CARBON-14 DATING OF ANTARCTIC METEORITES AND ANTARCTIC ICE,
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Carbon-14 is observed in the achondrite ALHA 77256, the activity is 17.7 ± 2.0 dpm/kg. The ALHA 77256 sample was fresh material chipped from the interior of a section from which the weathered zone had been removed. Its carbon content is similar to that of fresh Bruderheim (1960 fall). The specific activity of the ALHA 77256 carbon is six times that of contemporary carbon, the ^{14}C is therefore cosmogenic. If ALHA 77256 at fall had the same ^{14}C activity as Bruderheim, 60 dpm/kg, then its terrestrial age is $(10.1 \pm 0.9) \times 10^3$ yr.

Carbon-14 is not observed in the L-6 chondrite, ALHA 77214, its activity is less than 3.0 dpm/kg. If ALHA 77214 had 60 dpm/kg at its date of fall, then its terrestrial age is greater than 25×10^3 yr. On the other hand, the ^{26}Al activity in ALHA 77214 is indistinguishable from that in recent L-6 falls, so that its terrestrial age is less than 300×10^3 yr (1). ALHA 77214 is highly weathered and its carbon content is more than 100 times larger than in Bruderheim. We attribute the large amount of carbon to ancient terrestrial carbon introduced during the weathering process. The specific activity of the carbon is less than 1/50 that of contemporary carbon. Its weathering occurred more than 30×10^3 yr ago or ancient organic material was incorporated into the sample. The amounts of carbon and ^{14}C released as a function of temperature from ALHA 77256 and 77214 together with those of five Antarctic meteorites previously measured (2,3) are given in Table 1. ^{39}Ar activity was not detected in 77256, 77214, or 77272. The $(10.1 \pm 0.9) \times 10^3$ yr ^{14}C terrestrial age of ALHA 77256 is consistent with its $>1.0 \times 10^3$ yr ^{39}Ar age. The rare-gas exposure age and shielding correction for ALHA 77256 have not been determined; however, an exposure-age so short or a shielding correction so large as to affect seriously its 14C terrestrial age is unlikely.

The terrestrial ages of ALHA meteorites indicate that the meteorite collection process at Allan Hills has been going on for approximately 10^6 yr (1-5).

Antarctic ice is of interest partly because it contains air bubbles and dissolved gas that stored historical information on the earth's atmosphere and climate. Studies (6) of the gas in ice samples from cores taken at Byrd station, Antarctica, and Dye station, Greenland, are beginning to reveal this type of information for the past $\sim 10^4$ yr. The gas in Allan Hills ice may extend the record back to 10^6 yr.

John O. Annexstad, a member of Cassidy's field party, axed surface ice samples from three different locations at the ~ 100 km^2 Allan Hills area (7) for our study (8). C. C. Langway supplied us with two sections (5-in. diameter and 5-ft length) from the Byrd core; one from 282 m (887-892 ft) depth and the other from 360 m (1187-1192 ft) depth. The air and CO_2 contents at a number of depths in the Byrd core have been measured (6); the air contents ranged from 85 to 110 cm^3 STP/kg and the CO_2 contents from 0.04 to 0.06 cm^3 STP/kg. The CO_2 abundance in the air was also measured as a function of release time (6); the CO_2 abundance in the first fraction released (thought to be the bubble fraction) ranged between 200 and 400 ppm. An age-depth relation for the ice at Byrd station has been calculated (9) on the basis of a rheological model (accumulation rate—lateral flow rate). The ^{14}C contents of the CO_2 extracted in situ from four depths at Byrd station: 100 m, 175 m, 270 m, and 380 m have been measured (9). The ^{14}C ages obtained for the 27 m and 380 m ice are 1300 ± 700 yr and 3000 ± 500 yr, respectively, and agree with the rheological model (9).

Our gas extraction data are summarized in Table 2. The 1187-1192 ft Byrd core was divided into 2 parts; the gas from each was extracted by He purging after acidifying the melt with sulphuric acid to pH = 1. The purging was first done with the water at 24°C and then at 55°C. The gas with carrier He passed through a molecular sieve (5A)

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column at -176°C, which served as the collector, then through other traps and sieves, which served as checks on the collection. The air was recovered from the sieve at room temperature and stored for later analysis. The CO_2 was recovered from the sieve at 300°C, purified, and counted in Davis-type low-level proportional counters. The air in one part of the Byrd core section was 75 cm^3 STP/kg and in the other part 71 cm^3 STP/kg; the CO_2 was 0.50 cm^3 STP/kg in one part and 0.28 cm^3 STP in the other. The CO_2 from the two parts was combined for ^{14}C counting and gave $(6.1 \pm 0.6) \times 10^{-3}$ dpm/(cm^3 CO_2), compared to the value of 7.8×10^{-3} dpm/cm^3 for contemporary ^{14}C. The specific activity gives a ^{14}C age of $(2.1 \pm 0.8) \times 10^3$ yr. A more accurate comparison with a NBS oxalic acid standard is under way. The Allan Hills ice from the top of the monocline was divided into three parts of 9.95 kg, 11.96 kg, and 9.24 kg and the gas from each part extracted in the same manner. The air ranged from 27 to 37 cm^3/kg and the CO_2 from 0.056 to 0.095 cm^3/kg (cf. Table 2). The CO_2 from the three parts was combined and counted; its ^{14}C activity is $(27 \pm 3) \times 10^3$ dpm/cm^3 approximately three times the 7.8×10^{-3} dpm/cm^3 value for contemporary ^{14}C. We attribute its excess ^{14}C activity to contemporary bomb ^{14}C. Because of the high ^{14}C activity in the Allan Hills ice sample and because we want to separate the gas on the surface of the ice and also in the bubbles from that firmly bound, we modified our extraction procedure for the Allan Hills ice collected at stake 18. The gas, which escaped during melting, was first collected and analyzed; then the melt water was purged with He, and then the melt water was acidified to pH = 1, heated, and purged again. Practically all the air but only half the CO_2 was in the first fraction (cf. Table 2). The CO_2 from the first fraction was counted separately; it contained the high ^{14}C activity, that we attribute to bomb ^{14}C. The CO_2 from the second and third fractions, which were combined for ^{14}C counting, contained no detectable ^{14}C; its ^{14}C age is greater than 8×10^3 yr. The gas extraction from the 887-892 ft Byrd core ice was carried out with the same procedure used for the Allan Hills ice from stake 18. Its ^{14}C counting is not complete.

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Table 1. Amounts of CO_2 and ^{14}C from Antarctic meteorites and Bruderheim.

Meteorite type (wgt.)	Extraction temperature (°C)	CO_2 carrier (cm^3 STP)	CO_2 recovered (cm^3 STP)	^{14}C (dpm/kg)	$^{14}C/CO_2$ (10^{-3} dpm/cm^3 STP)	Total ^{14}C (dpm/kg)
ALHA 77256	500	none	1.08	<0.6		
Diogenite	1000	none	0.97	1.7 ± 0.5	42 ± 5	17.7 ± 2.0
(4.0 g)	Melt	none	0.71	16.0 ± 1.5		
	Remelt	0.53	0.60	<0.5		
ALHA 77214	500	none	5.95	<0.7		
L6	1000	none	107.0	<2.0	<0.12	<3.0
(6.70 g)	Melt	none	12.1	<1.0		
	Remelt	0.08	0.23	<0.4		
Bruderheim	500	none	1.80	<1.0	<4.0	
L6	1000	none	2.08	23 ± 2	78 ± 7	61 ± 4
(7.0 g)	Melt	none	1.29	38 ± 2	206 ± 11	
	Remelt	0.08	0.11	<0.2	<13	
ALHA 76005*	400	none	0.46	<0.4	<8.6	
Eurite	600	none	2.20	<0.6	<2.4	
(9.99 g)	800	none	0.30	-0.3	<10	<1.0
	Melt	none	0.46	<0.4	<8.7	
	Remelt	0.50	0.72	<0.5	<0.7	
ALHA 76006*	350	none	7.25	–	–	
H6	500	none	6.23	<1.0	<1.5	<1.2
(9.05 g)	Melt	none	1.02	<0.5	<4.5	
	Remelt	2.0	3.7	<0.7	<1.7	
ALHA 76007*	500	none	3.0	–	–	
L6	800	none	1.10	<0.4	<4.0	
(11.0 g)	1000	none	0.29	<0.2	<7.6	<0.8
	Melt	none	0.55	<0.2	<3.7	
	Remelt	0.90	1.31	<0.4	<3.4	
ALHA 76008*	300	none	7.3	–	–	
H6	500	none	4.03	<0.7	<1.7	<1.1
(10.08 g)	Melt	none	4.04	<0.8	<2.0	
	Remelt	0.10	0.32	<0.3	<9.4	
ALHA 77272*	500	none	2.72	<0.4	<1.4	
L6	1000	none	1.50	<0.3	<1.9	
(9.22 g)	Melt	none	0.33	<0.2	<5.6	
	Remelt	0.40	0.98	<0.2	<1.9	

*Fireman (1979).

Table 2. Air, CO_2, and ^{14}C in gas from Antarctic ice.

Ice	Extraction (water temp, pH)	Air (cm^3 STP)	CO_2 (cm^3 STP)	Total air (cm^3/kg)	Total CO_2 (cm^3/kg)	$^{14}C/CO_2$ (10^{-3} dpm/cm^3)	Age (10^3 yr)
6.2 kg Byrd	(24°C, 1)	460	0.30	75	0.050	6.1 ± 0.6	(2.1 ± 0.8)
(1187 ft depth)	(55°C, 1)	3.5	0.01				
8.0 kg Byrd	(24°C, 1)	554	0.183	71	0.028		
(1190 ft depth)	(55°C, 1)	10	0.046				
9.95 kg ALHA #2	(24°C, 1)	254	0.78	27	0.095		
(top of monocline)	(55°C, 1)	10	0.17				
11.96 kg ALHA #2	(24°C, 1)	435	0.64	37	0.056	27 ± 3	(Contemp. bomb)
(top of monocline)	(55°C, 1)	10	0.03				
9.24 kg ALHA #2	(24°C, 1)	765	0.41	30	0.063		
(top of monocline)	(55°C, 1)	9	0.17				
8.72 kg ALHA #3	(24°C, 7)*	188	0.177	24	0.041	(30 ± 6)*	(Contemp. bomb)*
(stake 18)	(24°C, 7)†	16	0.155				
	(55°C, 1)**	5	0.029				
7.9 kg ALHA #3	(24°C, 7)*	121	0.134	17	0.040	(<4.0)†	(>8.0)
(stake 18)	(24°C, 7)†	9	0.123				
	(55°C, 1)**	5	0.0560				
7.6 kg Byrd	(24°C, 7)*	470	0.216	67	0.047	(Counting not complete)*	
(887 ft depth)	(24°C, 7)†	37	0.140				
	(55°C, 1)**	1	0.001				
8.8 kg Byrd	(24°C, 7)*	475	0.170	58	0.038	(Counting not complete)†	
(890 ft depth)	(24°C, 7)†	29	0.087				
	(55°C, 1)**	1	0.074				

*First gas fraction released without He purge.

†Second gas fraction released with He purge.

**Third gas fraction released with He purge after acidifying.