

AMINO ACIDS IN LUNAR REGOLITH SAMPLES. Jamie E. Elsila¹, Michael P. Callahan¹, Daniel P. Glavin¹, Jason P. Dworkin¹, Hannah L. McLain,^{1,2} Sarah K. Noble¹, and Everett K. Gibson, Jr.³, ¹NASA Goddard Space Flight Center, Greenbelt, MD 20771, ²Catholic University of America, Washington, DC 20064, ³NASA Johnson Space Center, Houston, TX 77058. Email: Jamie.Elsila@nasa.gov

Introduction: Understanding the origin and distribution of organic compounds is a key goal in astrobiology research. The existence of organics on the lunar surface has been studied from the Apollo era to the present [1-3]. Investigations of amino acids immediately after collection of lunar samples yielded inconclusive identifications (e.g. [4,5]), in part due to analytical limitations. It was not possible to determine if the detected amino acids were indigenous to the lunar samples or the result of terrestrial contamination. We applied modern analytical techniques to determine the abundances, distributions, and carbon isotopic ratios of amino acids in lunar regolith and present these results in the context of four potential amino acid sources.

Analytical techniques and samples: We analyzed seven samples allocated from the lunar collection at NASA Johnson Space Center (Table 1). Samples reflected a range of maturities and included two samples collected to test exposure to lunar module exhaust.

Amino acid abundances and distributions were determined using previously published methods [6]. Compound-specific carbon isotopic analysis was performed on the large sample of Apollo 70011 using previously published methods [7].

Results and Discussion: *Amino acid content:* We observed a suite of amino acids at low concentrations ranging from 14.5 to 651 ppb in the hydrolyzed lunar regolith samples. These amino acids include glycine, β -alanine, D- and L-alanine, α -aminoisobutyric acid (AIB), D- and L- β -amino-*n*-butyric acid, α -amino-*n*-butyric acid, γ -amino-*n*-butyric acid, ϵ -aminocaproic acid, D- and L-aspartic acid, D- and L-glutamic acid, D- and L-serine, L-threonine, and L-valine [8]. We observed variability in both the relative and absolute

abundances of amino acids between aliquots taken of Apollo 70011, implying that the amino acids are distributed heterogeneously throughout the soil. This could indicate the presence of small carbonaceous particles mixed inhomogeneously through the regolith or could reflect different exposures of portions of the soil sample to sources of amino acids.

Compound-specific carbon isotopes: The $\delta^{13}\text{C}$ values for glycine, β -alanine, and L-alanine in Apollo 70011 were in the -20 to -30‰ range. Figure 1 compares these values to those of potential amino acid sources.

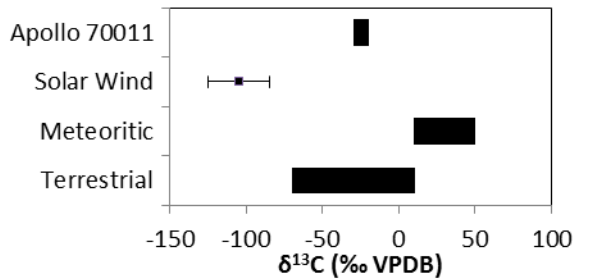


Figure 1. Range of carbon isotopic ratios measured for Apollo 70011 amino acids compared with solar wind, carbonaceous chondrites, and terrestrial biological sources.

Probable sources of detected amino acids: We considered four potential sources for the amino acids in the lunar samples: (1) contamination from the lunar module (LM) exhaust, which could implant amino acid precursors that would produce amino acids during sample workup; (2) solar wind implantation of amino acid precursors; (3) terrestrial contamination during the sample acquisition, handling, or curation process; and (4) meteoritic infall to the lunar surface.

Based on the amino acid distributions and carbon isotopic values, the most likely source of the amino acids found in the lunar samples appears to be terrestrial contamination [10]. However, meteoritic infall could be a contributing source, as indicated by the presence of nonproteinogenic amino acids such as AIB.

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Table 1. Lunar samples investigated in this study

Sample	Is/FeO ratio [9] (maturity)	Masses analyzed (g)
73131	16, immature	0.33 ^c
73241	18, immature	0.27 ^c
78501	36, submature	0.46
70011 ^a	54, submature	0.27 ^c , 0.49 ^d , 9.28
72501 ^b	81, mature	0.29 ^c , 9.84
78421	92, mature	0.25 ^c
69961	92, mature	11.82

^aCollected beneath lunar module (LM) as exhaust-exposed sample

^bCollected 6.5 km from LM as exhaust control

^cBoth hydrolyzed and unhydrolyzed extracts analyzed

^dSubsection of larger sample analyzed separately