APOLLO 17 EXPLORATION OF TAURUS-LITTROW: SUMMARY OF MAJOR FINDINGS. H. H. Schmitt[1], N. E. Petro[2], M.S. Robinson[3], R. A. Wells[4], C.M. Mercer[3], and B.P Weiss[5], [1] Dept. Eng. Phys., Univ. Wisconsin-Madison, P.O. Box 90730, Albuquerque, NM, 87199, hhschmitt@earthlink.net, [2]PGGGL, Goddard Space Flight Center, Greenbelt, MD, [3]SESE, Arizona State University, Tempe, AZ, [4]Tranquillity Enterprises, 445 Fairway Dr., Abingdon, VA, [5]EAPS, Massachusetts Institute of Technology, Cambridge, MA.

Introduction: After 45 years of thought, sample analysis, and orbital remote sensing, their detailed integration with Apollo 17 field observations and sampling in the valley of Taurus Littrow (Figure 1) has produced a number of major conclusions and hypotheses.

Mantle Samples: Three samples have been identified that have characteristics suggesting they once resided in the deep mantle of the Moon, making them possibly unique among the Apollo and Luna collection [1]: 1) A crushed dunite (72415) that has both an iron isotopic ratio and chrome-spinel + pyroxene symplectites suggesting an origin near the base of the upper mantle and subsequent exposure to rapid pressure release through mantle overturn. 2) A crystalline troctolite (76535) with chrome-spinel + orthopyroxene and chrome-spinel + clinopyroxene symplectite as coronas between olivine and plagioclase suggesting low-pressure replacement of coronas of chrome-garnet when also subjected to mantle overturn. 3) An apparently recrystallized, chrome-spinel and pyroxene-bearing troctolite (79215) with no symplectic textures evident.

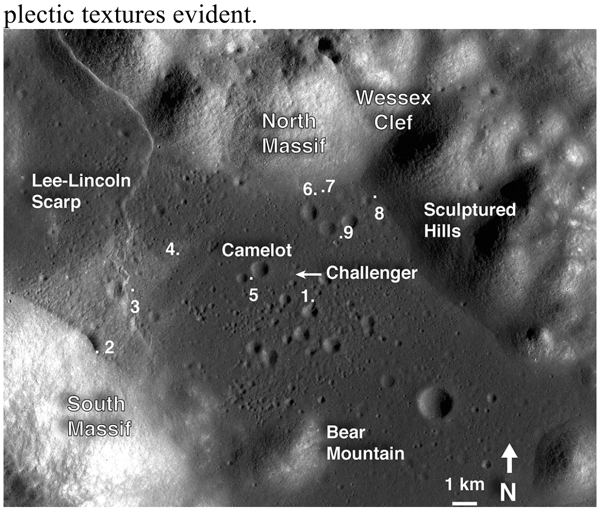

Figure 1. Overivew of the Taurus-Littrow Valley with named features and the locations of sample stations marked. Image is LROC NAC Apollo 17 LM low-Sun controlled mosaic (A).

Basin Ages and Ejecta Dynamics: Dating and petrographic characteristics of melt-breccia samples from boulders at Stations 6 (76315, 76295, 76215, 76015) and 7 (77115, 77135) at the base of the North Massif indicate that the massif consists of ejecta from the Crisium Basin overlain by ejecta from the Serenitatis Basin. [2] Both boulders include distinct, highly vesicular melt-breccia units that originally either overlay or intruded, but definitely metamorphosed, earlier generations of melt-breccia. The Sculptured Hills physiographic unit of fragmental ejecta overlies the older, Crisium-Serenitatis melt-breccias of the North Massif and appears to have been ejected from the Imbrium Basin. [2]

Mg-Suite Ejecta Distribution: Sample 78235 and data from M^3 and LROC images indicate that the Sculptured Hills consist of roughly coherent remains of a layered Mg-suite pluton ejected from the Imbrium Basin. [2] Boulders concentrated on the crests of hills within this physiographic unit appear to represent a variety of plagioclase, orthopyroxene, and olivine-rich rock types. Hills elsewhere in the valley that rise above the mare basalt floor of Taurus-Littrow appear to be kapukas (e.g, Bear Mountain), compositionally related to the Mg-suite rocks of the Sculptured Hills.

Pre-Mare Lithic Pyroclastic Eruptions: Comparisons of the mineral fragments and fragment size distributions in old regolith from the flank of the North Massif (76501) and young, post-avalanche regolith on the slope of the South Massif (72501) indicate that volatile-rich, lithic pyroclastic eruptions preceded mare basalt eruptions in the Taurus-Littrow region and likely occurred in other areas of the Moon, such as at Apollo 16. [3]

Mare Basalt Eruptive History: Seismic profiling and traverse gravity measurements indicate that the mare basalt that partially fills the valley of Taurus-Littrow is about 1200 m thick [4] in the geophysically explored area. It is underlain by relatively low velocity material, probably Imbrium ejecta. Seismic velocities show that local basalt fill is highly fractured to a depth of ~250 m.

The sampled basalts (Type AB) generally are highly vesicular and have TiO_2 contents of 12±2%. The *in situ* fractional crystallization and differentiation history of the flow sampled at Station 1 (71500) [5] show that olivine crystallized first, followed by plagioclase, ilmenite, and clinopyroxene. Olivine and ilmenite crystals presumably sank as they formed; however, less dense plagioclase floated, possibly aided by vesicle-enabled flotation.

Various isotopic systems give widely varying ages for basalt samples from across the valley (age variations exist in all isotopic systems), with the average being about 3.74 Ga for 33 isotopic age determinations, ranging between 3.54 and 3.805 Ga. [2] The potentially youngest sampled basalt eruptions in the valley (four Rb/Sr ages average 3.73 Ga) sampled at Station 4, have low Ba/Rb ratios [4] (Type C basalts 74245, 74255, 74275, 74240, 74260) suggesting that they formed from magma from which plagioclase had been separated.

Post-Mare Pyroclastic Eruptions: Pyroclastic eruptions, apparently following in time the appearance of Type C basalt, produced layered orange and black ash deposits (74220, 74001/2) between about 3.65 and 3.48 Ga. [6] Observations, samples (74220, 74001/2), exposure ages, and analyses of these deposits at Station 4 (Shorty Crater) also indicate that eruptions may have occurred periodically over at least 150 million years, driven by volatiles, including water, derived from a chondritic lower mantle. [6]

Pyroclastic fissure vents have been identified within the Sculptured Hills and in the North Massif. [2] The North Massif fissure may have been the source of the ash deposits sampled at Shorty Crater. Pyroclastic material accumulated on the steep slope (near angle-of-repose) of the North Massif appears to have been removed from the slope of the massif by a debris flow, now extending ~2 km from the base of the massif. [7] A volatile driven plume of ash expelled from this debris flow may have been sampled at Victory Crater (LRV-7, 75111). An associated, bordering plume of very fine-grained North Massif regolith may have been sampled about one km southeast of Victory Crater (LRV-8, 75121).

Reduced Regolith Maturation Around 3.4 Ga: For about 3.4 billion years, an ejecta blanket of Type C basaltic regolith, with a reported ~200 Myr exposure age, protected the ash deposit exposed at Shorty Crater from being incorporated into the general regolith of the valley. [6] This protective regolith (74240, 74260) and the upper ash layer (74220) have a very low Is/FeO maturity indices (<6) as compared with other regolith maturity indices at Taurus-Littrow (50-80). These data indicate that for several hundred million years around 3.4 Ga regolith maturation by solar wind sputtering [8] and/or micro-meteor impact [9] was very low. The lack of evidence of any significant maturation processes in the Shorty samples, including orange and black ash layers [6], suggests that a global magnetic field [10] diverted solar wind particles during this period. If this explanation is correct, it would indicate that micro-meteor impact is not a major factor in regolith maturation. At some later time, maturation processes became active, as witnessed by the moderate to high maturity indices of other valley regoliths.

Lee-Lincoln Thrust Fault: The Lee-Lincoln Scarp crosses the Taurus-Littrow valley floor from south to north, bends about 60° in strike at its contact with the North Massif, and follows contours along the lower, southwest facing slope of the massif. This scarp appears to be the surface expression of a thrust fault with a west and southwest dip of ~26º and a throw of about 500 m [2]. Size-frequency analysis of hanging wall craters [11] suggests that the last major movement on this fault occurred ~75 Ma.

Avalanche Flow Dynamics: Two avalanches of accumulated South Massif regolith, separated by ~100 Myr, formed the light mantle units that extends ~5 km from the base of the massif. [2] Solar wind volatiles were released by agitation of mobilized dust and/or acoustic wave fluidized flow, as indicated by the apparent sorting of rock fragments by size and by density. Exposure ages of post-avalanche boulders at the base of the South Massif and crater size-frequency analysis of the light mantle [11] indicate that the youngest avalanche took place between 110 and 75 Ma.

The identification of two overlapping avalanches at essentially the same location [2] casts doubt that Tycho secondary impacts were their triggers [12]. Two avalanches, however, suggest that two faulting events along the Lee-Lincoln Scarp may have initiated both. [2] The existence of the Nansen moat at the base of the South Massif and of at least two apparent granular debris flow units in the Sculptured Hills are consitant with this conclusion. If the thrust faulting caused the valley basalts to pull away from the South Massif and create Nansen moat, that release of support for the accumulated regolith on its slope could have precipitated both avalanches.

Regolith Development: Given the diversity and abundance of regolith samples from the Taurus-Littrow valley, a comprehensive investigation of regolith development has not been completed. It is now clear, however, that ilmenite in the parent rocks significantly reduces Is/FeO maturity indexes. [5]

Paleomagnetic Field Orientations: There have been no previous measurements on Apollo samples of the paleodirection of the lunar magnetic field. Such measurements would constrain the geometry of the lunar dynamo field as well as enable tests of the hypothesis that Moon experienced true polar wander. Three potential opportunities to determine paleomagnetic field orientations have been identified at Taurus-Littrow [2]: 1) Sample 70019's very young impact glass for which the immediate, post-impact spatial orientation has been determined. 2) Samples from basalt boulders (~3.74 Ga) at the rim of Camelot (75055, 75075) appear to be exposed wall rock that can be reoriented to the their pre-impact positions [10, 13]. 3) The contacts between relatively younger melt-breccias (~3.93 Ga and 3.83 Ga) and older melt-breccias in the boulders at Stations 6 and 7 (76215, 77135) may have been originally horizontal.

References: [1] Schmitt H.H. (2016) *LPS XXXXVII*, Abstract #2339; Wang, K. et al. (2015) *LPS XXXXVI,* Abstract 1980. [2] Schmitt H.H. et al. (2017) *Icarus*, 298, 2-33. [3] Schmitt H.H. (2016) *LEAG Ann. Mtg., Abstract*. [4] Kovach et al. (1973) *Science* 180, 1063-64; Cooper M.R. (1974) *Rev. Geophys. Spc. Phys*. 291-308. [5] Schmitt H.H. (2014) *LPS XXXXV*, Abstract 2732. [6] Schmitt H.H. (2017) *LPS XXXXVIII*, Abstract 1972. [7] Petro, N.E. (2018) *LPS XLIX*-submitted. [8] Pieters, C.M., et al. (2000) *Met. & Planet. Sci.,* 35, 1101-7; Hapke, B. (2001) *JGR*, 106, 10,039-73 . [9] Taylor, L.A., et al. (2001) *Met. & Planet. Sci.,* 285-299; Morris, R.V. (1978), *LPS IX*, 2287-2297; Heiken, G. and McKay D. (1974) *LPS V*, 843-860; Schmitt H.H. and Petro N.E. (2017) *AGU Fall Mtg* Abstract P44B-1. [10] Getzin B. L. et al. (2018) *LPS XLIX,* submitted. [11] van der Bogert et al. (2016) *LPS 47,* Abstract 1616. [12] Lucchitta, B.K., *Icarus*,30, 80-96. [13] Wells, R. A. et al. (2018) *LPSC XLIX*, submitted.