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Terrestrial age dating of antarctic meteorites

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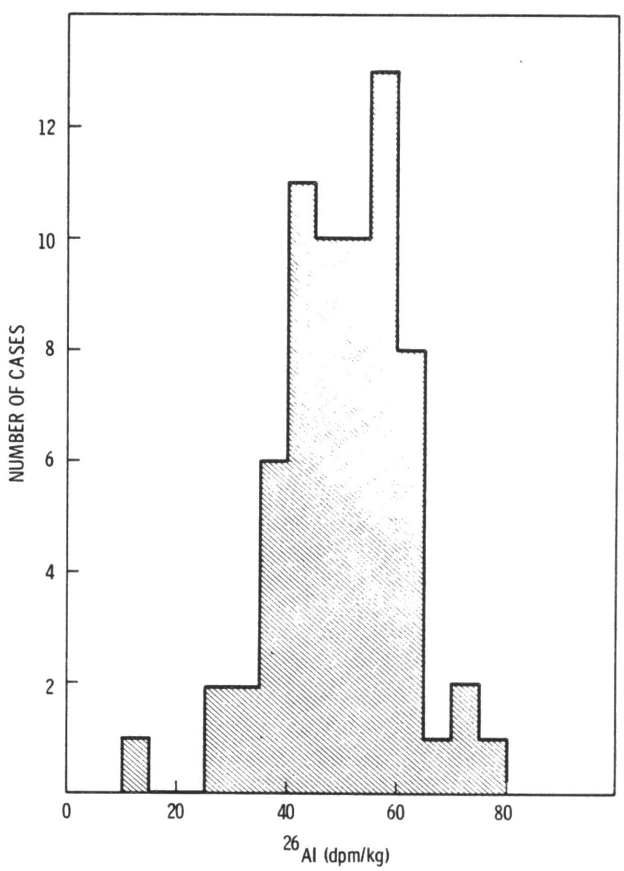
During the last three antarctic field seasons, U.S. and Japanese teams have collected several thousand meteorites. The terrestrial age of these objects is of interest because such knowledge enables the setting of lower bounds on the lower age of the ice sheet, provides information about ice movement, and aids understanding of the accumulation mechanism of the meteorites. Terrestrial ages can be established by measuring the decay of radioactive species produced by bombardment of cosmic rays while the objects are in space. After entering the Earth's atmosphere the meteorites essentially are completely shielded from cosmic rays. The radioactive products that exist at saturation values in space then decay exponentially toward zero activity.

Aluminum-26 ($T_1/2$ = 730,000 years) is ideally suited for terrestrial age dating. It decays by positron emission, with several correlated gamma rays produced by each decay. These gamma rays can be detected very sensitively by large-volume sodium iodide (Tl) detectors in heavily shielded, low-background assemblies. Measurements of whole meteorites or meteorite fragments can be carried out easily, and they are not destructive to the specimens. Our laboratory has, over the last decade, applied this technique extensively to the measurement of aluminum-26 (^{26}Al) in lunar samples and meteorites, thus providing a firm basis for understanding the expected saturation levels of ^{26}Al in meteorites with short terrestrial ages. Due to the relative ease with which we are able to measure ^{26}Al in antarctic meteorites, we have been able to begin a search of the entire collection for samples with long terrestrial ages, as indicated by relatively low ^{26}Al levels. We have reported data on 67 samples and are continuing these measurements at a rate of about one per date when samples are available. A histogram of those data is shown in the figure. A number of samples have shown rather low ^{26}Al (<35 dpm/kg),

^{26}Al CONTENT OF ANTARCTIC METEORITES NORMALIZED TO L COMPOSITION



Histogram of ^{26}Al contents in ordinary chondritic meteorites collected in Antarctica. All samples have been normalized to the same target chemistry. A typical newly fallen meteorite would have an ^{26}Al content of 55–65 disintegrations per minute/kilogram of sample.

suggesting that terrestrial ages of more than 500,000 years are fairly common. Unfortunately, in any single object a low value of ^{26}Al also can result simply from the object receiving a relatively short exposure to cosmic rays. Statistically that phenomenon is rather rare, but it cannot be ruled out for individual cases. To distinguish between these two effects, a measurement must be made on at least one other isotope having a different half-life. The two best candidates are chlorine-36 ($T_1/2$ = 300,000 years) and manganese-53 ($T_1/2$ = 3,700,000 years). Chlorine-36 (^{36}Cl) can be measured very sensitively by the newly developed method of accelerator spectrometry and manganese-53 (^{53}Mn) is detectable by radio-chemical neutron activation analysis. ^{36}Cl and ^{53}Mn analyses carried out by the La Jolla group (Nishiizumi et al. 1980) have confirmed long terrestrial ages for ALHA77007* and ALHA77272 (600,000 to 700,000 years) as well as ALHA77278 (400,000 years). At least one other case of low ^{26}Al, ALHA76008, clearly is due to short exposure in space, however; thus, caution must be used in computing terrestrial ages from ^{26}Al data alone.

By the end of 1980 we expect to have data on 150 to 200 selected samples. With that large a data base we should have a fairly clear picture of the terrestrial age distribution of antarctic meteorites.

* Meteorites are identified by official numbers assigned by the Antarctic Meteorite Working Group.

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Magnesium carbonate and magnesium sulfate deposits on antarctic meteorites

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More than 300 meteorite specimens were collected at the Allan Hills (approximately 76°S 159°E) during the 1977–78 field season. Seven of them have white evaporite deposits on their surfaces or in cracks. X-ray diffraction patterns and scanning electron microscope (SEM) energy dispersive analyses show that the white deposits consist chiefly of hydrated magnesium carbonates and magnesium sulfates (see table). The deposits are not restricted to any one variety of meteorite: They occur on 7 different classes of stony meteorite (5 ordinary chondrites, chemical groups H3, H4, H5, L3, and L6; 1 carbonaceous chondrite; C3; and 1 achondrite, a ureilite). None of these specimens is of the carbonaceous class (C1) that normally contains traces of carbonates or sulfates.

Only two of the specimens show any substantial degree of iron-oxide staining, a universal indicator of the degree of terrestrial weathering in meteorites. Magnesium salts are rarely observed on meteorites. Of the many specimens collected by Japanese field parties near the Yamato Mountains (approximately 71°S 35°E) before 1975, only one was partially covered with a carbonate, nesquehonite (Yabuki, Okada, and Shima 1976). The distribution of evaporites on the samples collected during 1977–78 varies from specimen to specimen. Small, isolated mounds of white material are arranged in a band, which may once have marked the snow or water line, around the ureilite (ALHA77257). On sample ALHA77003 the salts are confined mainly to a large crack beneath the fusion crust. The carbonaceous chondrite (ALHA77307) has surface deposits of epsomite concentrated in and near polygonal cracks in the crust (see figure).

The sources of the elements and processes leading to formation of the evaporites are problematical. Some of the

Evaporite deposits on antarctic stony meteorites

Meteorite	Class	Weathering type[a]	Evaporite	
ALHA77257	Achondrite, Ureilite	A	Hydromagnesite	$Mg_4(OH)_2(CO_3)_3 \cdot 3H_2O$
ALHA77307	Chondrite, C3	A	Epsomite	$MgSO_4 \cdot 7H_2O$
ALHA77003	Chondrite, H3	A	Leonhardite	$MgSO_4 \cdot 4H_2O$
ALHA77294	Chondrite, H5	A	Amorphous	Mg-carbonate
ALHA77231	Chondrite, L6	A/B	Nesquehonite	$MgCO_3 \cdot 3H_2O$
ALHA77262	Chondrite, H4	B	Gypsum; Nesquehonite	$CaSO_4 \cdot 2H_2O$
ALHA77140	Chondrite, L3	C	Not determined	

[a] Weathering type is based on degree of iron-oxide staining: A, essentially unweathered; B, intermediate; C, severely weathered.