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(NASA-CR-155337) RADIOACTIVITIES IN RETURNED LUNAR MATERIALS Semiannual Progress Report, 1 Aug. 1976 - 31 Jul. 1977 (Smithsonian Astrophysical Observatory) 8 p HC A02/MF A01 CSCL 03B G3/91

N78-13985

Unclas 55163

RADIOACTIVITIES IN RETURNED LUNAR MATERIALS

Semiannual Progress Report No. 12 & 13

For the period 1 August 1976 through 31 July 1977

Grant NGR 09-015-145

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November 1977

Prepared for

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Manned Spacecraft Center
Houston, Texas 77058

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The Smithsonian Astrophysical Observatory
and the Harvard College Observatory
are members of the
Center for Astrophysics

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1. INTRODUCTION

This progress report is late. I apologize. Near the end of January 1977, we wrote similar material in abstract form[1] for the 8th Lunar Science Conference. Later, we wrote an article[2] for the Conference Proceedings, which was an expansion of the abstract. Near the end of July 1977, the material was brought up to date in a Lunar Proposal to NASA.[3] Although the semiannual progress reports were not provided on schedule, NASA was informed of our progress.

During 1977, we continued our carbon-14 study in size-fractions of lunar soil, 10084. The 10-30 μ and 74-124 μ size-fraction results[2] have been supplemented by 30-37 μ results that are given in this report. The gases from the less than 10 μ fraction have extracted and purified and its carbon-14 counting is in progress. The preliminary results on the < 10 μ fraction particularly at 600°C are dramatic. We have not started work on the 37-74 μ fraction.

During 1977, we also started a carbon-14 study in meteorites with emphasis on those recently discovered in the antarctic. We measured carbon-14 in Bruderheim, which fell on March 4, 1960, in Allan Hills #6, and in Allan Hills #8. The Allan Hills meteorites are nine meteorites[4] found on a 100 km^2 patch of blue ice located on the plateau side of the Allan Hills barrier. Dr. W.A. Cassidy kindly gave us samples of Allan Hills #5, #6, #7, and #8; these meteorites are ones in which Dr. L. Rancitelli measured aluminum-26 radioactivity (private communication, 1977). Rancitelli found Allan Hills #5, #6, and #7 to have essentially contemporary aluminum-26 activities;

their estimated fall times are the following: $< 100\ 000$, $< 300\ 000$, and $< 600\ 000$ yr, respectively. On the other hand, Rancitelli measured Allan Hills #8 to have a lower than contemporary aluminum-26 activity with an estimated fall time of $\sim 1.7 \times 10^6$ yr. Good estimates for fall times of the Antarctic meteorites are a topic of high interest to lunar science because eventually a precise value for the rate of meteorite falls during the past 5 million years should be derived from them.

2. TECHNICAL DEVELOPMENTS AND MEASUREMENTS

We constructed additional low-level proportional counters of 1.5- to 5.0-cm^3 volume. These counters have larger volumes than the previous ones and are more appropriate for carbon-14 counting when more than 1.0 cm^3 STP of CO_2 is extracted. The counting characteristics have been improved by the baking out of the counters at ~300°C under vacuum. The cathodes for the new counters are either of Kovar or of zone-refined iron. The metal cathodes were heated at temperatures slightly below their melting points under vacuum for several hours before counter assembly. This severe heat treatment removed potassium from the material and lowered the backgrounds of the counters. The procedures for the extraction of the carbon from the samples, the conversion of carbon compounds to CO_2, and the CO_2 purification are described in previous publications[2, 5, 6] and have not changed.

Tables 1 and 2 summarize the carbon-14 measurements on bulk lunar soils and on size fractions of soil 10084 that have been reported.[2] Table 3 gives new results, which will be presented at the 9th Lunar Science Conference. The 30-37 μ size fraction gives a temperature release pattern intermediate to the 10-30 and 74-125 μ fractions. The < 10 μ size-fraction is now counting. Although it is too early to give values for all temperatures, it is not too early to say that there is a much larger amount of carbon-14 obtained at 600°C from the <10 μ size-fraction than from the other size-fractions. This result strengthens the evidence[2, 5, 6] for solar-wind carbon-14 in lunar soil.

Table 3 also gives our carbon-14 results in meteorites. Our Bruderheim sample had the normal amount of carbon-14 expected in a recent fallen chondrite and the result is in accord with previous Bruderheim measures.[7, 8] This expected amount of carbon-14 was found in the gas released at melting temperature. On the other hand, Allan Hills #6 and #8 had no observable carbon-14 released at melting. The carbon-14 releases at lower temperatures from the meteorites have not yet been investigated. A lower and upper limit for the time of fall for Allan #6 is 20 000 yrs and 300 000 yrs, respectively. The lack of carbon-14 in Allan Hills #8 is consistent with its fall date (~1.7 million years) obtained from aluminum-26 by Rancitelli (private communication, 1977).

Table 1. Carbon-14 temperature-release patterns (400–1000°C).

Sample	73221.3,.5,.10	73241.23	73261.15,.3	10084.1519	10084.937
Weight (g)	1.85	2.01	2.17	1.01	1.00
Depth (cm)	0–(~1)	0–(~5)	(~10)–(~20)	0–(~5)	0–(~5)
Grain size (μ)	bulk	bulk	bulk	10–30	74–125
Temp. (°C)	^{14}C (dpm kg^{-1})	^{14}C (dpm kg^{-1})	^{14}C (dpm kg^{-1})	^{14}C (dpm kg^{-1})	^{14}C (dpm kg^{-1})
400	-1.0 ± 0.9	-0.2 ± 1.0	-0.5 ± 0.8	2.3 ± 1.4	2.2 ± 1.2
600	2.0 ± 0.9	7.6 ± 1.0	0.1 ± 0.8	0 ± 1.1	2.4 ± 1.2
800	10.4 ± 1.5	1.7 ± 0.9	-0.5 ± 0.8	8.0 ± 1.2	1.5 ± 1.2
1000	24.0 ± 1.5	6.3 ± 1.0	0.9 ± 0.7	18.0 ± 1.9	-0.2 ± 1.2
Sum (600–1000)	36.4 ± 2.5	15.6 ± 1.7	0.5 ± 1.5	26.0 ± 2.5	3.7 ± 2.1

Table 2. Carbon-14 (dpm kg^{-1}) released after 1000 C extraction.

Sample	Depth (cm)	Melt	Remelt	Sum	Galactic*	Flare
73221.3,.5,.10	0–(~1)	16.3 ± 3.5	4.8 ± 1.2	≥21.1 ± 4.0	18	10
73241.23	0–(~5)	4.3 ± 0.7	7.0 ± 1.5	≥11.3 ± 2.8	19	6
73261.15	(~10)–(~20)	18.0 ± 2.5	3.2 ± 2.3	≥21.2 ± 3.5	21	0
10084.1519	0–(~5)	21.3 ± 2.1	3.6 ± 2.0	≥24.[illegible] ± 3.0	19	6
10084.937	0–(~5)	30.1 ± 5.0	-3.0 ± 2.5	≥30.1 ± 5.0	19	6

* ^{14}C (dpm kg^{-1}) production by galactic and solar (R_0 = 100 Mv and 100 protons cm^{-2} sec^{-1} above 10 Mev) cosmic rays as calculated by Reedy and Arnold (1972).

Table 3. Carbon-14 and carbon temperature-release patterns.

Sample Weight (g) Grain size (μ)	10084.939 1.28 30–37		10084.941 1.26 < 10		Bruderheim 10 –		Allan Hills #6 9.05 –		Allan Hills #8 10.08 –	
Temp. (°C)	^{14}C (dpm kg^{-1})	CO_2 (cm^3 STP)	^{14}C (dpm kg^{-1})	CO_2 (cm^3 STP)	^{14}C (dpm kg^{-1})	CO_2 (cm^3 STP)	^{14}C (dpm kg^{-1})	CO_2 (cm^3 STP)	^{14}C (dpm kg^{-1})	CO_2 (cm^3 STP)
300	0 ± 0.8	–	–	–	–	–	–	7.25	–	9.60
400	0 ± 0.8	0.33	counting	0.49	–	–	–	–	–	–
600	0.5 ± 0.8	0.28	13.5 ± 2.0	0.56	–	2.04	–	6.24	–	4.03
800	4.2 ± 13	0.36	counting	0.43	–	–	–	–	–	–
1000	3.6 ± 1.0	0.51	counting	0.14	–	–	–	–	–	–
Sum 600–1000°	7.8	1.48	>30	1.62	–	2.04	–	13.49		13.63
Melt	4.0 ± 1.5	1.75	counting	1.66	60 ± 5	1.08	<3	1.02	<5	4.03
Remelt	11.0 ± 1.0	0.84	counting	1.26	<2	0.13	–	–	–	–

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