

AUSTRALIAN MUSEUM SCIENTIFIC PUBLICATIONS

Chalmers, R. O., and B. Mason, 1977. Two chondrites from New South Wales. *Records of the Australian Museum* 30(18): 519–531. [31 December 1977].

doi:10.3853/j.0067-1975.30.1977.193

ISSN 0067-1975

Published by the Australian Museum, Sydney

nature culture **discover**

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6 College Street, Sydney NSW 2010, Australia



TWO CHONDRITES FROM NEW SOUTH WALES

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SUMMARY

The Rowena olivine bronzite chondrite (H6) was broken into many fragments when struck by a plough on "Franxton" property (lat. $29^{\circ}48'$, long. $148^{\circ}38'$), 27 km west of Rowena railway station. It was found in January 1962. The stone was weathered and the weight of fragments recovered was 34.42 kg. The mineral composition and structure are given.

The Willaroy bronzite chondrite (H3) was found lying on the ground on "Willaroy" property (lat. $30^{\circ}06'$, long. $143^{\circ}12'$) on 12 March 1970. It was in four pieces the total weight being 4.05 kg. It was weathered. Mineralogical compositions and a chemical analysis are given.

ROWENA INTRODUCTION

"Franxton" property is owned by Mr. Henry Morse. It is situated on the black soil flood plain of the Barwon River in northern New South Wales, about 500 km north-north-west of Sydney. The site of the discovery is on lat. $29^{\circ}48'$, long. $148^{\circ}38'$, 27 km west of Rowena railway station.

Some time in January 1962 Mr. C. M. Phelps of Glen Eden, Rowena, and his brother-in-law Mr. R. Colyvan of Narrabri were ploughing in a paddock on "Franxton". This stony meteorite was struck by the plough and 34.42 kg of fragments were recovered, the two largest weighing 14.8 and 9.2 kg respectively. The remainder of the fragments ranged down to quite small pieces.

Mr. Colyvan sent all the fragments to the Mining and Geological Museum in Sydney and they were later sent to the Australian Museum by Mr. H. F. Whitworth, then Curator of the Mining Museum. Mr. Ray Witchard, of the Preparation Section of The Australian Museum faithfully joined the fragments together. Views of this are shown in figures 1 and 2, with the original surface outlined in chalk. No original surface is present on the back of the reconstruction indicating a greater original unweathered mass. The original mass of the Rowena would therefore have been one of the largest of Australian stony meteorites, exceeded in weight in all probability, only by the Barratta stones Nos. 1 and 5, and Karoonda.

The prevailing colour of the remaining original surface is light brown. An extensive surface on one fragment is deep reddish brown. Small black patches are occasionally present. Many cracks due to weathering are present on the original surface. Weathering is so pronounced that it masks any original fusion crust and makes a chemical analysis futile. It is not a recent fall.

Thumb-marks are a notable feature. One is particularly deep and can be seen on the bottom edge of the centre fragment in figure 2.

On a cut smooth surface of a separate fragment the following features are visible: a. numerous open veins lined with limonite; b. fragments of nickel-iron relatively abundant and fairly evenly scattered through the stony matrix; c. occasional metallic fragments of bronze colour, presumably troilite; d. a patch of a greenish yellow mineral presumably reevesite.

MINERALOGICAL COMPOSITION AND STRUCTURE

A thin section of this meteorite shows a granular aggregate of olivine and pyroxene, with interstitial opaque material, largely nickel-iron and troilite; weathering has converted much of the nickel-iron to limonite, which has stained the silicate minerals brown and extends as microscopic veinlets throughout the meteorite. A little reevesite was observed in the limonite veinlets. Chondritic structure is not prominent; the few chondrules in the section, averaging 1-2 mm in diameter, merge almost imperceptibly with the matrix. The commonest type of chondrule shows alternate thin lamellae of olivine and pyroxene. The matrix has an allotriomorphic-granular texture; olivine grains range up to 0.5 mm in diameter, while the pyroxene grains are generally smaller. Microprobe analyses show that the olivine and pyroxene are essentially uniform in composition, the olivine averaging 19.5% Fa, the pyroxene 17.6% Fs; the pyroxene contains 0.6% CaO. A few small grains of plagioclase, some of them polysynthetically twinned, were observed. Ramdohr (1966) has studied the opaque minerals in this meteorite, and records kamacite, native copper, troilite, chromite, pentlandite, chalcopyrrhotite, and valleriite (the latter mineral is probably mackinawite). The finely-granular nature of the matrix and the partial obliteration of the chondrules suggest a shock episode in the meteorite's history; the network of limonite veinlets may follow fractures produced by shock.

The composition of the olivine and pyroxene shows that Rowena belongs to the olivine-bronzite chondrites (H group); the texture and the presence of plagioclase place it as H6 in the classification of Van Schmus and Wood (1967).

WILLAROY INTRODUCTION

Willaroy is a property in the Western Division of New South Wales. It is situated approximately 88.5 km by road, north-north-east of the opal mining town of White Cliffs.

The country is low lying, sparsely vegetated and characterized by red sandy soil. It is a semi-arid region. The annual average rainfall approximates 220 mm.

On 12 March, 1970, Mr. L. S. Brown, owner of "Willaroy" found four fragments of a stony meteorite lying close together on bare ground. The site is about 4 km north (lat. 30°06', long. 143°12') of the homestead and 0.8 km south-west of an earth dam known as Red Tank.

GENERAL DESCRIPTION

Mr. Brown brought one of the fragments into the Australian Museum where it was identified as a chondrite. In July 1970, R. O. Chalmers accompanied by Mr. H. O. Fletcher, visited Mr. Brown and were taken to the site where he had left the three remaining fragments as he had found them (Fig. 3). A thorough search over several kilometres surrounding the site, on foot and with good visibility through sparse vegetation yielded no other masses.

The four fragments were subsequently found to fit together to form a single mass. Their close mutual proximity when found suggests that the original single mass broke into four pieces on hitting the ground or, subsequent to the fall, weathering along planes of weakness may have caused separation. The total weights of the four fragments is 4.05 kg. The largest fragment weighs 2.54 kg.

The colour of the Willaroy is reddish-brown. Remnants of the fusion crust were visible, but the characteristic lustrous fused appearance observed in meteorites that had fallen recently had been dulled by weathering over a long period. The rest of the crust had lifted and flaked off. In places layers of small quartz fragments cemented by iron compounds adhered firmly to the surface.

Chondrules were clearly visible, standing out in relief on the broken weathered surface of the fragments. Nowhere could the fresh appearance of the unaltered meteorite be observed. It is apparent that it is not a recent fall. A surface from which a slice was cut for sectioning is dark grey, almost black, with numerous lighter grey chondrules showing prominently. Minute particles of nickel-iron are sparsely distributed within the meteorite. The specific gravity is 3.54.

The shape of the Willaroy is roughly pyramidal. The base has four main edges and is smooth. Rising from the base, four main relatively smooth surfaces meet forming a blunt cone. The blunt cone can be seen on the top right-hand corner of the specimen (figure 4). Conical shaped meteorites are considered to be oriented (Mason 1962, p. 39), so that Willaroy belongs to this type. The fragments, fitted together, show the shape of the complete mass (figure 4). This illustration also shows portion of the base and two of the roughly triangular main surfaces. There are three other main surfaces on the back of the specimen. One of these, roughly four-sided, is the largest of all and measures $16 \times 10 \times 4.5 \times 1.9$ cm. Two of the three back surfaces meet the two triangular faces shown in figure 3 to form the blunt cone. At the back of the specimen two smaller curved surfaces join the edge of the base to the largest surface. These are the only faces to show regmaglypts (thumb-marks), three in all. All are shallow. The largest and best developed one measures 3×4 cm.

MINERALOGICAL COMPOSITION AND STRUCTURE

A thin section of the meteorite (figure 5) shows a close-packed aggregate of chondrules, 0.5-2 mm in diameter, with a small amount of angular mineral fragments, in a black opaque matrix. Brown limonitic veinlets, the result of terrestrial weathering, cut through the body of the meteorite. A wide variety of chondrules can be distinguished, some of which are illustrated in figures 5-12. Most chondrules consist dominantly of olivine crystals with interstitial glass, which is sometimes transparent and pale brown, but is more often turbid and dark grey because of partial devitrification. Some chondrules contain both olivine and clinobronzite, the latter usually as subhedral prismatic crystals showing the characteristic thin polysynthetic twin lamellae. A few chondrules are extremely fine-grained, almost cryptocrystalline, and probably represent devitrified glass; microprobe analyses show that these vary somewhat in composition from point to point, but are dominantly of pyroxene.

An X-ray diffractometer trace shows fairly sharp olivine peaks, indicating an average composition of Fa_{13} according to the technique of Yoder and Sahama (1957); the peaks are somewhat asymmetric and are skewed towards higher Fa values. The pyroxene peaks correspond to clinobronzite, although a minor amount of orthopyroxene could be present but undetected. The pyroxene peaks are rather broad, suggesting variable composition. These X-ray results have been confirmed by microprobe analyses. Olivine compositions range from Fa_{10} to Fa_{19} , with a mean of $Fa_{14.6}$. Pyroxene compositions range from Fs_6 to Fs_{30} , with a mean of $Fs_{14.5}$; the calcium content is also variable, ranging from 0.2% to 4.6% CaO.

Accessory minerals include nickel-iron, troilite, pentlandite, chromite, spinel, and tridymite; no feldspar was seen. Microprobe analyses show that the metal is uniformly of low nickel content, ranging from 3.0% to 6.4% Ni, with an average of 4.4%. Troilite contains less than 1% nickel. Pentlandite shows a variable nickel content, ranging up to 25.6% but averaging 10.0%; some of the variability in nickel content may be due to the redistribution of nickel during weathering. Chromite occurs as small grains with composition close to $FeCr_2O_4$; a minor amount of aluminium (3.3% Al_2O_3) was determined with the microprobe. A little spinel with composition approximately halfway between $MgAl_2O_4$ and $FeAl_2O_4$ was found with the microprobe. A mineral with composition close to pure SiO_2 was found in the interstitial glass of a pyroxene chondrule; its lath-like form suggests tridymite rather than quartz or cristobalite.

The limonite veinlets resulting from weathering are narrow (usually less than 0.1 mm across), and consist of red-brown goethite with some areas of bright yellow highly birefringent reevesite.

A thin slice was cut from the meteorite and analysed by Mr. E. Jarosewich of the Smithsonian Institution according to established procedures (Table 1). Because of the weathered state of the meteorite, iron was determined as total iron, from which was subtracted iron determined as metal and iron equivalent to S as FeS; the remaining iron was divided between FeO and Fe_2O_3 by calculating FeO from the mean composition of olivine and pyroxene determined by the microprobe. If the Fe_2O_3 in the analysis is recalculated as metallic Fe and the analysis recalculated to 100 after eliminating terrestrial oxygen and water, the nickel-iron content is 18.5 percent and the total Fe 28.2 percent, figures typical of bronzite (H group) chondrites. The calculated normative composition corresponds closely to the actual mineralogical composition, except that plagioclase was not observed in the meteorite, this mineral being represented by the glass in the chondrules. The highly chondritic nature of the meteorite, the variability of olivine and pyroxene composition and the presence of transparent glass in the chondrules indicate that it is an H3 chondrite according to the classification of Van Schmus and Wood (1967).

ACKNOWLEDGEMENTS

Thanks are due to Mr. L. S. Brown for his care in leaving three of the four pieces *in situ* until they could be examined, for having presented the meteorite to the Australian Museum and for his hospitality to Messrs Chalmers and Fletcher when they visited "Reola" the property on which Mr. Brown resides and which is near "Willaroy".

Mr. Brown's powers of observation are worthy of note. He is the finder of three meteorites. On 21 March, 1944, when as a young man he was mustering on his father's property "Nardoo", 26 km north-west of Wanaaring, in the Western Division of New South Wales, he found two stony meteorites, Nardoo No. 1 and Nardoo No. 2, lying about 9.5 km apart. These he also presented to the Australian Museum. Incidentally the general locality of the two Nardoo stones is about 109 km north-east of "Willaroy". When Mr. Brown found the Willaroy, although it was much more weathered than the two Nardoo stones, he was quite convinced that it, too, was a stony meteorite.

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- Van Schmus, W. R. and J. A. Wood, 1967. A chemical-petrologic classification for the chondritic meteorites. *Geochim. Cosmochim. Acta* 31: 747-766.
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Manuscript accepted for publication 25 March 1976

**Table 1. Chemical and Normative Composition of the Willaroy Meteorite
(E. Jarosewich, Analyst).**

Chemical Composition		Norm	
Fe	1.35	Olivine	25.3
Ni	1.37	Pyroxene	31.1
Co	0.07	Plagioclase	8.5
FeS	4.63	Troilite	4.6
SiO ₂	33.85	Nickel-iron	2.8
TiO ₂	0.13	Apatite	0.4
Al ₂ O ₃	2.13	Chromite	0.7
Cr ₂ O ₃	0.48	Ilmenite	0.2
Fe ₂ O ₃	22.50	Limonite	25.9
FeO	6.70		
MnO	0.27	<u>Total</u>	<u>99.5</u>
MgO	21.02	H ₂ O } C }	0.82
CaO	1.61		
Na ₂ O	0.61		
K ₂ O	0.12	<u>Total</u>	<u>100.3</u>
P ₂ O ₅	0.19		
H ₂ O (+)	2.70		
H ₂ O (-)	0.65		
C	0.17		
<u>Total</u>	<u>100.55</u>		
<u>Total Fe</u>	<u>25.30</u>		

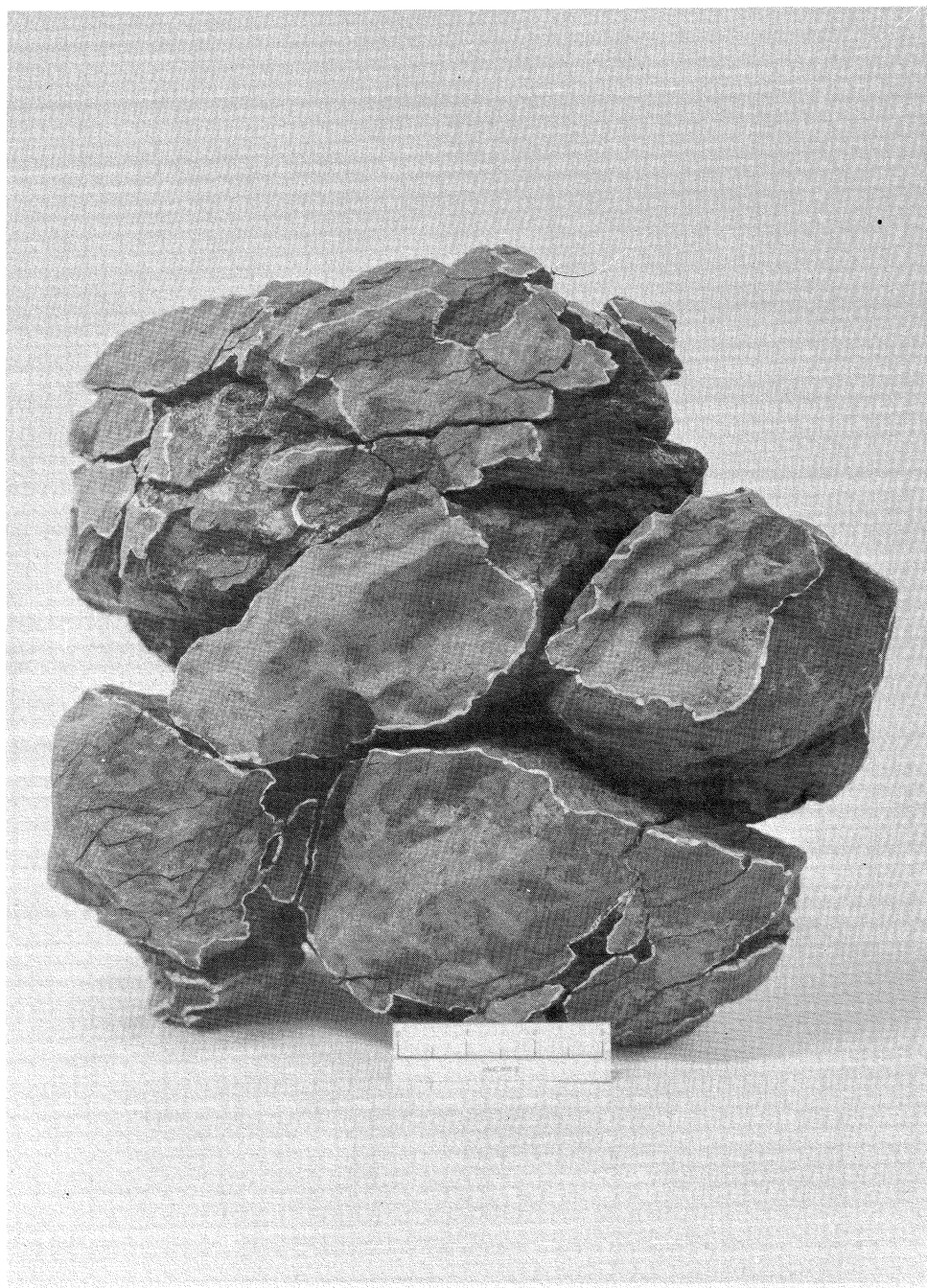


Fig. 1. A view of the reconstruction of the mass of the Rowena chondrite from 34.43 kg of fragments.

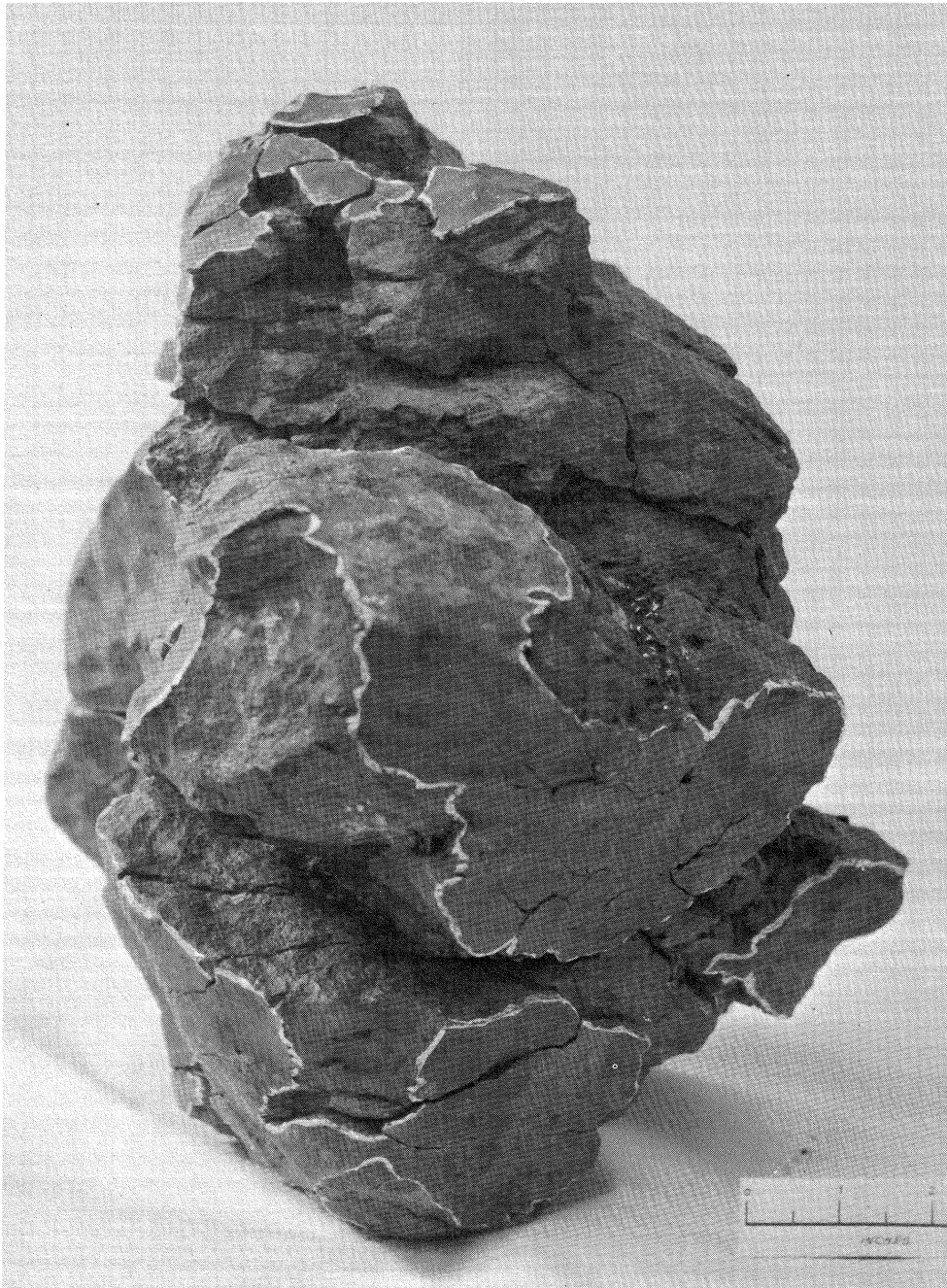


Fig. 2. Another view of the reconstruction of the mass of the Rowena chondrite from 34.43 kg of fragments.

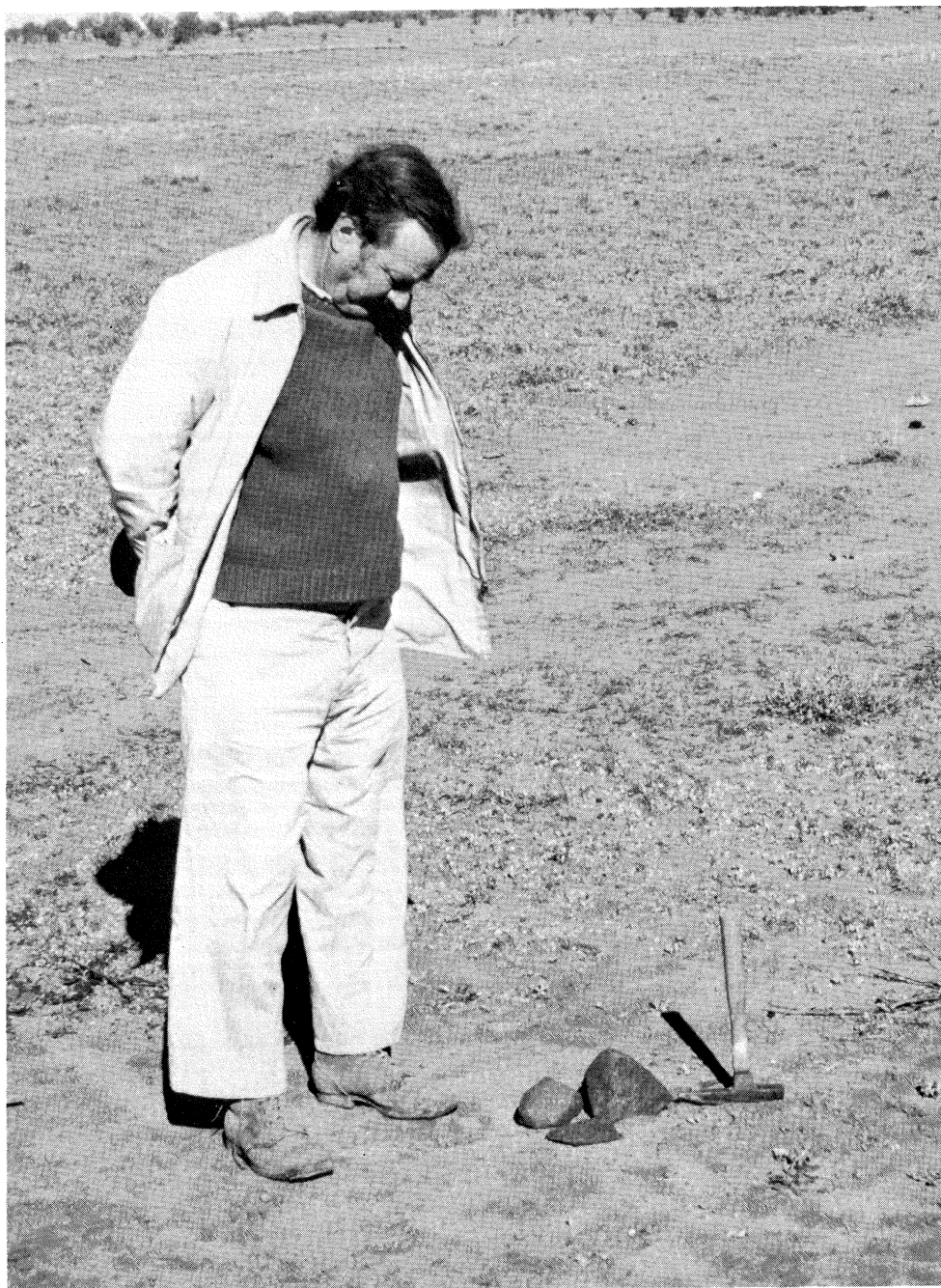


Fig. 3. Three fragments of the Willaroy chondrite *in situ*.



Fig. 4. The four fragments of the Willaroy chondrite fitted together.

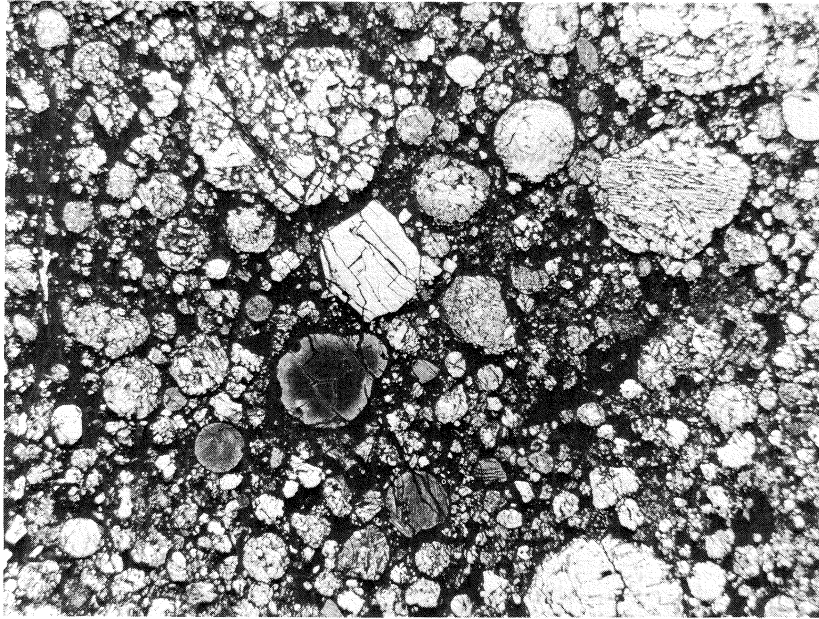


Fig. 5. Thin section, at low magnification, showing closely packed chondrules, 0.5-2 mm diameter, and irregular mineral fragments in a black opaque matrix; the large crystall fragment (1.0 mm across) is olivine.

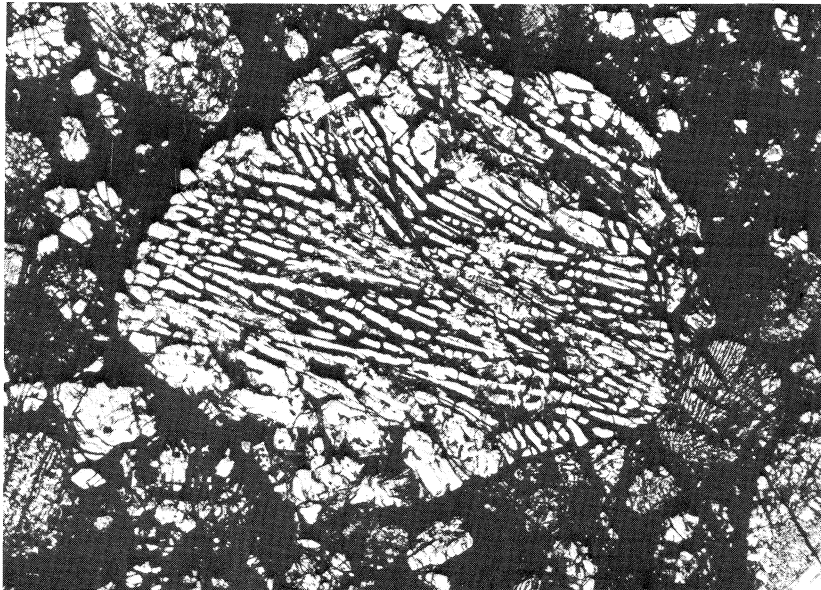


Fig. 6. Barred olivine chondrule with irregular form (maximum dimension 1.5 mm); the dark material between the olivine bars is partly devitrified glass.

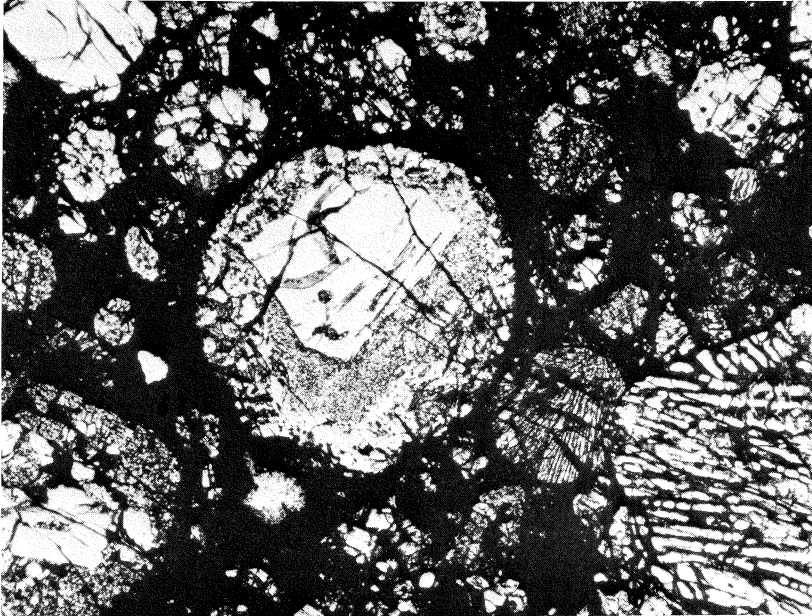


Fig. 7. Chondrule (0.9 mm diameter) consisting of an angular olivine fragment enclosed in a fine-grained groundmass, probably devitrified glass.

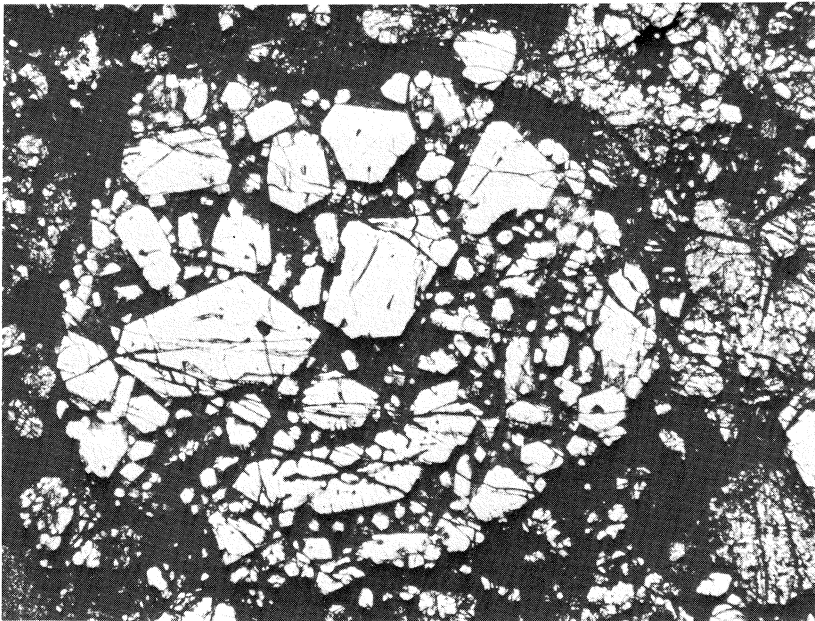


Fig. 8. Porphyritic olivine chondrule (maximum dimension 2.1 mm), with euhedral and subhedral olivine crystals in a dark matrix of partly devitrified glass.

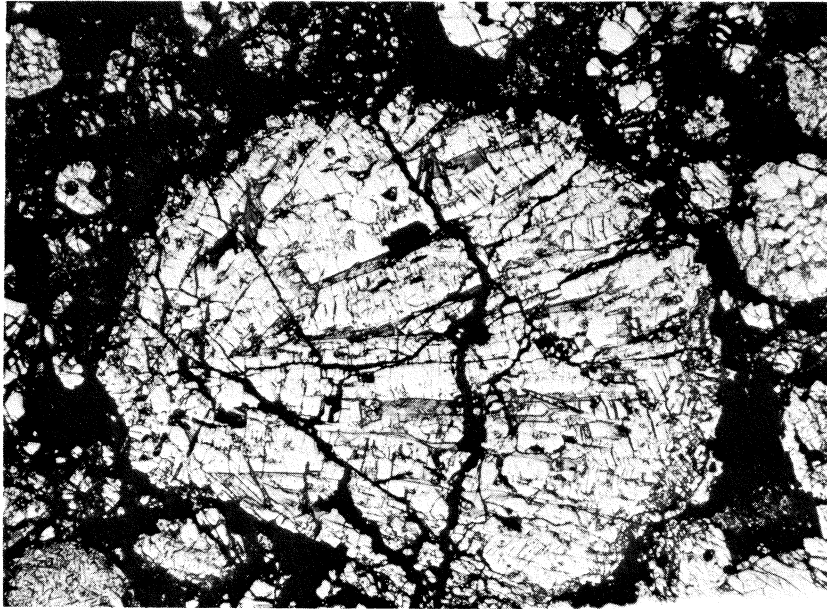


Fig. 9. Radiating pyroxene chondrule (maximum dimension 1.5 mm); a small amount of interstitial pale brown glass is present.

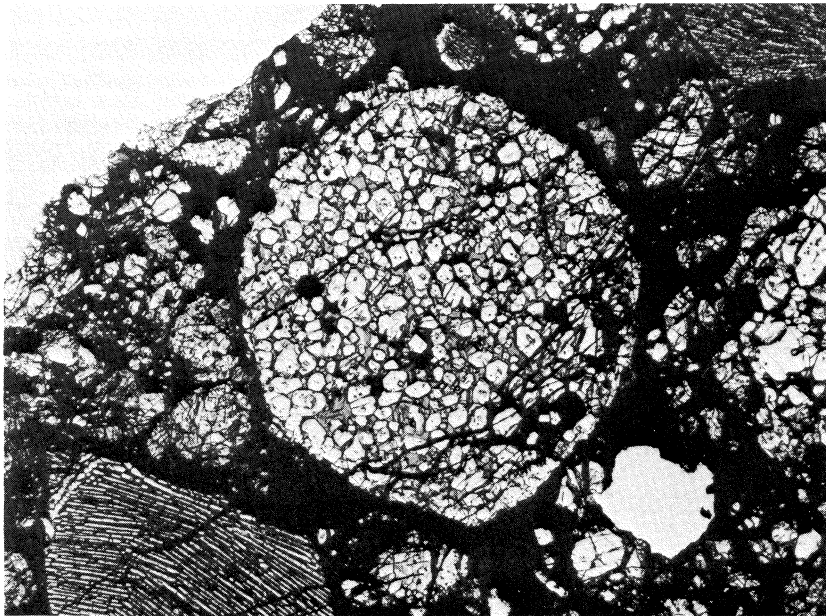


Fig. 10. Granular olivine chondrule (1.0 mm diameter); the material between the grains is pale brown undevitrified glass.

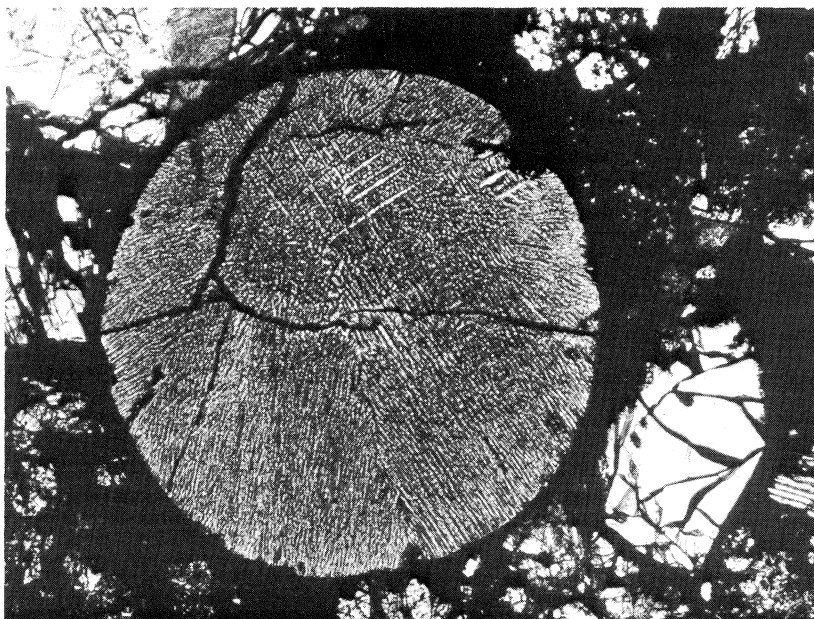


Fig. 11. Chondrule (0.5 mm diameter) of pale brown material, probably devitrified glass; under high magnification the material appears to be finely fibrous pyroxene.

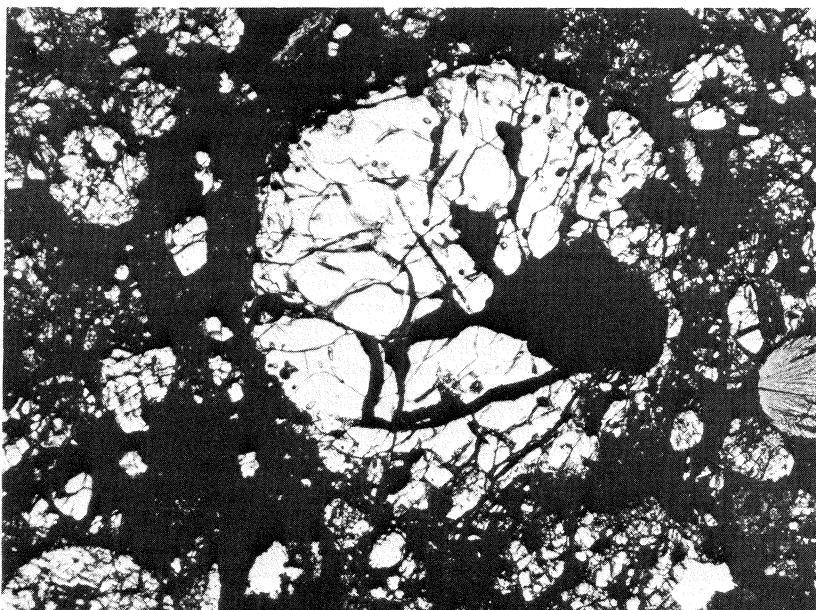


Fig. 12. Chondrule (1.2 mm diameter) of closely packed irregular olivine grains; the opaque material appears to be infiltrated carbonaceous matrix.