et al., (1975) *The Moon* 14, 407-444. [18] Heiken, G. H., et al. (1992) *Lunar Source Book*, 187.