N O T I C E

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RADIOACTIVITIES IN RETURNED LUNAR MATERIALS AND IN METEORITES

Semiannual Progress Report No. 22
For the period 1 August to 31 January, 1982

Grant NGR 09-015-145

Principal Investigator
Dr. Edward L. Fireman

January 1982

Prepared for
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
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We recently (1) began making ^{14}C measurements in meteorites with a Van der Graaf Accelerator. Accelerator ^{14}C dating improves the precision by a factor of ten, allows the use of smaller sample sizes, and gives speedier results than ^{14}C dating with counters. We are continuing to make ^{39}Ar and ^{14}C measurements in meteorites and lunar samples with counters and supplementing them with accelerator measurements whenever an accelerator is available.

Attachment

(1) E.L. Fireman, H.R. Andrews, G.C. Ball, R.M. Brown, and J.C.D. Milton. ^{14}C Terrestrial Ages of Antarctic Meteorites with Counters and with a Van der Graaf Accelerator (abstract). Submitted to Lunar and Planetary Science XIII (1982).

Attachment 1

^{14}C TERRESTRIAL AGES OF ANTARCTIC METEORITES WITH COUNTERS AND WITH A VAN DER GRAAF ACCELERATOR.

E.L. Fireman, Smithsonian Astrophysical Obs., 60 Garden St., Cambridge, MA 02138, H.R. Andrews, G.C. Ball, R. M. Brown, and J.C.D. Milton, Atomic Energy of Canada Ltd., Chalk River Nuclear Labs., Chalk River, Ontario, Canada

Terrestrial ages of meteorites are based on the amount of a cosmic-ray-produced radioactivity in a sample and the amounts in observed falls of similar size and cosmic-ray exposure histories. Measurements(1-7) of ^{53}Mn (3.7×10^6 yr half-life), ^{26}Al (7.3×10^5 yr half-life), ^{36}Cl (3.1×10^5 yr half-life), and ^{14}C (5.73×10^3 yr half-life) indicate that the terrestrial ages of Antarctic meteorites are between $\sim 10^4$ yr and $\sim 10^6$ yr. Practically all the ages are limit ages being greater than $\sim 2 \times 10^4$ yr for ^{14}C and less than $\sim 10^5$ yr for the long-lived radioactivities. Of the ~100 Antarctic meteorites in which ^{26}Al and ^{53}Mn have been measured, only two have low activities caused by old terrestrial ages, $(600 \pm 100) \times 10^3$ yr. ^{14}C measurements(5-7) have been done on only twelve Antarctic meteorites with low-level proportional gas mini-counters. Long counting times (~2 months per sample) are necessary to obtain results of limited accuracy. In addition to these twelve, counting results on ALHA 78084 will be presented.

If the counting times necessary with mini-counters and the attendant counting errors can be reduced, ^{14}C dating would probably give actual terrestrial ages for the majority of the Antarctic meteorites. With this aim, we began to date meteorites using the Chalk River accelerator. The Chalk River Van der Graaf accelerator and procedure for the conversion of CO_2 gas to elemental carbon accelerator sources have been described.(8,9)

The gas was extracted from meteorites, converted to CO_2, and purified with the same system that we have been using for meteorites and lunar samples.(5-7) All the meteorites, with the exception of Yamato 7304, had been counted with low-level proportional gas minicounters. Since argon was added to the CO_2 for good counting characteristics, the CO_2 was removed from the Ar by freezing it down on a cold finger. The CO_2 was then shipped to Chalk River.

Table 1. Accelerator ^{14}C measurements.

Sample	Wgt. (g)	Temp. fract.	CO_2 cm^3 (STP)	$\left(\frac{^{14}C}{^{12}C}\right) / \left(\frac{^{14}C}{^{12}C}\right)_{Ox. Acid}$*	^{14}C dpm/kg	Terr. Age (10^3 yr)	Weath. Age (10^3 yr)
Farmington	18.0	total melts	34.0	3.38 ± 0.06	49.0 ± 1.0	–	–
Bruderheim	30.0	total melts	6.7	19.0 ± 1.0	49.1 ± 2.0	–	–
Estacado	13.1	total melts	35.0	0.63 ± 0.02	12.0 ± 0.3	11.7 ± 1.0	–
Yamato 7304	5.8	total melts	6.6	2.28 ± 0.05	19.7 ± 0.3	7.5 ± 0.4	–
ALHA 77003	7.2	1000°C	20.6	0.046 ± 0.003	1.01 ± 0.07	–	25.8
		melts	3.4	0.170 ± 0.017	0.61 ± 0.06	35.0 ± 1.0	–
ALHA 77004	10.0	800°C	8.5	0.286 ± 0.015	1.87 ± 0.10	–	10.3
		1000°C	5.4	0.320 ± 0.025	1.32 ± 0.10	–	9.5
		melts	8.9	0.095 ± 0.005	0.65 ± 0.03	35.8 ± 1.0	–
ALHA 77214	5.7	1000°C	107.0	0.043 ± 0.003	6.22 ± 0.42	–	26.0
		melts	12.3	0.022 ± 0.002	0.36 ± 0.03	40.7 ± 1.0	–

*N.B.S. oxalic acid standard has 7.8×10^{-3} dpm/(cm^3 of CO_2)

Table 1 gives preliminary accelerator results. Farmington is an L5 chondrite observed to fall (June 25, 1890). The same CO_2 had been counted with 47 ± 10 dpm/kg.[10] The accelerator value is 49.0 ± 1.0 dpm/kg. Bruderheim is an L6 chondrite observed to fall (March 4, 1960); the 20.0 g sample was from a ~3 kg fragment in which 57 ± 3 dpm/kg was counted.[5] The accelerator value is 49.1 ± 2.0 dpm/kg. Estacado is a highly weathered H6 chondrite find; the ^{14}C activity of another sample in another laboratory was 23 ± 2 dpm/kg.[11] The accelerator value for our sample is 12.0 ± 0.3 dpm/kg. Using our Bruderheim sample as a standard, we obtain $(11.7 \pm 1.0) \times 10^3$ yr for the age of Estacado. ^{14}C had not been measured in any meteorite from the Yamato site. For Yamato 7304, we obtain 19.7 ± 0.3 dpm/kg, the highest ^{14}C activity observed in an Antarctic meteorite. ALHA 77003 is an Antarctic meteorite with very high thermoluminesence.[12,13] Activities of 2.8 ± 0.9 dpm/kg in the 1000°C extraction and 1.8 ± 0.5 dpm/kg in the melts, were given.[7] (The error is the 1σ statistical standard deviation in ~2 month count.) The accelerator results are a factor of two lower. In ALHA 77004, a ^{14}C terrestrial age limit of greater than 21×10^3 yr and limits of about 10^4 yr for the weathering ages (500°C and 1000°C extractions) were obtained.[7] Accelerator dating gives 35.8×10^3 yr for its terrestrial age and 10.3×10^3 and 9.5×10^3 yr for its weathering ages. In ALHA 77214, a ^{14}C terrestrial age limit of greater than 25×10^3 yr and a limit of about 15×10^3 yr for the weathering age were obtained.[7] Accelerator dating gives 40.7×10^3 yr for its terrestrial age and 26.0×10^3 yr for its weathering age.

Since the weathering process is rapid when meteorites are exposed to a combination of water and wind and not when meteorites are solidly encased in ice, the ALHA 77003 and 77214 weathering ages indicate that these meteorites were at Allan Hills when a climatic melt occurred about 26×10^3 yr ago and that ALHA 77004 did not arrive at Allan Hills until later.

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