TAURUS-LITTROW DATA SYNTHESIS: PROGRESS REPORT. H. H. Schmitt[1]
[1]University of Wisconsin-Madison, P. O. Box 90730, Albuquerque NM, 87199 <hhschmitt@earthlink.net>

Introduction: The integration of field observation, image interpretation, and analytical data related to the Taurus-Littrow lunar samples yields new insights into the geology of the regolith, the geological evolution of the valley and the Moon, as well as the history of the Sun and, indirectly, of the Earth.

The initial conclusions resulting from this several-year continuing effort in multi-disciplinary synthesis are summarized below, in part, by reference to earlier reports [1,2,3,4,5,6]. A more comprehensive monograph is in work that includes modifications to a number of original conclusions as additional relationships are identified. [7]

Stratigraphy in Deep Drill Core 70001-9:

1. Taurus-Littrow deep drill core is comprised of 13 zones of regolith ejecta from specific valley impact craters.
2. Upper regolith ejecta zones are dominated by Ti-basalt lava and Ti-rich ash components while lower zones are a mix of fragments from Ti-basalt, Ti-rich ash, Mg-Suite, and VLT ash parents.
3. Decrease in thermoluminescence with depth [8] in deep drill core zones is due to electron trap leakage in excess of their formation by a decreasing alpha particle flux.

Origin Deep Drill Core Regolith Ejecta Zones:

1. Thirteen valley craters, ~400-1300 m in diameter [9], are the sources of regolith ejecta zones in the deep drill core.
2. Zones are defined by significant changes in Is/FeO values (10] (maturation) and in petrographic characteristics [e.g. 11,12).
3. The source crater for each zone has been identified by petrographic data and relative age observations and diameter to depth ratio data.
4. Regolith ejecta in a given zone is derived from thick, mature, zoned regolith overlying fractured bedrock near the point of impact.
5. The leading, highest energy portion of an impact's parabolic ejecta sheath contains most of the regolith ejecta mass.
6. Based on zone thickness and distance from its source crater, the majority of regolith ejecta in the leading portion of the parabolic ejecta sheath is deposited ~2.8 km from the crater rim.
7. Regolith at the trailing edge of the ejecta sheath is deposited continuously between the crater rim and ~2.8 km from the rim.
8. Ballistic turbulence in ejecta sheaths results in homogenization of cosmic ray exposure ages, Is/FeO values, and elemental concentrations.
9. Bedrock beneath ejected regolith is excavated subsequent of regolith ejection and deposited, irregularly ~one crater diameter from the crater rim.

Nitrogen Isotope Systematics in Deep Drill Core:

1. $^{15}N/^{14}N$ values [13] in Taurus-Littrow core 70001-9 increase linearly with Is/FeO, but with a sharp increase in $\delta^{15}N‰$ indicating a rise in solar energy at ~0.5 Ga. Determination of a more precise age for this change is in work.
2. $^{15}N/^{14}N$ values in the deep drill core indicate the current solar $\delta^{15}N‰ = -113 \pm 9‰$.
3. Taurus-Littrow core 79001-2 indicates solar $\delta^{15}N‰ < -210‰$ prior to the rise of a lunar global magnetic field at ~4.25 Ga [14].

Maturity Indices in the Deep Drill Core:

1. Maturity indices [10] in the Taurus-Littrow deep drill core zones vary directly with uranium+thorium content [16].
2. Maturity index increase from solar wind protons reaches an Is/FeO threshold of 32 ± 10 due to alumino- silicate glass accumulation on regolith particles.
3. Above a TiO_2 content of ~7 wt %, ilmenite content is sufficient to attenuate regolith Is/FeO values by a factor of ~1.39.
4. Alpha particle-induced excess Is/FeO in buried and stabilized regolith zones reaches limits that are a function of the FeO / U+Th ratio.
5. Excess Is/FeO added by the alpha particle induced Is/FeO in deep drill core buried regolith zones ranges from~9 to ~23.

Cosmic Ray Calibration of deep drill core Is/FeO data:

1. Integrated cosmic ray exposure ages [15] for deep drill core regolith zones provide a means to calculate a value for Is/FeO per Myr for that zone.
2. Long-term additional maturation of initially very immature regolith ejecta from the Crater Cluster (zone T) allows calculation of total Is/FeO per Myr = <0.243 for zone T [6], although consideration of excess maturation after zone burial may change this conclution.
3. Deposition ages of regolith ejecta zones in the Taurus-Littrow deep drill core reach a maximum of ~1 Ga at 277 cm (zone Z - Shakespeare Crater). Determination of a more

precise age is in work, however, the preliminary indication of this age is that the total regolith thickness at the deep drill core site is about 10 m.

Origin and Ages of North Massif Melt Breccias (see [1]).

Sculptured Hills Origin and Composition (see [1])

Pre-Mare Lithoclastic Volcanism (see [4])

Mare Basalt Volcanism and Magnetic Field (see [1], [17])

High-Titanium Pyroclastic Volcanism (see [2]).

Very Low Titanium (VLT) Pyroclastic Volcanism:

1. Pyroclastic eruption of VLT basaltic ash probably occurred soon after the ~3.48 Ga eruption of TiO_2-rich orange+black ash.
2. Pyroclastic eruptions of VLT ash accompanied volatile release during VLT magma fractional crystallization.
3. Rare, VLT basalt lavas came from fractionally crystalized, ilmenite basalt magma sources, depleted in TiO_2, FeO and CaO**.**

Pyroclastic Eruptive Fissures (see [1]).

Upper Mantle Overturn Beneath Procellarum (see [18]).

Ages of Shorty and Van Serg Craters:

1. Exposure ages [19] and regolith breccia life-time constraints indicate ages of ~0.003 Ga and ~0.001 Ga for Shorty and Van Serg craters, respectively.

Ages of Old and Young Light Mantles [see [20]:

1. Data synthesis on samples 72240, 73220, 73240, and drive tube 73001-2 yields separate light mantle ages of 54 and 97 Myr.
2. The ~5 km run-out of the light mantle avalanches indicate they were fluidized by solar wind volatiles released by agitation during transport.
3. At least four mass-wasting event have occurred from the north-facing slopes of the South Massif since ~3.74 Ga.

Lee-Lincoln Thrust Fault (see [1]).

History of the Sun and Earth:

1. The increase in $\delta^{15}N‰$ as a function of Is/FeO by a factor of over 2 in the deep drill core around 500 Ma indicates an increase in the energy of the solar wind that may correlate with the timing of Earth's Cambrian Explosion and the proliferation of land plants. [20]

Stability of Is/FeO during Impacts:

1. Is/FeO = 16 for fresh crater wall sample 73230 indicates that impact shock and/or heat locally partially re-oxidizes nano-phase iron and reduces Is/FeO.

References: [1] Schmitt, H.H., et al. (2017) *Icarus*, 298, 2-33 [2] Schmitt, H. H. (2017) *LPS VLIII*, Abst. 1072. [3] Schmitt, H. H. (2016) *LPS VLII*, Abst. 2732 [4] Schmitt, H. H., 2016, LEAG Ann. Mtg, Abst. 5008. [5] Schmitt, H. H. (2014) *LPS VL*, Abst. 2732. [6] Schmitt, H. H. (2022) *LPS LIII*, Abst. 2723. [7] Schmitt, H. H. (2022+) *Diary of the 12th Man.* [8] Sehlke and Sears (2022) *LPS VIII* 1267. [9] LRO Quick Maps (2022). [10] Morris, R. V. et al. (1979) *LPS X,* 1141-1157. [11] Taylor, L. A., et al. (1979) *LPS X*, 1159-1184. [12] Meyer, C. (2008) *Lun. Sample Compend.* [13] Thiemans, M. H., and Clayton, R. N. (1980) *LPS XI*, 1435-1451. [14] Tikoo, S. M. (2014) *Sci. Adv.* 3:e1700207, 1-9. [15] Eberhardt, P., et al. (1974) *LPS V*, 197-199 (abst.). [16] Silver, L. T., (1974) *LPS V*, Abs. 2446. [17] Nichols, C. I. O., et al. (in review). [18] Schmitt, H. H. (2016) *LPS VLII*, Abst. 2339. [19] Eugster, O. (1977) *LPS VIII*, 3059-3082. [20] Schmitt, H. H. (2021) *LPS 52*, Abstract #2575. [21] Schmitt, H. H. (2019) *LPS ,L* Musursky Lecture.