PREPARING FOR ARTEMIS THROUGH LESSONS LEARNED FROM APOLLO 17. HIGHLIGHTING THE PROGRESS OF THE ANGSA INITIATIVE. C.K. Shearer[1,2], F.M. McCubbin[3], R.A. Zeigler[3], J. Gross[3], S.B. Simon[1], A. Meshik[4], F. McDonald[5], R.V. Morris[3], H.H. Schmitt[6], M. Neuman[4], K. Wang[4], B.L. Jolliff[4], K. Joy[7], Z. Sharp[1], M. Cato[1], A. Gargano[1], S. Eckley[3], E. Cano[1], R. Para[4], J. Simon[3], K.C. Welten[8], J.J. Barnes[9], M. Dyar[10], K. Burgess[11], N. Petro[12], N.M. Curran[12], J.E. Elsila[12], J. Gillis-Davis[4], A. Sehlke[13], B. Cohen[12], O. Pravdivseva[4], M.S. Thompson[14], C.R. Neal[15], P. Lucey[16], L. Sun[16] and the ANGSA science team[17]. [1]Dept. of Earth & Planet. Sci., Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131; [2]Lunar and Planetary Institute, Houston TX 77058; [3] ARES, NASA Johnson Space Center, Houston TX 77058-3696, [4]Washington University in St. Louis, St. Louis, Mo 63130; [5]ESA/ESTEC, Noordwijk, Netherlands; [6]University of Wisconsin-Madison, P.O. Box 90730, Albuquerque NM 87199; [7]University of Manchester, Manchester, UK; [8]Space Sciences Laboratory, University of California, Berkeley, CA 94720; [9]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; [10]Department of Astronomy, Mount Holyoke College, South Hadley MA 01075; [11]United States Naval Research Laboratory, Washington DC 20375; [12]NASA Goddard Space Flight Center, Greenbelt, MD 20771; [13]NASA Ames Research Center, Moffett, CA 94035; [14] Purdue University, West Lafayette, IN 47907; [15]University of Notre Dame, Notre Dame IN 46556, [16] University of Hawaii at Manoa, Honolulu, HI 96822; [17]ANGSA Science Team list at https://www.lpi.usra.edu/ ANGSA /teams/. (cshearer@unm.edu).

Introduction: Analyses of 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. After 50 years of analysis and study, the sophistication for handling and examining samples has greatly increased. Some special samples that were collected or preserved in unique containers or environments (e.g., Core Sample Vacuum Container (CSVC), frozen samples) have remained unexamined by standard or advanced analytical approaches. The Apollo Next Generation Sample Analysis (ANGSA) initiative was designed to examine a subset of these special samples. The initiative was purposely designed to functions as a proxy for a new sample return mission with processing, preliminary examination, and analyses utilizing new and improved technologies and lunar mission observations. The ANGSA initiative links the first generation of lunar explorers (Apollo) with the next generation lunar explorers (Artemis) [1-4]. Here we highlight the progress made by ANGSA in the examination of these special samples.

Progress and Results:

Gas extraction from CSVC 73001: To extract any potential gas phase from the CSVC, the European Space Agency (ESA) designed, built, tested, and delivered to JSC a CSVC piercing tool. To collect and store the gas phase, WUStL designed, built, and delivered to JSC a gas manifold system. Together these tools are being used to open and sample the CSVC (Fig. 1). This sampling experiment took place in early 2022.

Fig. 1. Manifold (upper image) and piercing tools (lower image) prepared for opening the CSVC in early 2022.

Extrusion of 73001: Following extraction of gas using the piercing and manifold tools, the lower part of the double drive tube (73001) was imaged by XCT, extruded, and dissected.

Frozen samples: The cold curation facility for processing Apollo 17 frozen samples was approved in mid-December 2021. These special samples are being processed and allocated in early 2022.

Stratigraphy of 73001 and 73002: The stratigraphy of the double drive tube has been examined by multiple approaches. For 73002, the stratigraphy has been documented by XCT imaging [5], reflectance properties [6,7],

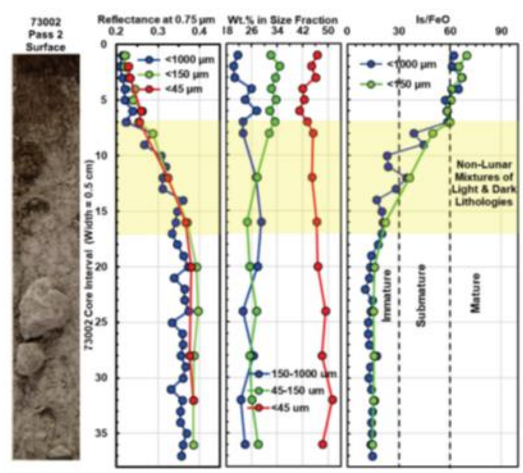

Fig. 2. (left): Image of pass 2 illustrating contact between light and dark horizons in the 73002 core. (center left): Reflectance of different grain sizes at 0.75µm. (center right): wt.% of different size fractions. (right): I_S/FeO. From Morris et al [7].

I_S/FeO [7; Fig. 2], major, minor, and trace element geochemistry [8,9], grain size and modal proportions [7,10,11], and continuous thin sections of core [12,13;

Fig. 3]. Based on Is/FeO [7] and mineralogy [10,11] maturity characteristics of 73002 are illustrated in Fig 2.

μXCT imaging of lithic fragments: Lithic fragments >3 mm in size were removed from Passes 1-3 from core

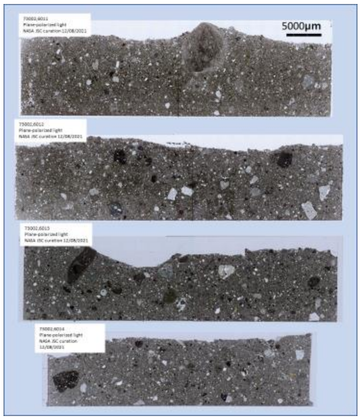

Fig. 3. Plane-polarized images of continuous thin sections from double-drive tube core section 73002 [12,13].

73002. XCT images of 131 of these lithic fragments were obtained. Fragments include a variety of breccias, high-Ti basalts with different cooling histories, and a number of unique lithologies presumably derived from the south Massif (Fig 4). The ANGSA lithic analysis group is carrying out collaborative studies of these fragments [5,14].

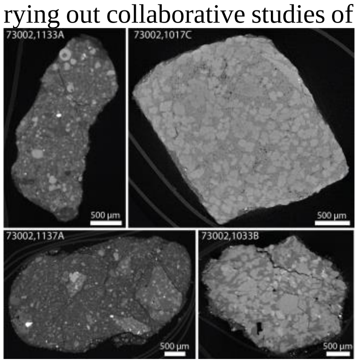

Fig. 4. XCT images of lithic fragments from 73002. ,1133A: regolith breccia with glass spherules; ,1017C: pyroxene "porphyry" [14]; ,1137A: regolith breccia with a variety of lithologies from the south massif; and1133B: low-Ti basalt.

Less than 1mm lithic fragments: During processing of Pass 1 and 2 from 73002, samples were sieved into greater than 1 mm and less than 1 mm size fractions. The < 1 mm size fractions were sieved into several size fractions (i.e., 1000-500, 500-250, 250-150, 150-90, 90-20, and <20μm). In addition to determining modes of each size fraction within the stratigraphy, lithic fragments were also classified and documented. Impact melt rocks are abundant. Igneous lithologies include FANs, Mg-suite, felsites, low-Ti basalts, and a variety of high-Ti basalts (Fig. 5) [10,11,15].

Behavior of volatiles from stable isotope systems: A variety of volatile elements and their stable isotopes have been or are being measured on core sample splits, distinct size fractions, and individual mineral and glass phases. These elements include O, H, halogens (Cl, F, Br, I), S, Zn, Cu, K, Rb, and Pb. The results illustrate distinct behaviors of each element and isotopic system that provides a perspective of volatile element behavior and factors influencing that behavior [16,17]. Reflectance FTIR spectroscopy was used to observe gradients in H in lunar glass beads. Results are interpreted to correspond to H enrichments in the bead centers grading to depletions toward the rims or in fractures [18].

Organic compounds: Volatile organic compounds and hydrogen cyanide abundances were analyzed in samples from three depths in 73002. Low abundances of several species were observed [19].

Cosmogenic radionuclides: The depth profile of cosmic ray produced ^{10}Be, ^{26}Al and ^{36}Cl in 73002 indicates recent regolith mixing of the top ~9 cm of the core [20].

Investigation of Space Weathering Features: Grains from the first three intervals have been examined for evidence of space weathering and determination of surface exposure age using transmission electron microscopy. Results show exposure ages for individual grains ranging between 1 - 5 Ma [21].

Thermoluminescence: TL measurements show that samples remain highly luminescent after nearly 50 years in storage. The results enable a better understanding of the TL kinetics in lunar samples, improving the method for cold trap and resource prospecting on the Moon [22].

Lessons Learned Document (LLD): Given that the ANGSA initiative is being treated as a lunar sample return mission, the activities have direct implications for the Artemis Program and sample return/analyses/processing associated with that program. The ANGSA Team has assembled an initial LLD that can be accessed through the ANGSA website. Now that ANGSA is moving forward with several studies, we will present an introduction to LL2 at LPSC 2022.

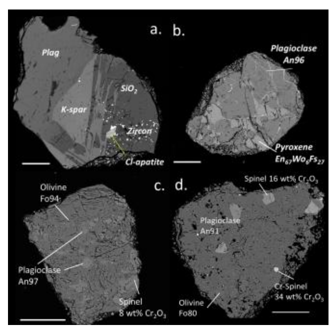

Fig. 5. Examples of igneous lithologies found in the 250-125μm size fraction from 73002. a. felsite, b. Noritic anorthosite, c. dunite, d. anorthosite. Scale bar in all images is 50μm (images from [10]).

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