

ORGANIC COMPOUNDS AND CYANIDE IN THE APOLLO 17 ANGSA SAMPLES. J. E. Elsila^{1,*}, J. C. Aponte¹, J. P. Dworkin¹, D. P. Glavin¹, H. L. McLain^{1,2}, D. N. Simkus^{1,2}, and the ANGSA Science Team. ¹NASA Goddard Space Flight Center, Greenbelt, MD 20771, ²Department of Chemistry, Catholic University of America, Washington, DC 20064, *Email: Jamie.Elsila@nasa.gov

Introduction: The organic content of lunar samples has been a focus of studies from the Apollo era through the present day [1-6]. Early studies prioritized amino acids because of their significance to life on Earth; multiple early studies reported amino acid contents and their molecular distributions, but without a clear consensus on their origin [1-5]. Using modern techniques, we determined that amino acids detected in returned lunar samples were likely a combination of terrestrial contamination and meteoritic or cometary infall to the lunar surface [6]. The majority of the amino acids detected appeared to originate from precursor molecules that may have reacted to form amino acids during laboratory procedures including hot-water extraction and acid-catalyzed hydrolysis. The identity of these precursor molecules remained unknown, but may include cyanides (CN⁻) and other organic species such as amines, carboxylic acids, and aldehydes or ketones [7-9].

The effects of curation conditions (e.g., temperature, nitrogen gas purge) on the preservation of these compounds is unknown. The Apollo Next Generation Sample Analysis (ANGSA) program [10] allows an opportunity to examine this question by providing a variety of samples curated under different conditions, including frozen samples and a vacuum-sealed core. Analysis of these samples can answer science questions about the abundance and distribution of these organic compounds as well as curation questions about the effects of these differing conditions.

In our ANGSA-funded study, we are examining samples from both halves of a double drive tube collected by Apollo 17 astronauts. The top half (73002) was curated under standard conditions until its opening in 2019 [10], while the bottom half (73001) was sealed under vacuum on the Moon and opened in 2022. Our project includes analysis of three samples from different depths within each half of the drive tube (six samples total). In addition, we are studying six non-core samples, which represent frozen and non-frozen portions from three different lunar sites (sunlit, partially shadowed, and completely shadowed) also collected by Apollo 17 astronauts. Figure 1 compares the sample locations and curation conditions. For each of these samples, we are examining the presence of amino acids and their potential volatile precursors, including cyanides, aldehydes, ketones, amines, and monocarboxylic acids.

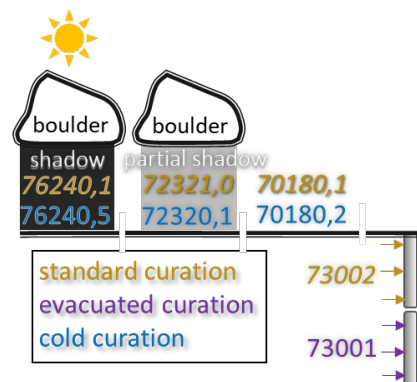


Figure 1. The 12 samples analyzed in this project include a range of surface illumination environments and core depths, as well as curation conditions including frozen storage and vacuum conditions.

Methods: All lunar samples were provided by the curation team at NASA Johnson Space Center (JSC). Samples consisted of unsieved regolith. Corresponding contamination control coupons of ashed aluminum foil (~3 cm x 3 cm) that witnessed the processing environment were also provided. Samples and witness foils were shipped in separate cleaned stainless-steel containers from JSC to NASA Goddard Space Flight Center (GSFC); empty stainless-steel containers were also sent as additional contamination witness material. The frozen samples were sent in a cold shipping container, remained frozen throughout transit, and were placed in a -20 °C freezer upon arrival at GSFC.

At GSFC, samples and witness foils were processed in batches: 73002 samples in November 2019 and May 2021, 73001 in April 2022, and the frozen and standard-curation surface samples (76240, 72320, and 70180) in July 2022. Each batch also included two additional control samples: 1) a procedural blank, and 2) a pre-baked 2 g portion of JSC-1 lunar simulant [11] that was shaken inside the cleaned empty stainless steel container sent from JSC. Each sample was sealed in an ampoule with ultra-pure water and heated at 100°C for 24 hours. After extraction, each sample was split into multiple portions, each designated for a specific organic analysis as shown in Figure 2. Sample splitting and the methods for analysis have been described elsewhere [12].

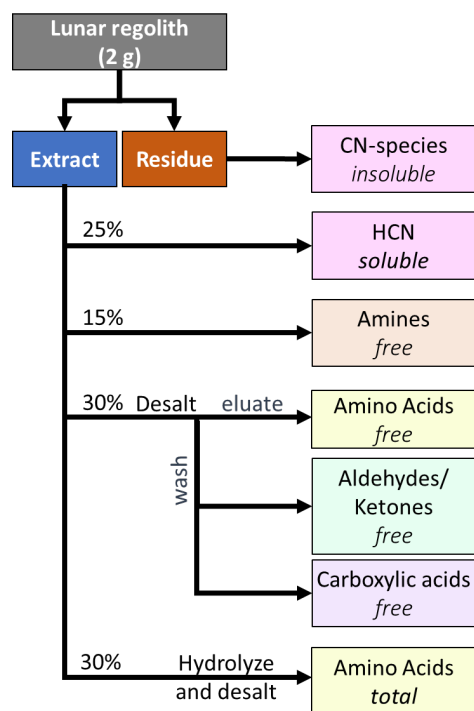


Figure 2. Hot-water extracts of each sample and control were split into aliquots to allow the targeted analysis of multiple compound classes.

Discussion: Very low abundances of organic compounds were observed in all of the 73002 samples. Quantitation was difficult for many organic compounds due to observations of low concentrations of the same species in the witness materials. Analyses of the 73001 samples and the surface samples (standard and frozen curation) are underway, but similarly low abundances have been observed in the first analyses.

Insoluble cyanide species show a correlation with depth in the 73002 samples, with concentrations decreasing with depth. This is consistent with previous analyses of Apollo lunar regolith samples [14]. This correlation could indicate that the cyanide species are delivered exogenously and that the delivery rate is faster than any potential destruction processes, or could potentially indicate a correlation with mineralogy depth profile.

We will present up-to-date analytical results on the detection of cyanides, amino acids, amines, carboxylic acids, aldehydes, and ketones, including data from the 73001 and surface samples. A full comparison of these data from the various lunar samples and controls will help in understanding several aspects of lunar organic volatiles, including depth profiles and the effects of illumination on the lunar surface. In addition, the comparison of these samples will aid in understanding the effects of various curation conditions and may inform

choices to be made in the curation of future Artemis returned samples from the Moon, as well as samples returned from asteroid Bennu and from Mars.

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