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METEORITES FROM RECENT AMOR-TYPE ORBITS.

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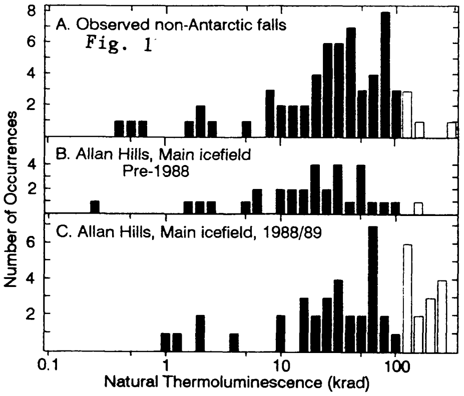
Observations of observed falls (including three photographed falls) have shown that most meteorites derive from meteoroids in orbits similar to those of Earth-crossing (Apollo) asteroids with perihelia close to 1 AU. We report here the discovery of a recent meteorite shower in Antarctica, the members of which have very high natural thermoluminescence levels. It is apparent from these data that (1) the shower has been on Earth only a short time (terrestrial age ~ 1000 years) and (2) the meteorite probably came to Earth through rapid (<10^5 years) evolution from an orbit with perihelion >1.1 AU, similar to Amor asteroids. Only a very small number of meteorites, including a few modern falls, appear to have had similar orbital histories.

On January 14-15, 1989, a party from the European Meteorite Recovery expedition (EUROMET) discovered 59 meteorites in an area of the Allan Hills blue ice field (159°20'W, 76°45'S) which only days earlier had been searched with negative results [1,2]. The discovery of such a large number of samples was largely fortuitous; many are very small (<20 g) and would have been blown away by the strong winds of the region [2,3]. An additional, related sample was found by an American ANSMET expedition three years earlier. Natural thermoluminescence (TL) measurements were made on a number of these meteorites as part of their intial characterization. Of the 50 EUROMET samples we measured, 15 had very high levels of natural TL (>100 krad) (Table 1). Such high natural TL levels are not only unusual by Antarctic meteorite standards but are higher than all but a very few non-Antarctic falls, the large majority of which have natural TL levels between 20-80 krad (Fig. 1). Although our conservative criteria for pairing [4], identify seven groups of samples (Table 1), the circumstances of recovery and their common classification suggest that most of them are from a single meteorite, the exception being ALH88020. The total mass of this fall, designated ALH85110, is nearly 0.5 kilogram and might be considerably more, since we have not examined all samples found in the vicinity.

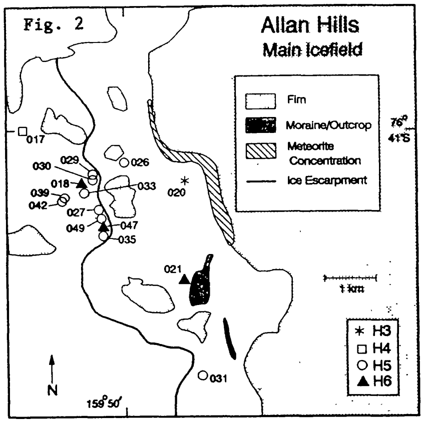
All but four of the samples were found along a line near the ice escarpment along the west edge of the Allan Hills blue ice field (Fig. 2), most of the samples covering a region about 1.5 km wide and 2 km long. The SE-NW trend of these samples may reflect concentration by wind in crevasses during previous periods of surface exposure [2], or the strewn field of a single meteorite fall. If the latter is the case, larger additional masses may in future be found at one end of this trend line [5].

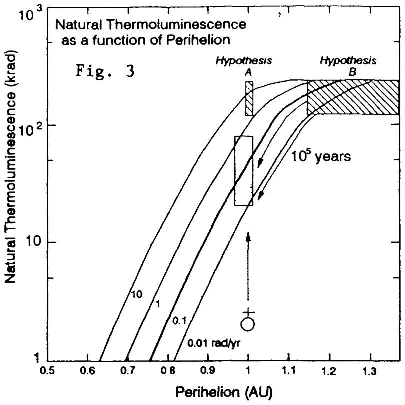
The very high natural TL levels of these meteorites indicates that they have not been on Earth very long. Confirming this, A.J.T. Jull (per comm.) measured ^{14}C activities in two members of the ALH85110 group corresponding to terrestrial ages of 350 ± 1300 and 2,300 ± 1300 years These terrestrial ages are extremely short by Antarctic meteorite standards; at the Allan Hills Main ice field most meteorites have terrestrial ages well in excess of 40,000 years and are often on the order of 10^5 years [6].



Even with such short terrestrial ages, the natural TL levels of these meteorites are unusually high, higher than virtually all recent falls. There are two ways in which very high levels of natural TL can be obtained in meteroid bodies, shown schematically in Fig. 3. A meteoroid body must either (a) be exposed to radiation levels at least 10 times that of typical bodies or (b) be irradiated at lower temperatures than are typical by being in orbits with unusually large perihelia and impacting the Earth before adjusting its TL level to that appropriate at 1 AU.

The dose rate experienced by a sample depends on the external cosmic ray flux and the depth of the point ("shielding") in relation to the size of the body. We have calculated the effects of shielding [7] and find that high TL levels should be restricted to very small meteorites and therefore this does not explain data for modern falls with very high natural TL levels (Table 1). Shielding effects could, however, at least partly explain the range of natural TL seen among the present samples. An order of magnitude greater external cosmic ray flux is also unlikely. While such high dose rates could be obtained through solar cosmic rays, these are too low in energy to contribute to the flux more than a few centimeters below the surface of a meteoroid





body. Another possiblilty is that these bodies have been in unusual orbits which were at least partly beyond the heliosphere, i.e., in orbits with very large aphelion or perhaps with high inclinations [8]. However, data from the Pioneer and Voyager spacecraft indicate that the cosmic ray flux outside the heliosphere is only a factor of 2-3 higher than a 1 AU [9], far less than the factor of 10 needed to explain the very high natural TL levels.

The remaining possibility, that meteorites with very high natural TL levels were irradiated while in large perihelion orbits and reached Earth without adjusting their TL, clearly depends on the kinetics of the TL decay process. Calculations (summarized in Fig. 3) show that equilibrium natural TL levels for meteoroid bodies will be very high (>150 krad) at perihelion >1.1 AU and will reach a saturation level in perihelion >1.2 AU. Approximately 10^5 years are required for TL levels to decay from an equilibrium level of 250 krad at ≥1.1 AU to 80 krad at 1 AU [10]. While this is a short period of time relative to the orbital evolution of most meteoroid bodies, orbital calculations suggest that rapid changes in perihelion are possible on less than this time scale in some cases [11]. Less than 5% of ordinary chondrites have very high natural TL levels (Fig. 1), suggesting that few meteoroid bodies undergo such rapid perihelion changes. It is probably not a coinicidence that one of the best-characterized of these meteorites, Jilin, has a two-stage irradiation history in which the most recent stage is only about 0.4 Ma long [12]. If this interpretation is correct, these rare meteorites are the only documented samples from meteoroid bodies in orbits similar to Earth-approaching (Amor) asteroids, although it has been suggested that three Amor asteroids are potential sources for basaltic meteorites [13].

In summary, we have identified a major Antarctic meteorite shower which is an H-chondrite breccia and which was found along a geographic trend line which may reflect a preserved strewn field or wind concentration of small meteorites in ice crevasses. The meteorite has been on Earth only ~1000 years and had experienced a very unusual orbital history, probably involving a change of perihelion from ≥1.1 AU to 1 AU within the last few hundred thousand years. Only a very small number of other meteorites have had similar histories.

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TABLE 1.

Sample	Class	Weight (g)	Natural TL (krad at 250°C)	Pairing+
ALH				
85110	H5	22.2	148 ± 2	A
88017	H4	70.4	130 ± 1	
88018	H6	67.1	108 ± 1	B
88020	H3	53.7	210 ± 2	
88021	H6	51.0	170 ± 1	
88026	H5	37.1	127 ± 1	C
88027	H5	31.6	177 ± 1	A
88029	H5	29.1	226 ± 2	D
88030	H5	28.5	120 ± 3	C
88031	H4-5	27.8	160 ± 1	A
88033	H5	27.3	118 ± 1	C
88035	H5	26.6	123 ± 4	C
88039	H5	24.9	145 ± 1	A
88042	H5	22.6	238 ± 1	D
88047	H6	20.6	109 ± 1	B
88049	H5	20.1	225 ± 4	D
Observed Falls				
Bo Xian	LL4	13000	207 ± 1	
Jilin	H5	4000000	290 ± 15	
Saratov	L4	328000	130 ± 7	
Tennasilm	L4	28500	120 ± 6	
Qidong	L5	1300	125 ± 1	

+ Letter indicates assignment to groups of meteorite fragments thought to have been pieces of the same body immediately prior to fall. Grouping is on the basis of compositional and TL properties.