**A "NEW" LUNAR SAMPLE RETURN MISSION REVEALS A FRESH PERSPECTIVE OF LUNAR MAGMATISM FROM LITHIC FRAGMENTS FROM DOUBLE DRIVE TUBE 73001/73002.** C.K. Shearer[1,2], S.B. Simon[1], B.L. Jolliff[3], F.M. McCubbin[4], R.A. Ziegler[4], J. Gross[4], C. J.-K. Yen[3], K.H. Joy[5], S.K. Bell[5], M. Cato[1], S. Eckley[4], L. Borg[6], N. Marks[6], B. Jacobsen[6], C.R. Neal[7], J.L. Valenciano[7], J.I. Simon[4], N. Petro[8], H.H. Schmitt[9], D. Moriarty[8,10], R. Tartese[5], M. Anand[11], and the ANGSA science team[12]. [1]Dept. of Earth and Planetary Science, Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87131; [2]Lunar and Planetary Institute, Houston TX 77058; [3]Washington University in St. Louis, St. Louis, Mo 63130; [4]ARES, NASA Johnson Space Center, Houston TX 77058-3696; [5]University of Manchester, Manchester, UK ; [6]Lawrence Livermore National Laboratory, Livermore, CA 94550; [7]University of Notre Dame, Notre Dame IN 46556, [8]NASA Goddard Space Flight Center, Greenbelt, MD 20771; [9]University of Wisconsin-Madison, P.O. Box 90730, Albuquerque, NM 87199; [10]University of Maryland, College Park, Md 20742, [11]The Open University, Milton Keynes, UK, [12]the list of co-authors includes all members of the ANGSA Science Team (https://www.lpi.usra.edu/ ANGSA /teams/) (cshearer@unm.edu).

**Introduction**: Analyses of the samples returned by the Apollo Program have provided fundamental insights into the origin and history of the Earth-Moon system and how planets and solar systems work [1]. Special samples that were collected or preserved in unique containers or environments (e.g., Core Sample Vacuum Container, Double Drive Tube container) remained unexamined until the start of the Apollo Next Generation Sample Analysis (ANGSA) program. This initiative was designed to examine a subset of these special samples (e.g., 73001/73002) and to function as a new sample return mission with processing, preliminary examination, and analyses utilizing new and improved technologies and recent mission observations. The ANGSA initiative has identified, and is studying, several rare and unique magmatic lithologies in the landslide deposit at the base of the South Massif in the Taurus-Littrow Valley (TLV).

**Samples:** Lithic fragments from several 73001/73002 sample suites were examined: the >4 mm size fraction, the <1 mm size fraction, and continuous core thin sections. Here we emphasize igneous lithologies. These samples are being documented and analyzed with micro-X-ray Computed Tomography (XCT), EPMA-SEM, Laser Raman spectroscopy, Nano-SIMS, and LA-ICP-MS.

**Results:**

***Distribution of magmatic rocks in the TLV:*** A variety of volcanic landforms and lithologies are identified in the TLV by orbital observations (Fig. 1). The TLV floor is dominated by high-Ti mare flows, whereas to the NE of the TLV there is evidence for eruption of volcanics associated with fractures within the Sculptured Hills [2].

***Rock types observed:*** A majority of the rock types identified in the 73001/73002 lithic fragment populations are regolith and impact melt breccias. However, a small proportion represent magmatic lithologies derived from the floor of the TLV and the South Massif. In the >4 mm size fraction the magmatic lithologies are dominated by mare basalts, whereas in the < 1 mm size fraction highland magmatic lithologies are more common than the mare basalts. Observed magmatic lithologies include (1) high-Ti (HT) and very low-Ti (VLT) mare basalts, (2) pyroclastic volcanic glasses, (3) Mg- and FAN highland suites, and (4) evolved lithologies such as alkali suite and granites.

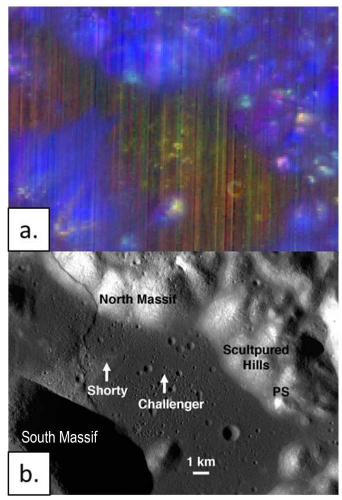


*Figure 1. (a) Standard Chandrayaan-1 M3 Color Composite showing compositional variations associated with the Sculptured Hills and portions of the North and South Massifs. R: 1-micron band strength. G: 2-micron band strength B: 1450 nm reflectance. Highland materials will show up as blue, mare will be yellow-red, and noritic material will be green-yellow. (b) LROC image composite.*

***Mare basalts:*** Examples of lithics representing mare magmatism are illustrated in Fig. 2. HT basalts exhibit a broader textural range than observed in the larger basalt samples collected during A17 (e.g., samples 70185, 75035). The HT basalts exhibit mineralogy and textures that indicate distinct (1) cooling histories, (2) liquid-lines-of-descent (LLD), and (3) mantle sources. Although there is remotely collected evidence suggesting the eruption of LT or VLT magmas in the Sculptured Hills [2], overall VLTs are relatively rare at the A-17 site, occurring only in the deep drill core, as individual green pyroclastic glasses, and as "volcanic ash" (e.g., 78526). Different textural variations of VLTs are found in 73001/73002 (Fig. 2). These VLTs appear to lie along the LLD of the A-17 green glass and therefore provide a broader picture of regional VLT magmatism.

***Pyroclastic volcanic glasses:*** Pyroclastic glasses representing lunar fire-fountaining occur as glass-rich breccias (Fig. 3a), glass-rich clods (Fig. 3b), and individual glass spheres (green, yellow, orange, red, black) in regolith (Fig. 3c,d). The HT glasses appear to represent melts derived from mantle sources distinct from the crystalline HT basalts. The relationship between the VLT glasses and crystalline VLT basalts is unclear.

***Mg-suite and FANs:*** Both Mg-suite and FAN lithologies occur in 73001/73002. The Mg-suite lithologies include dunite, troctolite, spinel troctolite and norite (Fig. 4a-c). They appear to be distinct from the larger Mg-suite rocks collected in the TLV (e.g., 72415, 76535, 78235) in that they do not exhibit cataclastic or other shock textures and they do not have mineralogical or textural evidence to indicate excavation from significant depths. The spinel troctolite has multiple types of spinel (Fig.4c). FANs thus far identified are predominantly noritic or troctolitic anorthosites (Fig. 4d). Coarse pyroxene with FAN affinities and thick exsolution lamellae have been identified.

***Evolved magmatic lithologies:*** These samples include material from the ≤1 mm size fraction from the Station 3 double drive tube (73001/73002), surface samples from Station 3, and Boulder #1 from Station 2. Some fragments are clasts from impact melt breccias derived from the South Massif (Fig. 5). BSE images of $SiO_2$-rich lithic fragments from 73002 are shown in Fig. 5. These fragments are dominated by a $SiO_2$ polymorph, Ba-rich potassium feldspar ($Or_{85-98}$), and ternary plagioclase (~$An_{67}Ab_{25}Or_{08}$). Iron-rich clinopyroxene occurs in some fragments. The pyroxene may exhibit fine exsolution lamellae on a scale of three microns or less in width. Important accessory phases that enable the unraveling of the volatiles and chronological record include Cl-rich apatite, zircon, and baddeleyite. Textures range from holocrystalline (micrographic to granular) to glassy. Preliminary observations of exsolution lamellae in pyroxene, Ti concentration in $SiO_2$ polymorphs, and structural state of $SiO_2$ (tridymite) and K-feldspar (sanidine) indicate that these lithologies crystallized at high-T, relatively shallow depths and under water-poor conditions.

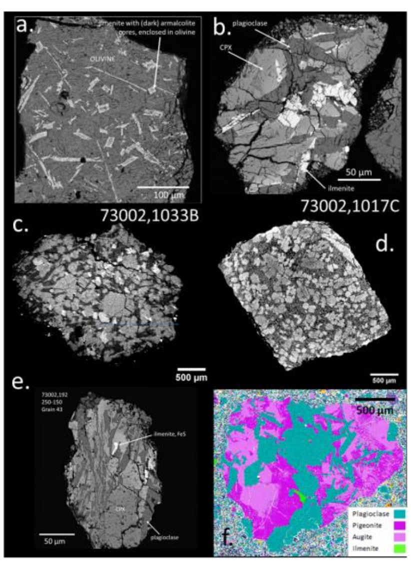


***Figure 2.*** *Mare basalt lithologies represented in the landslide deposit. a, b. BSE images of distinct HT basalts. c, d. XCT images of VLT basalts. e. BSE image of VLT basalt. f. QEMSCAN False-color X-ray map of VLT in a continuous-core thin section.*

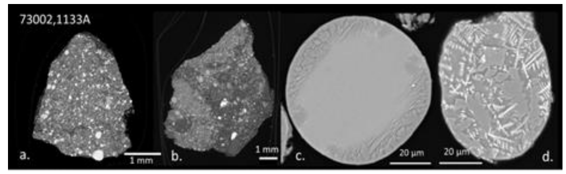


***Figure 3.*** *Volcanic glasses from the Station 3 double drive tube. a. XCT image regolith breccia. b. XCT image of glass clod. c. BSE orange glass, d. BSE black glass.*

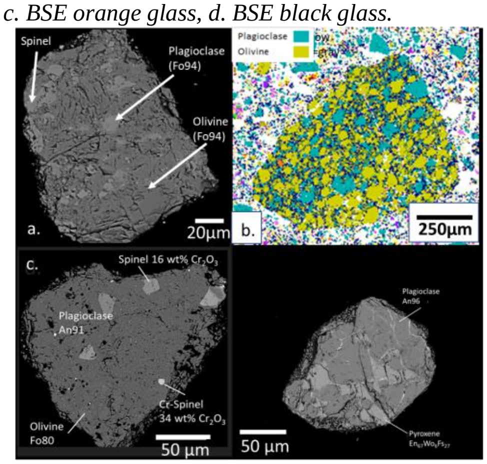


***Figure 4.*** *Examples of Mg-suite and FAN lithologies identified in 73002. a. Dunite (BSE image of < 1 mm size fraction), b troctolite (QEMSCAN continuous thin section imaging by Bell and Joy, 2022), c. Spinel troctolite (BSE image of < 1 mm size fraction), d. FAN (BSE image of < 1 mm size fraction).*

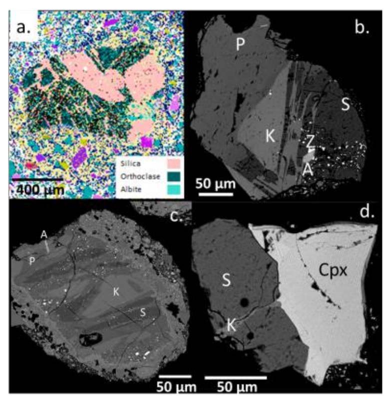


***Figure 5.*** *Evolved lithologies associated with the landslide deposit. a. Alkali suite lithology (QEMSCAN Continuous thin section imaging from Bell and Joy, 2022), b. Crystalline granitic lithology (BSE image of <1 mm size fraction), c. Glassy granitic lithology (BSE image of < 1 mm size fraction), d. Pyroxene-$SiO_2$-K-spar lithology (BSE image of < 1 mm size fraction).*

**References:** [1] Tartese et al (2022) Space Science Reviews 215, 1-50. [2] Schmitt et al. (2017) Icarus 298, 2-33.