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The Wiluna Meteorite fall, Western Australia—2 September 1967

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(with a chemical analysis by C. J. ELLIOTT, British Museum (Natural History))

SUMMARY. The fall of a shower of meteorites numbering several hundred fragments at Wiluna, Western Australia, on the night of 2 September 1967, has been investigated. Although the dispersion ellipse had been largely obscured by removal of fragments before a party of scientists were able to make a field investigation, it has, nevertheless, been possible to make a reasonable estimate of the shower distribution pattern. In spite of this removal of fragments, a number of pieces of meteorite were still found *in situ*. The bulk of the total recovery is in the collections of the Western Australian Museum, and the physical characteristics of these masses and their petrography is described. In all, some 490 individual fusion-crust coated stones and a large number of broken stony fragments are known to have been recovered. The meteorite is an olivine bronzite chondrite remarkably rich in discrete nodules of nickel iron, up to an inch across, commonly aggregated with troilite. A full chemical analysis of this fresh meteoritic material has been supplied by the British Museum (Natural History).

A LARGE shower of meteorites fell at 26° 35′ 34″ S., 120° 19′ 42″ E., 5 miles due east of Wiluna township, Western Australia, at 10.46 p.m. local time (1446 h G.M.T.) on Saturday, 2 September 1967, over an elliptical area 4 miles long by 2 miles wide (fig. 1); all the large fragments recovered came from the north-west end of the ellipse, indicating an approach from the south-east. It is estimated that between 500 and 1000 individual stones fell, with a total weight exceeding 250 kg; 480 individuals and many fragments, totally 145·7 kg, are held in the Western Australian Museum, and 9 individuals and 2 fragments, together 1·66 kg, in the School of Mines, Kalgoorlie, and more material is known to be in private hands. The largest fragment weighed nearly 14 kg, and the largest complete stone (fig. 2) 10 kg, while the smallest complete stone collected weighed only 2·2 g. Detailed reports of observations of the fall and of the finding of many of the masses are held by the authors.

The physical character. The 490 individual fusion-crust coated masses recovered, divided between the Western Australian Museum and the School of Mines, Kalgoorlie, show very similar characteristics, the matt black fusion crust contrasting with light grey, finely mottled areas where the crust has been broken off to reveal the interior of the stone.

The larger masses display very coarse regmaglypt patterns, forming quite regular networks, of a type characteristic of moderate-sized iron meteorite masses; other large

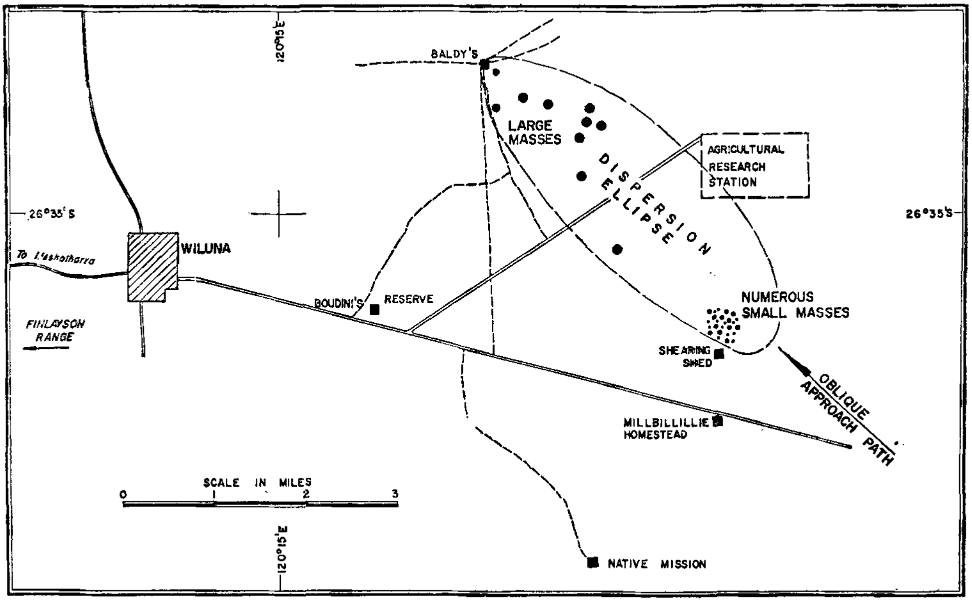
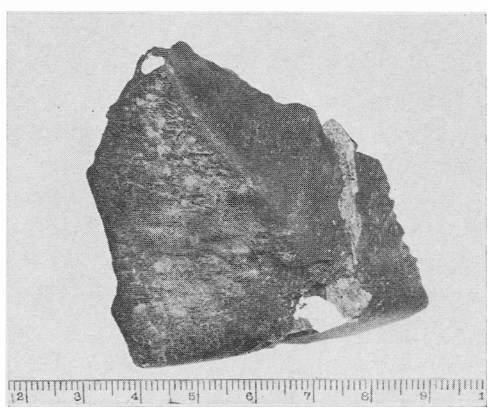


FIG. 1. Sketch-map of the Wiluna township area, showing the distribution of masses in the dispersion ellipse.



FIGS. 2 and 3: Fig. 2 (left). The largest entire fusion-crust coated mass recovered (weighing 23 lb.). Fig. 3 (right). Anterior surface of an oriented mass, showing thin crusting, faceted shape, and ablation striations.

masses, however, display quite smooth fusion crust surfaces, indented only by scattered and irregular regmaglypts, showing just the beginnings of a network pattern (fig. 2). Some of the medium-sized masses display pronounced orientation characteristics, a thin, brown, striated crust on the anterior surface (fig. 3) contrasting with a thickened, black, warty crust on the posterior surface (fig. 4); this orientation phenomenon is normally associated with single masses that come in through the atmosphere without fragmentation, and it is surprising to find it developed in a fragment that must have developed its crust subsequent to atmospheric fragmentation.

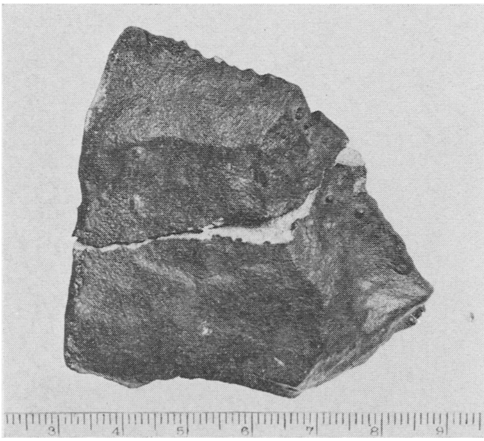


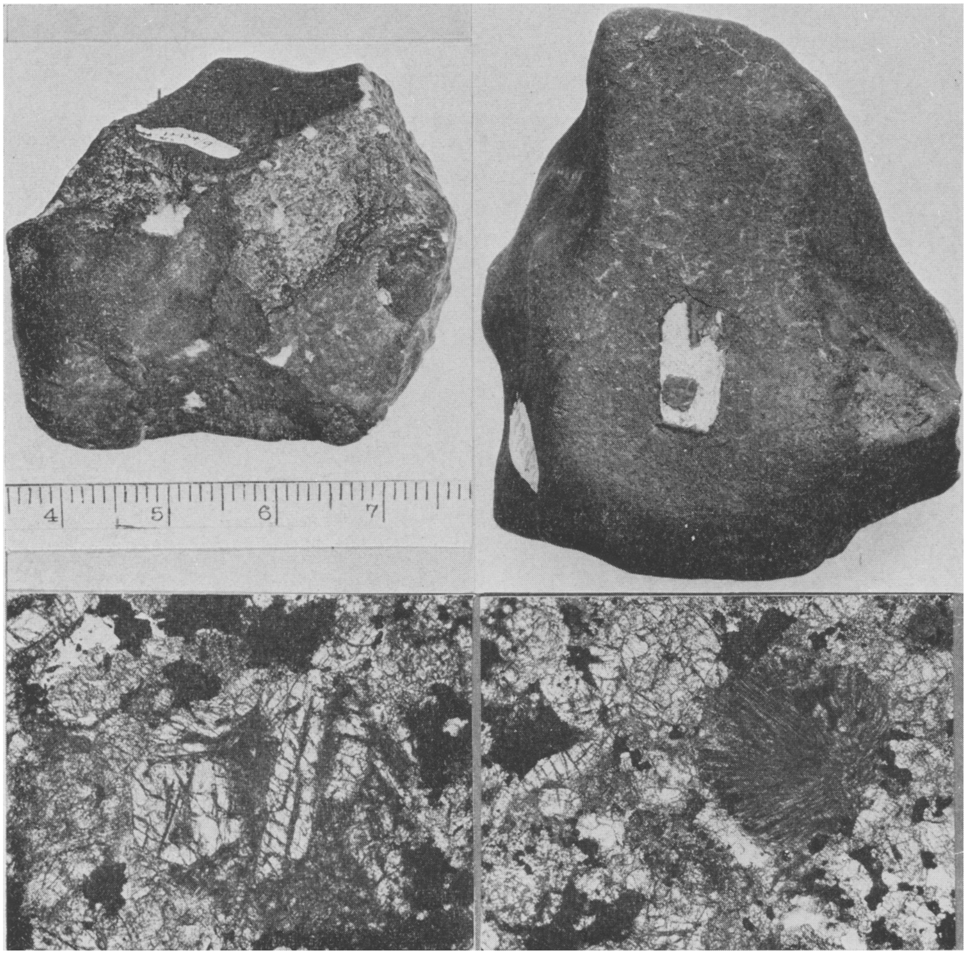
FIG. 4. The posterior surface of the same oriented mass, showing the thickened, knobbly black crust and the faceted form.

There were certainly two fragmentation events, for many of the smaller fragments display two quite distinct types of crusted surface, which may be regarded as two crusting generations consequent on two distinct fragmentations. The normal black, even crust covers some facets, whereas others display a thin crusting through which the rough surface of the broken interior of the mass is still recognizable (fig. 5). In rare cases the crusting is an incomplete veneer and the light colour of the interior material looms patchily through the semi-transparent crust; the second stage of fragmentation must have taken place late in atmospheric entry, and there was not sufficient time for a full crusting of such surfaces to be produced before the deceleration terminated the frictional heating.

Some specimens display patterns of brecciation of the freshly broken surfaces, which are traversed by veinlets of dark glass in continuity with the fusion crust. Such specimens appear to reflect abortive fragmentation, probably during the second fragmentation episode.

Many of the fragments display prominent nodules of metal projecting through the fusion crust. These nodules may be up to an inch long (fig. 6). Such large metallic nodules are unusual in chondrites. A number of the masses display small laths of olivine (?) within the fusion crust, producing a megascopically visible decussate texture (fig. 6).

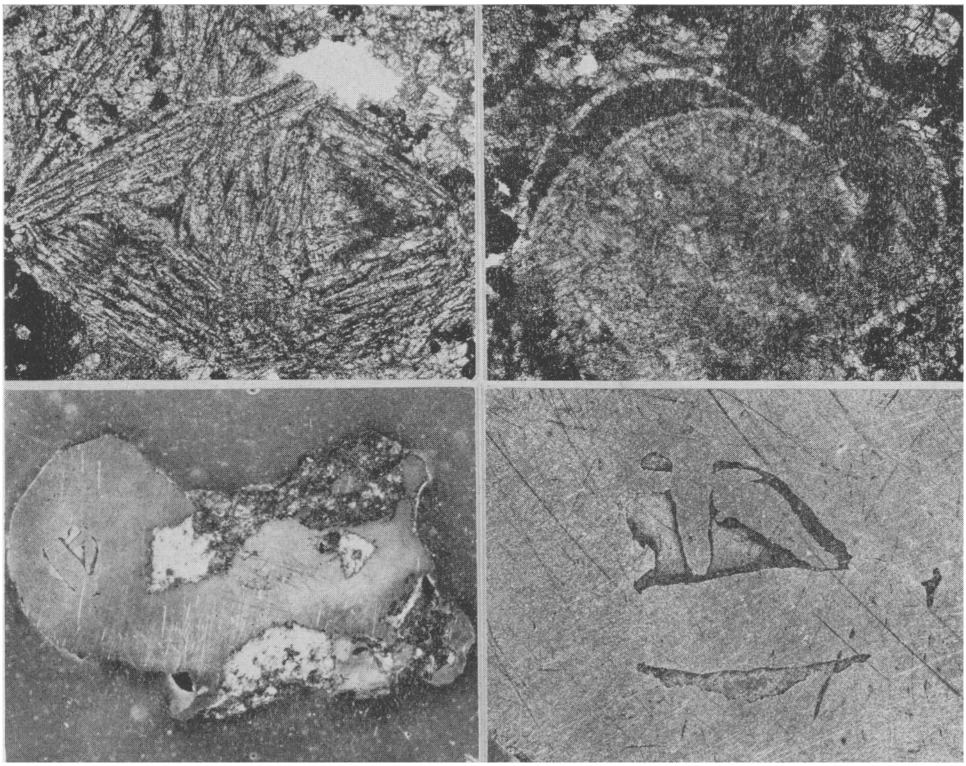
Petrography. Even with the restriction of surface weathering to periods ranging from a few days to three months, some of the masses recovered show brownish discoloration along fine hair-line cracks, and around metallic specks on broken surfaces of the interior of the masses. It is probable that many of the masses recovered, though collected shortly after fall, were stored in the open air, and this explains the appreciable weathering effects. A few masses are completely fresh, displaying no trace of this oxidation, and these are believed to be the ones collected shortly after fall and stored indoors. The rapid oxidation of some of the Wiluna masses does demonstrate the fact that any completely fresh chondrite mass found lying on the land surface must be of very recent arrival—not more than a few weeks—even in this arid climate. The



FIGS. 5–8: Fig. 5 (top left). Mass displaying a second type of fusion-crust surface; the rough facets are completely coated with fusion crust but the rough texture of the interior of the chondrite shows through. Scale in inches. Fig. 6 (top right). Iron nodule protruding through the fusion crust of a small mass ($\times 1\frac{1}{2}$); the crust shows faint, decussate inset laths of olivine (?), recrystallized within it. Fig. 7 (bottom left). Porphyritic chondrule consisting of subhedral olivine crystals inset within a turbid, devitrified glass base. The hazily defined nature of the chondrule boundary is apparent. ($\times 50$, plane polarized light.) Fig. 8 (bottom right). Exocentric fan chondrule, composed of olivine needles. ($\times 33$, plane polarized light.)

petrographic examination of the Wiluna meteorite was carried out, as far as possible, on the fresh masses.

In addition to the late brecciation already described, the freshly broken surfaces do tend to display a faint patchiness, indicating a degree of inhomogeneity before atmospheric entry. However, no evidence of true polymict breccia character has been recognized, and such patchiness—a very faint development of the well-known ‘light-dark’ structure of some chondrites (Frederiksson and Keil, 1963)—is essentially a monomict brecciation, produced by areas of the same mineralogy but contrasting fineness of texture.



FIGS. 9–12: Fig. 9 (top left). Complex internal fan structure of another chondrule. ($\times$33, plane polarized light.) Fig. 10 (top right). A triple chondrule showing overlapping structure. ($\times$33, plane polarized light.) Fig. 11 (bottom left). Polished surface of a large metallic nodule, with a small area of etch-pattern visible on the left ($\times$2). Fig. 12 (bottom right). Enlargement of the small area of etch pattern in fig. 11. Inset within the kamacite are small areas of taenite (dark grey) and plessite (light grey, at centre). ($\times$12, reflected light.)

The texture of the Wiluna meteorite is seen under the polarizing microscope to be *recrystallized*, the rather small chondrules ($\leqslant$ 1 mm diameter) being inset within a finely crystalline base of the same minerals. The outlines of the chondrules are hazily defined, and they are commonly enveloped in a corona of opaque minerals.

Olivine is the most prominent silicate mineral component; orthopyroxene (bronzite) is the only other silicate abundantly present; clinopyroxene, of the type first described by Tschermak (1885), showing low birefringence and inclined extinction of the fine twin lamellae, is conspicuous among the smaller silicate grains. This pyroxene was formerly identified as pigeonite, but is now recognized as clinohypersthene (verbal communication, R. A. Binns). Plagioclase (presumably oligoclase, the normal species

TABLE I. *Analysis of B.M. 1968, 189(a) Wiluna using the procedure described in* Min. Mag. *36, 101–19* (*Anal. C. J. Elliott*)

% Bulk composition			
Non-magnetic attacked		% Composition of sulphide phase	
Fe	2·15	Fe	63·1
S	1·24	S	36·4
Mn	155 ppm	Mn	0·46
Ti	11 ppm	Ti	0·03
Cr	< 4 ppm		
Magnetic attacked		% Composition of attacked metal	
Fe	14·23	Fe	91·3
Ni	1·28	Ni	8·21
Co	0·08	Co	0·51
Ge	8 ppm	Ge	51 ppm
Ga	1 ppm	Ga	7 ppm
Cu	31 ppm	Cu	199 ppm
Ti	6·6 ppm	Ti	43 ppm
Magnetic unattacked		% Composition of unattacked metal (taenite)	
Fe	0·50	Fe	62·3
Ni	0·30	Ni	37·36
Co	10·5 ppm	Co	0·131
Cu	11·7 ppm	Cu	0·146
Ge	1·0 ppm	Ge	125 ppm
Ga	0·7 ppm	Ga	87 ppm
Non-magnetic unattacked			
SiO_2	39·59		
TiO_2	0·10	Total trace element content	
Al_2O_3	2·65	Ge	9·0 ppm
Cr_2O_3	0·63	Ga	5·5 ppm
FeO	9·50	Cu	53·3 ppm
MgO	24·06	Mn	2855·0 ppm
MnO	0·27	Cr	4311 ppm
CaO	1·88	K	830 ppm
Na_2O	0·95	Ti	618 ppm
K_2O	0·10		
P_2O_5	0·16		
H_2O	0·08		
Ge	< 0·8 ppm		
Ga	4 ppm		
Cu	11 ppm		
Grand total	99·775		

Olivine composition of Fa 17 was determined by Dr. M. J. Frost according to the method of Yoder and Sahama.

for chondrites) is present in the form of sparse, minute, untwinned grains of low relief and birefringence. These feldspar grains are commonly aggregated with the opaque, metallic minerals.

Of the chondrules examined, in the four thin sections prepared (each from a separate mass) *porphyritic* types, consisting of olivine phenocrysts set in a devitrified glass base (fig. 7), and *exocentric fan* types, with olivine or orthopyroxene needles making up the fan-shaped aggregate (fig. 8), predominate. Rare types are the *monosomatic* chondrules composed of either a single crystal of olivine with a distinct rim suggestive of partial resorption, or else of a *barred* olivine crystal. Complex internal arrangements of *fan* and *grating* textures are also rarely observed (fig. 9). The most unusual chondrule form of all is a triple chondrule (fig. 10), reminiscent of the well-known double overlap structure of a chondrule in the Bjurbole meteorite (Wood, 1963, Plate 6c); such overlapping, compound chondrule structures are highly significant, for they must surely impose severe limitations on the nature of the originating process responsible for the enigmatic chondritic structure of most stony meteorites.

The metallic fraction of the Wiluna meteorite is mostly present in the form of scattered, skeletal specks of kamacite aggregated with subordinate troilite. The kamacite is about four times as abundant as the troilite. The larger nodules, already mentioned, do, however, show very restricted areas of intergrowth between different phases of nickel-iron on etching with nital reagent. One such nodule displays both taenite and plessite within a large expanse of kamacite (figs. 11 and 12).

The material filling the veinlets of the breccia is a dark, opaque, magnetite-dusted (?) glass. A search for garnets, such as have been found in the Coorara, Western Australia (Mason, Nelen, and White, 1968), and Tenham, Queensland (Binns, 1969), meteorites, has proved unavailing, though the veinlets appear to be of very similar type. It was considered possible that garnet might be present in the light of the extreme atmospheric fragmentation characterizing both the Tenham and the Wiluna meteorites, but there is, of course, no certainty at the present state of knowledge whether the high-pressure shock conditions responsible for the development of garnets from pyroxenes (and spinel from olivine in the case of Tenham) occurred in the pre-terrestrial or terrestrial stage of the meteorites' histories.

The olivine of the Wiluna meteorite has been determined on separate fragments by B. Mason and M. J. Frost, using the diffractometric method of Yoder and Sahama (1957). Mason obtained a value of Fa_{19}, whereas Frost obtained a value of Fa_{17}. Both values are characteristic of olivine-bronzite chondrites (Mason, 1963). The slight discrepancy between the two results may possibly reflect variation in the fayalite indices of the olivines within a very restricted range.

A full chemical analysis was carried out at the British Museum (Natural History) on material from the interior of a fresh, fusion-crust coated individual mass. The results of this chemical analysis are given in Table I. The specific gravity of the fresh material of the medium-sized, individual meteorites averages 3·69.

The analysis, together with the presence of turbid glass, clinopyroxene, and minute 'secondary' feldspar aggregates, and the hazy boundaries to the chondrules, show that Wiluna belongs to Van Schmus and Wood's class 4 of the olivine-bronzite chondrites (Urey and Craig's H-group); in the Rose–Tschermak–Brezina classification, it is an intermediate veined brecciated crystalline chondrite.

REFERENCES

BINNS (R. A.), 1968. *International Symposium on 'Phase transformations and the Earth's Interior'.* International Upper Mantle Committee & Australian Academy of Science, Canberra, Jan. 6th–10th, p. 55 (Abstract Volume).

FREDRIKSSON (K.) and KEIL (K.), 1963. *Geochimica Acta*, **27**, 717–39.
MASON (B.), 1962. *Meteorites*. New York (Wiley).
—— 1963. *Geochimica Acta*, **27**, 1011–23.
—— NELEN (J.) and WHITE (J. S.), 1968. *Science*, **160**, 66–7.
MCCALL (G. J. H.) and JEFFERY (P. M.). *Journ. Roy. Soc. Western Australia*, **47**, 33–42.
VAN SCHMUS (W. R.) and WOOD (J. A.), 1967. *Geochimica Acta*, **31**, 747–65.
WOOD (J. A.), 1963. 'Physics and chemistry of meteorites', in *The Moon, Meteorites and Comets*, (eds. G. P. KUIPER and B. MIDDLEHURST), pp. 337–401. University of Chicago Press.
YODER (H. S.) and SAHAMA (TH. G.), 1957. *Amer. Min.* **42**, 475–91.

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