THE BRUDERHEIM METEORITE—FALL AND RECOVERY

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Abstract

Bruderheim, a detonating bolide, entered the earth's atmosphere at 1:06 a.m., M.S.T., March 4, 1960, creating a flash visible for 200 miles, followed by detonations resembling a sonic boom audible over an area of 2,000 square miles. Ten reliable sightings and many flash-sound intervals assisted in pinpointing the fall area. The fireball, travelling on an azimuth of N. 100°, slope 40°, in the direction of the earth's revolutionary path, had an initial atmospheric velocity of about 8–10 miles per second, facilitating entry. More than 300 kilograms fell as individuals within a well-defined ellipse of fall at latitude 53° 54′ N., longitude 112° 53′ W. This ellipse is 3½ miles long and 2¼ miles wide (5.6 by 3.6 km.), with its long axis N.80° W. and the larger individuals located near the south-east apex of the ellipse. Falling vertically onto frozen ground at terminal velocity, most individuals rebounded onto the snow surface, facilitating recovery. Mapping and recovery were continued during the spring break-up period, yielding the university a total of 188 sizable gray chondritic meteorites weighing 303 kilograms. The largest individual weighed 31 kilograms; 500 recovered individuals, each smaller than 100 grams, are uncatalogued.

Introduction and Acknowledgments

Bruderheim, a gray chondritic meteorite which fell on March 4, 1960, at 1:06 a.m. Mountain Standard Time, is, in aggregate weight (over 300 kilograms), Canada's largest known meteorite (Millman 1953). By strange coincidence the bolide detonated halfway between the point where the Edmonton meteorite was found, and the Abee meteorite fell (figure 1). At 1:06 in the morning the late show on television had just finished, a factor adding substantially to the number of eye witness accounts. Bruderheim is a typical evening meteorite, solving the entry problem by reason of its relatively low atmospheric velocity (figure 2).

This paper will deal principally with the fall of the meteor and recovery of the meteorite; chemistry and mineralogy of the stones will be considered in a later report.

Earl Milton, past president of the Edmonton Centre of the Royal Astronomical Society of Canada, was instrumental in alerting the public through the media of press, radio and television, to the possibility that a meteorite fell from the bright detonating bolide. He obtained eye witness reports that narrowed down the possible fall area. Stanley Walker and Tyrone Balacko of Fort Saskatchewan, following a lead given by recovery of a single fragment, mapped the principal fall area in outline, and recovered about 75 kilograms of meteorite in the two days

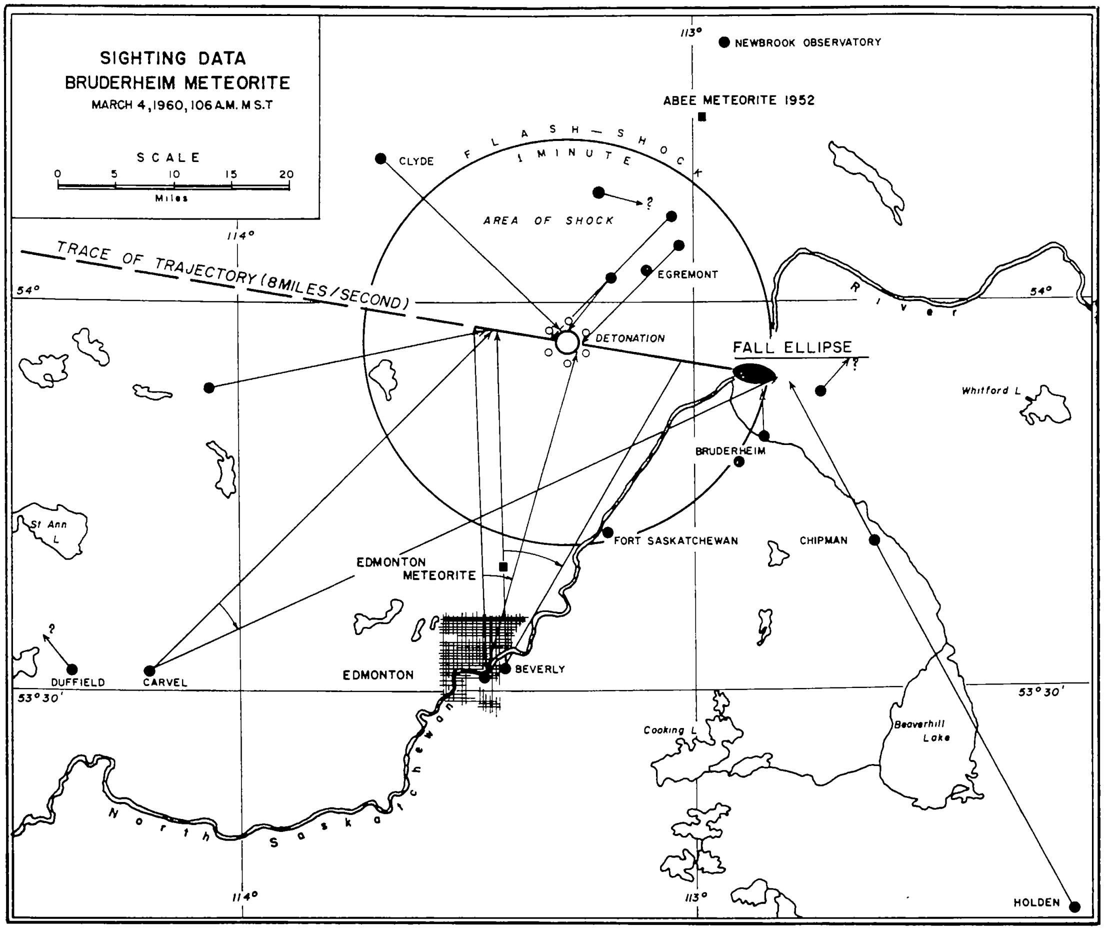


FIG. 1—Visual sighting data and area within which detonations were heard.

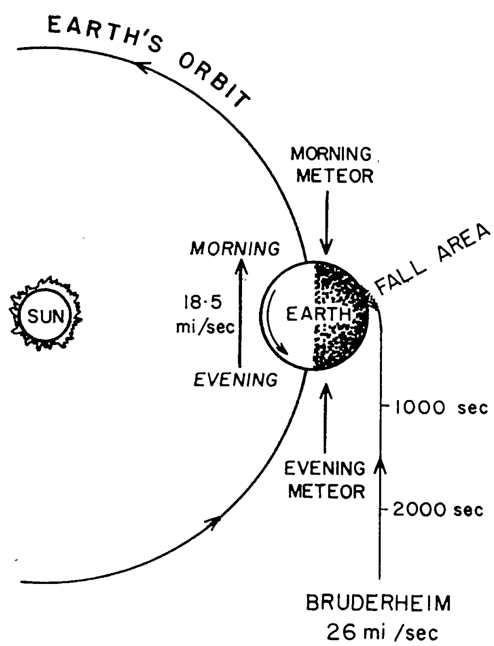


FIG. 2—Schematic diagram showing how the Bruderheim meteorite fell. Bruderheim, an evening meteor, solved the entry problem by reason of its low atmospheric velocity (after Whipple 1957).

immediately after the fall. Heavy snow then fell, and no further recoveries were made till spring.

The farmers of the Bruderheim area co-operated in the search for fragments and made their finds available to the University of Alberta, where special funds were provided by the President, W. H. Johns, for acquisition of the meteorite.

R. S. Taylor assisted in mapping the ellipse of fall. F. Dimitrov drafted the illustrations. All this assistance is gratefully acknowledged.

Fall

The Bruderheim bolide was probably first observed by Alèxis Simon, an Indian of the Paul's Band Indian Reserve at Duffield, Alberta (figure 1). His account is as follows:

> On the night [*sic*] of Friday, March 4th, 1960, I happened to be outside of my home at midnight when I saw a large meteorite in the north-westerly direction from Duffield. It lighted up the sky as it passed swiftly in a north-easterly direction, giving off what appeared to be flashes of fire.

He describes also a rushing sound, resembling a high wind, which lasted for 5 to 6 seconds after the fireball passed, a phenomenon distinct from the shock-wave detonations accompanying meteorites, and characteristic of reports of fireballs (Smith and Hey 1952). It may be primarily due to suggestion, without real existence (Heard 1949).

It is interesting to speculate that the more acute senses of Alexis Simon enabled him to observe the meteorite during the time when it first was entering the atmosphere, and to note a sound phenomenon not recorded by other observers whose vision and hearing, dimmed and dulled by television, were quickened only by the bright glare of the fireball lower in the atmosphere, and shaken by the sonic boom at detonation point. However, more prosaically, there was considerable patchy overcast in the Edmonton area, and at Newbrook, though the all-sky camera was on and recorded the general brightening brought about by the bolide at 1:06 a.m., the meteor cameras were not operating (Jack Grant, Newbrook, personal communication).

Mrs. P. I. B. Wood of Carvel (figure 1) observed the fireball from point of detonation to disappearance, as did a number of observers from the slightly overcast city of Edmonton. The most accurate observations of which the writers have record were made from Edmonton by D. B. Russell, a student at the University of Alberta, and from Beverly by M. Reis at the Texaco Oil Refinery. Cross sighting was made by S. E. J. Mitchell of Clyde and by a number of observers near Egremont and in Fort Saskatchewan (Miller 1960).

Some of the sighting and sound data from the Egremont district suggested a fall area north-east of this village: flash sound intervals were small, averaging 20 seconds (from seven observations where time could be judged by repeating motions). L. A. Bayrock and R. S. Taylor spent considerable time in air and ground searches in this area on March 6th and 8th, and as late as April 4th, with negative results. The theory that the Bruderheim bolide had an initial north-easterly trajectory, and at the detonation point split into two main masses, one travelling approximately north 20° east over Egremont, the other 100° (10° south of east) to fall in the Bruderheim area, while plausible, has not been substantiated by finds. The assignment of an azimuth of north 100° to Bruderheim (figures 1, 3) is based largely on the shape of the ellipse of fall and on the

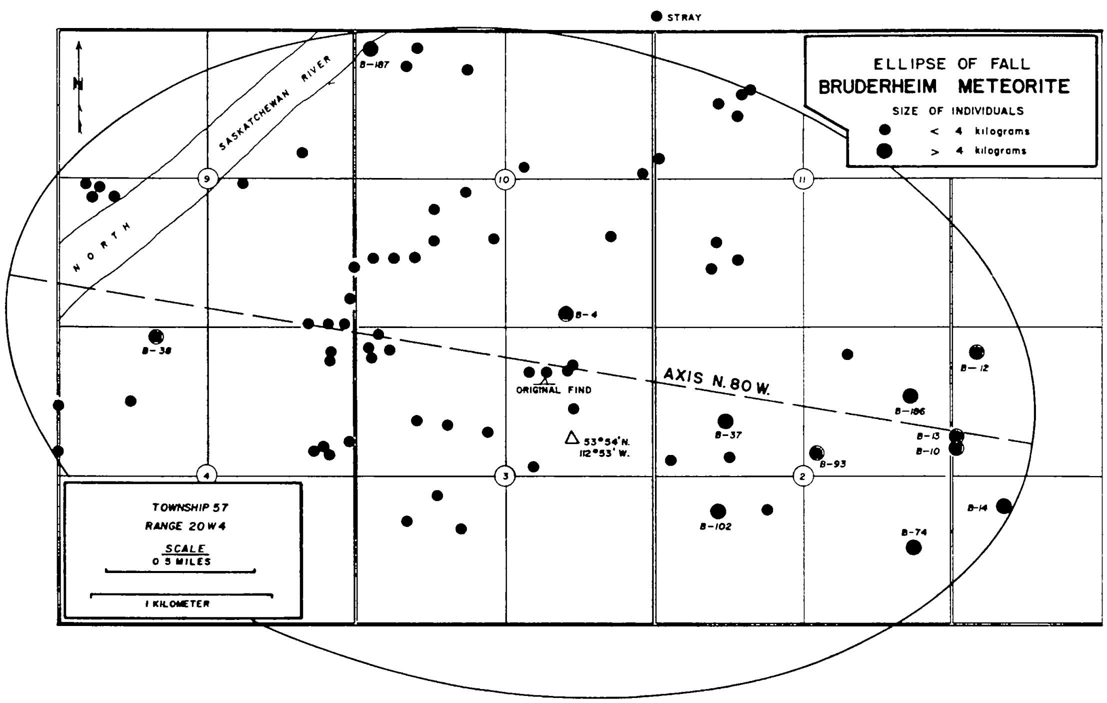


FIG. 3—Mapped individuals from the Bruderheim meteorite define an ellipse of fall.

fact that most of the sighting evidence does not directly contradict such an interpretation. One hundred miles east of the fall area, on this 100° azimuth, Mr. and Mrs. A. C. Butz of Dewberry observed the flash and "... about two to three minutes after light, a thundering noise was heard, windows rattled...." This is the outer limit of sound reports.

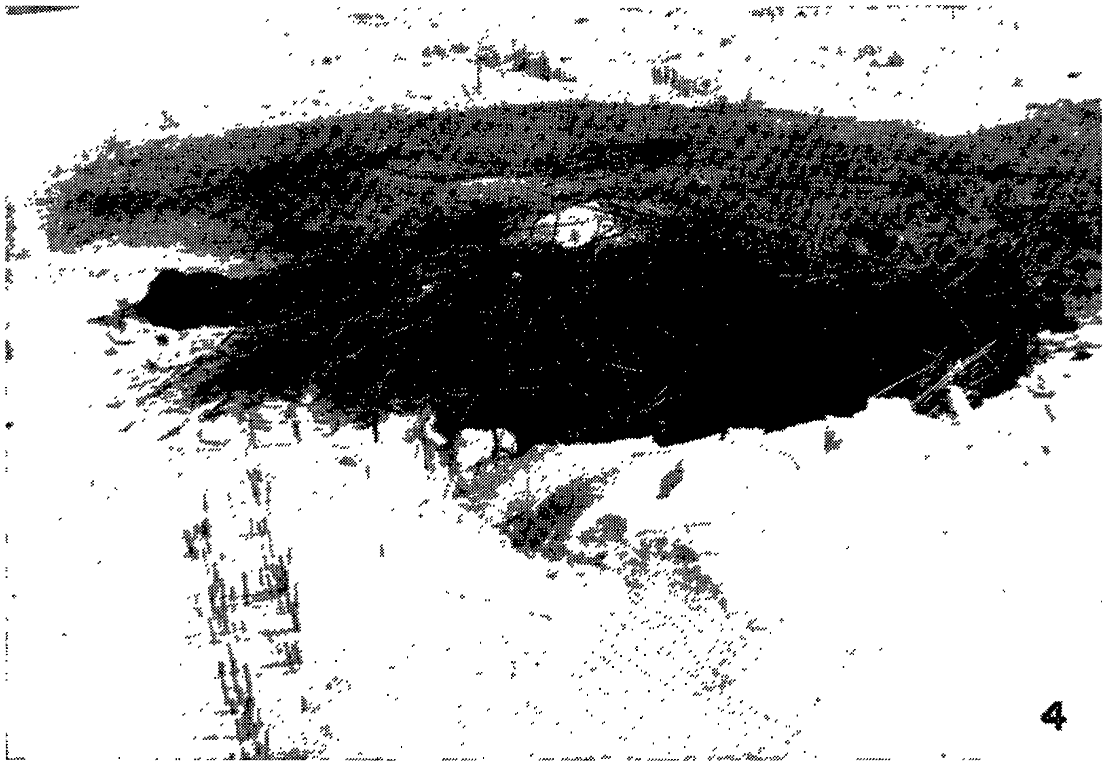
Though it is clear that the bolide first became brightly illuminated almost directly north of Edmonton, reports of its height at this time vary greatly, and the slope of the path and the geocentric velocity needed for calculation of the radiant, or direction in space from which the body was coming, are not easily judged. The best evidence suggests that at a height of about 30 miles the fireball flared a bright blue-white, of sufficient intensity to attract the attention of ground observers, and continued in this halo of plasma-type illumination for 25 air miles to the detonation point at a height of 16–17 miles. Fragments thrown off at detonation remained bright, though changing from white to red as they approached the ground point, about 25 air miles east of the point of detonation. The slope of the illuminated path therefore was about 40°, and since most observers recorded a 5–6 second duration for illumination, the geocentric velocity was about 8–10 miles per second. This interpretation is a best fit interpretation of available sighting data. Heard (1949) describes a fireball similar in many respects to Bruderheim, and gives the equations necessary for solution of the meteor's path in space, given azimuth, slope, and geocentric velocity.

It becomes clear, on examining the university report forms (based on a Russian example), that these were too complex for an unskilled observer. Most of the forms that were turned in provided little more enlightenment than this initial letter received from John Mandryk of Bruderheim:

"I have seen the light and heard the crash. If you wish to send me a form I shall answer it to best of my ability."

Recovery

Nick Broda, a farmer of the Bruderheim district, recovered the first stone from his barnyard on Friday, March 4. It was brought to the Sherritt Gordon Nickel Refinery at Fort Saskatchewan by an employee, and identified as a meteorite. S. Walker and T. Balacko proceeded to the area and began systematically to map the fall and recover fragments which, upon striking frozen ground, had rebounded onto the hard-packed snow surface where they became clearly visible from district roads (figures 4, 5). On Saturday and Sunday, March 5 and 6, Walker and Balacko mapped and collected a total of 155 pounds of meteorite, which they later made available to the university as the nucleus of its collection. At the same time district farmers collected fragment B-74 (figure 1), a complete individual weighing more than 25 kilograms. This stone was then broken by the collectors into a number of fragments, and widely distributed. Most of these pieces mere ultimately acquired by the university, and since B-74 was a completely unweathered specimen it was used as the source of all samples employed in analyses of the meteorite. Andreas Bawel and Walter and Nick Holowaty of Bruderheim collected about 10 kilograms of fragments from their farms on March 4, 5, and 6. Walter Holowaty made the first collections off the ice on the North Saskatchewan River, digging down through the snow to the ice surface



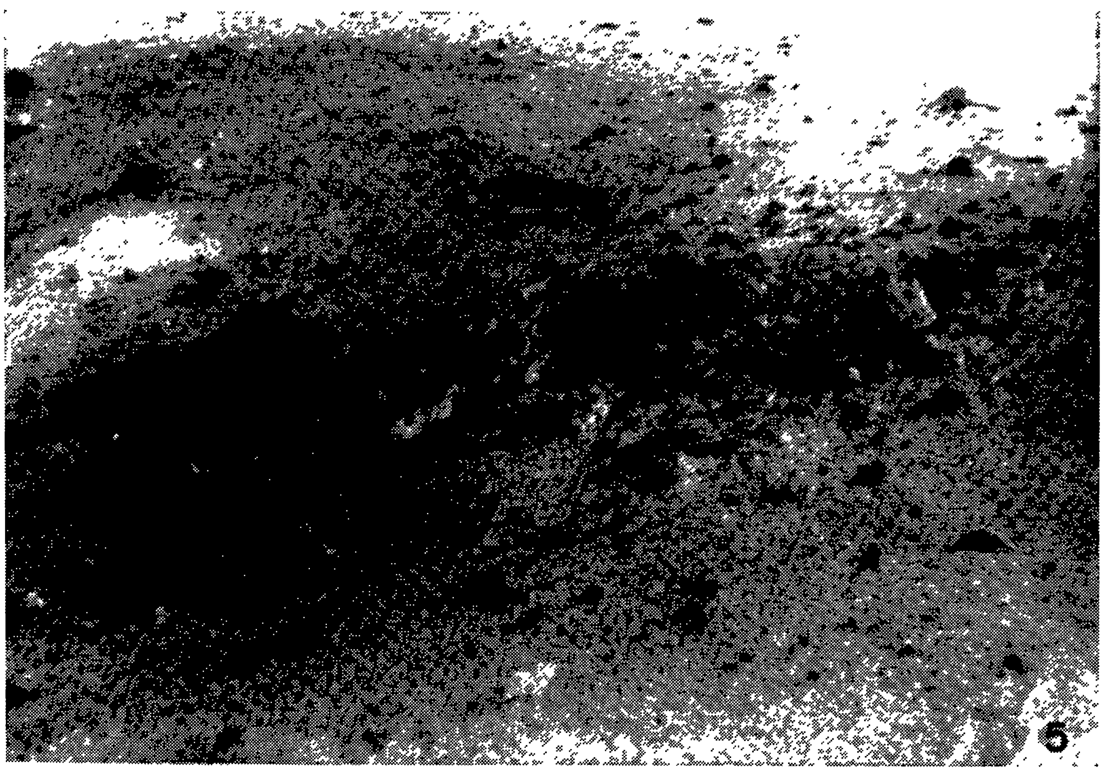


FIG. 4—Looking east at the impact crater formed by Bruderheim individual B-12 which fell in a field of swathed wheat. (Photograph by Walker and Balacko.)

FIG. 5—Bruderheim B-10, which fell on fallow ground. (Photograph by Walker and Balacko.)

wherever he observed an impact hole. On March 7 it snowed heavily and no further recoveries could be made until spring, with the exception of a few small fragments collected from snow banks.

With Walker and Balacko's map of the general fall area as a guide, a concerted effort was made during spring break-up to complete the recovery. Legal opinion held that meteorites on the surface were probably the property of the user of the land and every effort was made to get the farmers to bring in this early crop. Systematic sweeps of the fall area with groups of geology students convinced the writers that local residents could do this more efficiently, and the majority of specimens in the university collection were purchased from Bruderheim farmers. University collecting concentrated on the ice surface of the North Saskatchewan River. Hundreds of grit- and pebble-sized fragments were collected off the river ice, collection continuing up to the day before break-up. These small fragments could not be successfully collected against the black background of stubble and fallow fields in the area and undoubtedly many thousands of them were plowed under. While preparing the fields for seeding, district farmers collected additional large specimens, further defining the fall area.

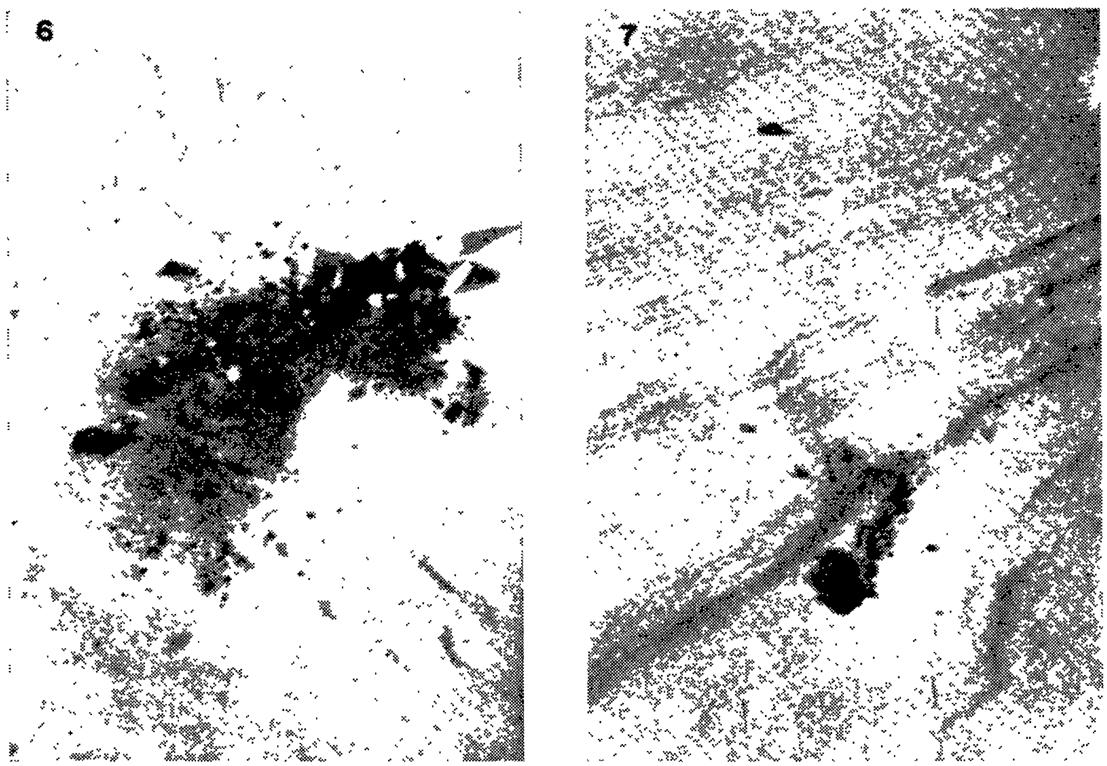
Title to the Walker-Balacko collection was ensured by settling with the farmers on whose fields these fragments were collected, and an effort was made to purchase as many other fragments as could be obtained at a reasonable price. The Geological Survey of Canada, interested in the fall for the National collection, refrained from competition, and a 40-kilogram suite of especially fine material was made available for this collection at cost.

Bruderheim individuals struck the ground almost vertically, apparently at terminal velocity, perhaps 200 miles per hour at impact. The largest fragments (Table I), weighing 30 kilograms, travelled farthest, and are grouped at the south-east apex of the ellipse. They dug holes about 8 inches deep in the frozen ground and then rebounded onto the snow surface, ending up about 6 to 8 feet east of the impact point, with a shower of dirt splayed south-east of the impact craters. One individual fell onto a cushion of swathed wheat (figure 4). The position of these large individuals confirms the 100° azimuth traced by the fireball, coincident with the axis of the ellipse of fall.

Point of impact of the larger fragments (greater than 4 kilograms) was surveyed with a plane table. Smaller individuals were plotted from the Walker-Balacko map, from mapping on aerial photos while collecting, and from all reliable information obtained from farmers in the area.

The Bruderheim bolide continued breaking up into smaller fragments even after the initial detonation at high altitude, and in this and other respects the fall resembles Tenham (Spencer 1937). A small but significant number of fragments, perhaps 10 per cent. of the individuals, show partial fusion crusts, in one instance three stages, late-formed fragmentation surfaces that are not completely blackened. There is evidence from the fall pattern that some individuals broke into two or more pieces while still in the air, though travelling below the speed at which fusion crust would form.

In the case of the smaller individuals, direction of fragments from pits is almost random, though there is a suggestion of it being outward from the centre of the ellipse. This probably represents motion imparted by the detonations. These smaller individuals in some cases rebounded onto the snow surface (figures 6, 7).



FIGS. 6, 7—Impact craters formed by smaller individuals of the Bruderheim fall, which came to rest on drifted snow. (Photographs by Walker and Balacko.)

Most of the material recovered from Bruderheim was in the form of individuals weighing over 4 kilograms (figure 8). There is a significant grouping of weights around 25–30 kilograms, which seems to be an optimum size for chondrite fragments surviving the penetration of the earth's atmosphere (Lightfoot, MacGregor and Golding 1935), as evidenced by the weight distribution of stones in the British Museum.

FIG. 8—B-37, a perfect individual of the Bruderheim fall, showing details of the fusion crust and an exceptional development of piezoglyphs (thumbprints). (Photograph by Dimitrov.)

TABLE I

LARGE INDIVIDUALS, BRUDERHEIM FALL

U.A. No.	Weight Grams	Pounds	Found Twp. 57 Rge. 20 W4	Now located
B-10	31360	69	Lsd. 12 Sec. 1	Geological Survey, Ottawa
B-14	28600+	63 (68)	Lsd. 5 Sec. 1	University of Alberta
B-12	30300	67	Lsd. 13 Sec. 1	Edmonton Planetarium (on loan from U. of A.)
B-74	25100+	55 (60)	Lsd. 8 Sec. 2	Distributed for analysis
B-13	24420	54	Lsd. 12 Sec. 1	University of Alberta
B-37	17370	38	Lsd. 11 Sec. 2	University of Alberta
B-186	12590	28	Lsd. 16 Sec. 2	Royal Ontario Museum
B-93	10220+	23 (24)	Lsd. 10 Sec. 2	Distributed on exchange
B-102	10165	22	Lsd. 7 Sec. 2	University of Alberta
B-187	7995	18	Lsd. 13 Sec. 10	University of Alberta
B-4	6045	13	Lsd. 2 Sec. 10	University of Alberta
B-38	4560	10	Lsd. 14 Sec. 4	University of Alberta
Total	208725	460		

The statutes of Alberta now contain a clause (embodied in Bill 40 of the 2nd Session, 14th Legislature, Alberta 9 Elizabeth II: A Bill for the Protection of Historical, Archaeological, Palaeontological, Ethnic and Meteoric Sites and Objects) relating to meteorites:

9. (1) In this section "meteorite" means a stony or metallic body that has fallen to earth from outer space.

(2) Where an object that may be a meteorite falls on any land, whether publicly or privately owned, no person, other than a person authorized by the Minister, shall

(*a*) disturb any crater, furrow or other marking of the earth's surface that may have been caused by the object, or

(*b*) disturb or remove the object from the place where it fell.

(3) The ownership of every meteorite that falls anywhere in the Province after the commencement of this Act is hereby vested in the Crown.

Use

Specimens of Bruderheim have been made available to scientists interested in meteorites, and the fall was early reported in *The Meteoritical Bulletin* by Krinov (1960) from information supplied to Peter M. Millman. Meteorites, it has been said, are the poor man's space probe, and can be made to yield much information on the nature of radiation in space, the origin and nature of the solar system, and indeed of the universe. Results of these investigations have appeared and will be appearing in scientific literature from time to time, and the data accumulating suggests that Bruderheim will be one of the world's most extensively studied chondritic meteorites.

Chemically, Bruderheim is an average chondrite, of the low iron group. The analysis and normative mineral composition are as follows:

TABLE II

Chemical Analysis and Normative Mineral Composition of the Bruderheim Meteorite

SiO_2	39.94		
TiO_2	.12		
Al_2O_3	1.86	*Normative composition*	
Fe°	8.59	Nickel-iron	9.94
FeO	12.94	Troilite	6.38
FeS	6.38	Olivine	41.65
MnO	.33	Hypersthene	25.90
MgO	24.95	Diopside	5.34
CaO	1.74	Albite	8.52
Na_2O	1.01	Anorthite	0.17
K_2O	.13	Orthoclase	0.78
P_2O_5	.29	Chromite	0.92
H_2O^-	.01	Apatite	0.74
H_2O^+	.10	Ilmenite	0.21
Ni°	1.30		
Co°	.05	Analysis by H. Baadsgaard	
Cr_2O_3	.60	and A. Stelmach	
C	.04		
Total	100.38		

Summary and Conclusions

A multitude of observations on the Bruderheim bolide, combined with a well defined ellipse of fall, contribute to the documentation of this new Canadian chondrite. Collection is believed to have been reasonably complete and a wealth of recently fallen meteorite material was made available, particularly for the study of short half-life isotopes developed in space as products of cosmic radiation. Chemical, mineralogical, and rare gas studies of the meteorite are under way.

REFERENCES

Heard, J. F. 1949, "The Fireball of April 3, 1949," *R.A.S.C. Jour.*, vol. 43, p. 149.

Krinov, E. L. 1960, "Fall of Bruderheim stony meteorite shower, Canada," *Meteoritical Bull.*, no. 18, p. 1.

Lightfoot, B., MacGregor, A. M. and Golding, E. 1935, "The meteoric stone seen to fall in the Mangwendi Native Reserve, Southern Rhodesia, on March 7, 1934," *Mineralogical Mag.*, vol. 24, p. 1.

Miller, F. D. 1960, "The Meteorite," *Sherritt Nickelodeon*, vol. 6, p. 11.

Millman, Peter M. 1953, "Canadian Meteorites," *R.A.S.C. Jour.*, vol. 47, pp. 29, 92, 162.

Smith, W. C. and Hey, M. H. 1952, "The Monze meteorite shower," *Colonial Geology and Mineral Resources*, vol. 3, p. 52.

Spencer, L. J. 1937, "The Tenham (Queensland) meteoritic shower of 1879," *Mineralogical Mag.*, vol. 24, p. 437.

Whipple, F. L. 1957, "Meteors," Smithsonian Report for 1957, p. 239.