Reports

Iron Meteorites with Low Cosmic Ray Exposure Ages

Abstract. *Analysis of argon-38 and argon-39 produced by cosmic rays in four iron meteorites gives normal amounts of the radioactive product argon-39 and abnormally low amounts of stable argon-38. This indicates that these meteorites were exposed to cosmic rays for unusually short periods of time. These exposure times are one or two orders of magnitude shorter than those for the average iron meteorite, and they overlap the periods found for chondrites. It is suggested that perhaps 20 percent of the iron meteorites have similarly short exposure periods.*

As part of a program of measuring Ar^{39} and Ar^{38} in iron meteorites with the purpose of determining the cosmic ray exposure age, I have found four samples with unusually low exposure ages. Table 1 summarizes the pertinent data. Both Ar^{38} and Ar^{39} are produced by interactions of cosmic rays with the meteorite while it is in space. The exposure age, T, can be calculated from the formula

$$T = 512 \quad (G_{39}/G_{38})(Q_{38}/Q_{39})$$

where Q_{38} is the concentration of Ar^{38} in units of 10^{-8} cm^3/g, Q_{39} is the concentration of Ar^{39} in units of disintegration per minute per kilogram, and G_{39}/G_{38} is the ratio of the production rates for Ar^{39} and Ar^{38}. This parameter has been experimentally determined to have the value of 0.51 (*1*) and also to be insensitive to the small range in chemical composition found for the iron meteorites.

Table 1. The Ar^{39}/Ar^{38} ages of some iron meteorites.

Date of fall	Ar^{39} (dpm/kg)*	Ar^{36}/Ar^{38}	Cosmogenic Ar^{38} (10^{-8} cm^3/g)	Exposure age (10^6 yr)
	Pitts (Ni, 13.0%)			
Apr. 1921	27.5 ± 1.1	3.4	0.42	4.0
	Braunau (Ni, 5.32%)			
July 1847	22.3 ± 1.3	0.86	0.64	7.5
	Bahjoi (Ni, 7.35%)			
July 1934	25.0 ± 3.3	0.90	1.5	16
	Boguslavka (Ni, 5.18%)			
Oct. 1916	19.9 ± 2.0	0.68	3.8	50

* At time of fall.

An exposure age for the meteorite Braunau of 4.5 million years was previously reported by Vilcsek and Wanke (*2*). These authors used Ne^{21} as a measure of the Ar^{38} content and assumed a constant Ne^{21}/Ar^{38} ratio for iron meteorites. The discrepancy between the age they obtained and the age reported in Table 1 is due to the fact that Braunau has an anomalously low Ne^{21}/Ar^{38} ratio.

The calculation of cosmogenic Ar^{38} shown in Table 1 was made on the assumption that the measured Ar^{36} and Ar^{38} were derived from two sources: a cosmogenic source with an Ar^{36}/Ar^{38} ratio of 0.65, and an atmospheric (or primordial) component with an Ar^{36}/Ar^{38} ratio of 5.3. The correction was significant only for the Pitts meteorite. The measured Ar^{40}/Ar^{36} ratio for this meteorite was 260, which indicates that most of the noncosmogenic argon was atmospheric in origin.

The interest in the four ages reported in Table 1 is that there is now definite evidence of an overlap in exposure age between the chondrites and the iron meteorites. Previously, with the single exception of Braunau, ages for iron meteorites ranged from 120 to 2200 million years (*3*), while ages for most chondrites range from 2 to 40 million years with a maximum at 70 million years (*4*).

It is of interest to note that I have results on 18 iron meteorites, of which 4 fall within the range of chondrites. If this small sample is representative of iron meteorites in general, about 20 percent of the iron meteorites would overlap the chondrites. Published data on the abundances of cosmogenic helium, neon, and argon in iron meteorites disclose numerous cases where these abundances are low (*5*).

Low concentrations of cosmogenic rare gases in iron meteorites were thought to be due to shielding effects attributable to the size of the meteorite, since there are many cases in which the recovered mass is significantly larger than the exponential mean free path of an average cosmic ray proton. Degassing of the meteorite sometime during or after its sojourn in space is ruled out because these meteorites contain the Widmanstatten pattern which is characteristic of iron meteorites and which would be destroyed at a temperature needed to expel rare gases. It is quite probable that, in many cases, low concentrations of rare gases simply reflect short exposure times.

It may be seen from the nickel contents reported in Table 1 that the four meteorites show a range in structure. The Braunau and Boguslavka meteorites are hexahedrites, and the Bahjoi meteorite is a coarse octahedrite. The Pitts meteorite has been reported (*6*) to be an octahedrite with 6.7 percent nickel. The sample I worked on contained 13 percent nickel, which is in the range of a fine octahedrite or ataxite.

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References and Notes

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7. I thank the various people who provided the meteorites used in this study: Prof. H. von Englehardt, University of Tübingen (Braunau); E. P. Henderson, U.S. National Museum (Pitts); E. L. Krinov, Academy of Sciences, Moscow (Boguslavka); and C. B. Moore, Arizona State University (Bahjoi). Nickel analyses on the meteorites were done by R. W. Stoenner and the analytical group at Brookhaven National Laboratory. Research performed under the auspices of AEC.

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