

THE CARBON COMPOUNDS  
IN APOLLO 14 LUNAR SAMPLES

by

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Amino acids, a few other heteroatomic compounds and hydrocarbons were found in trace quantities. They were identified by ion exchange chromatography and vacuum pyrolysis-mass spectrometry, respectively. A far greater abundance of carbon was present in the carbonaceous gases  $\text{CO}_2$ ,  $\text{CO}$  and  $\text{CH}_4$ , which were also liberated by vacuum pyrolysis.

The amino acids were determined in the SESC sample and in fines 14421, 9 by refluxing for a period of 24 hours, followed by hydrolysis with 6 N HCl and the hydrolysates were analyzed by ultra high resolution, high sensitivity ion exchange chromatography. Glycine>serine>aspartic acid>glutamic acid were the more prominent constituents of the SESC sample. In the other lunar sample glycine>aspartic acid>serine were the more important amino acid constituents. Methylamine was also present in both samples. It should be noted, however, that individual amino acids in the lunar samples were present in less than 1 nanomole per gram concentrations. Extreme care was taken to exclude terrestrial contaminations. In addition an astronaut's glove used for simulation and training was extracted for its amino acid constituents for the purpose of identifying sources of potential contaminations.

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P. 355

The gas analyses have shown that the total carbon from CO, CO<sub>2</sub> and CH<sub>4</sub> varied between 76.0 and 161.3 ppm, as established by high resolution mass spectrometry. The carbon content of the SESC sample was similar to the contingency sample and it was almost identical to that of one of the other fines. Interestingly, the rock samples showed higher methane content among all samples that were analyzed, but the interior rock chip contained approximately as much carbon as the fines. The results of the gas analyses are shown in Tables I and II.

Vacuum pyrolysis-mass spectrometric analyses for hydrocarbons have shown the presence of ions of  $m/e = 78, 91, 104$  as well as lower molecular weight aliphatic hydrocarbon fragments. SO<sub>2</sub>, CS<sub>2</sub> and COS were prominent constituents of the fines and of the exterior rock. CN and HCN were also detected. The fines and the exterior rock chip showed approximately the same hydrocarbon and heteroatomic ion composition. The interior rock chip contained less carbon compounds but showed strong  $m/e = 78$  and  $104$  ions. A control experiment involving pyrolysis of a small sample of the surface of the astronaut's training glove yielded mass spectra which were entirely different from those of the lunar samples.

In order to attempt to find the locales where the carbonaceous substances are held in the lunar samples transmitted light and scanning electron microscopy were employed. The results showed that the Apollo 14 fines are morphologically similar to Apollo 11 and 12 fines. The concentration of the glass beads and dumbbells did not appear to be homogeneous among different samples and large inclusions were less common in the Apollo 14 fines than in those from the previous missions. Glass beads after vacuum pyrolysis at 1000°C showed no inclusions or blow holes, although some lens-shaped openings were observed occasionally. Scanning electron microscopy revealed a number of wrinkled, flaky sheets in the SESC sample. It was established by control experiments that these sheets were not artifacts from the electron microscopic preparation. These particles were very unstable under the heat of the electron beam when they were not coated with the Au-Pd alloy. Scanning electron microscopy of the glove material showed morphologically different particles than the sheets found in the lunar samples.

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P. 356

Table I

Apollo 14 - Results of Gas Analyses

Sample	ppm C from the Gases			Total ppm C
	CO	CO <sub>2</sub>	CH <sub>4</sub>	
14240 (SESC)	82.1	31.2	1.0	114.3
14003, 55 (contingency)	72.1	28.3	1.4	101.8
14421, 9	88.6	22.6	2.0	113.2
14163, 101	57.7	17.1	1.2	76.0
14298, 6	86.1	18.7	1.3	106.1
14047, 18 (rock)	94.2	58.1	9.0	161.3
14311, 58 (rock)	57.0	42.3	4.8	104.1

Table II

Apollo 14 - Results of Gas Analyses

Sample	% C from Gases		
	CO	CO <sub>2</sub>	CH <sub>4</sub>
14240 (SESC)	71.8	27.3	0.9
14003, 55 (contingency)	70.8	27.8	1.4
14421, 9	78.3	20.0	1.7
14163, 101	75.9	22.5	1.6
14298, 6	81.1	17.6	1.3
14047, 18 (rock)	58.4	36.0	5.6
14311, 58 (rock)	54.8	40.6	4.6