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THE CHEMISTRY AND MINERALOGY OF THE HOMEWOOD, MANITOBA, METEORITE

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The Homewood meteorite is a slightly weathered find of 325 grams discovered in 1970 about 64 km southwest of Winnipeg, Manitoba. It consists of olivine ($Fa_{25.4}$; 43.8 normative wt. percent), orthopyroxene ($Fs_{23.3}$; 28.5 percent), kamacite and taenite (7.5 percent), troilite (5.6 percent), maskelynite (8.3 percent), chromite (1.0 percent), whitlockite (0.7 percent) and minor patchy Ca pyroxene. Bulk chemical analysis yielded Fe_{total} 21.60 wt. percent, Fe/SiO_2 0.55, SiO_2/MgO 1.53 and Fe^0/Fe_{total} 0.29. Barred olivine, radiating pyroxene and porphyritic chondrules, all with ill-defined outlines, occur in the meteorite. Most chemical and mineralogical features characterize the Homewood meteorite as an L6 (hypersthene) chondrite. The presence of maskelynite, the undulatory extinction, extensive fracturing and pervasive mosaicism of olivine, and the poor definition of chondrule outlines suggest that the Homewood meteorite has been shocked in the range of 300-350 kbar.

INTRODUCTION

A stony meteorite was found in the summer of 1970 by R. Froebe on the farm of R. Bates, 4 km east of Homewood, Manitoba and approximately 64 km southwest of Winnipeg, Manitoba (lat. = 49°30.5′N, long. = 97°49′W). It was brought to the Department of Earth Sciences, University of Manitoba and it is now in the Department's Mineralogy Museum.

The Homewood is roughly cube-shaped with a mean edge length of ~ 45 mm (Fig. 1). The surface is covered by a slightly weathered thin black fusion crust that is generally smooth and has several regmaglypts. Sawn surfaces show only minor oxidation along internal fractures, with minor fresh metal and traces of troilite dispersed among the silicate phases.

ANALYTICAL TECHNIQUES

Thin sections and polished thin sections were examined in transmitted and reflected light. Electron microprobe analyses of minerals were performed on a MAC-5 instrument operating in the wave-length dispersive mode with an accelerating voltage of 20kV and a sample current of 0.04 μamps except for

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maskelynite where a sample current of 0.02 μamps was used in order to minimize vaporization of Na under the electron beam. The analyzing crystals used were LiF, PET and TAP. The following standards were used: pure metallic Fe, Ni and Co for kamacite and taenite; orthopyroxene XYZ (Burnham *et al.*, 1971) for Si, Ti, Al, Fe, Ca and Mn, and synthetic diopside for Mg, in orthopyroxene; olivine of known composition for Si, Fe, Mg and Mn in olivine; synthetic fluorapatite for Ca and P, Amelia albite for Na and orthopyroxene XYZ for Mg, Fe and Mn in whitlockite; chromite of known composition for all elements in chromite; Amelia albite for Si, Al and Na, orthoclase for K and rhodonite for Ca in maskelynite. Data reduction was done with EMPADR VII (Rucklidge and Gasparrini, 1969), and the results are given in Table 1.

A chemical analysis was carried out on both a whole rock sample and on the solute from a dilute HCl leach using the fine cuttings from a slab sawn in cooling water using a small thin blade. Samples used for analysis were dried

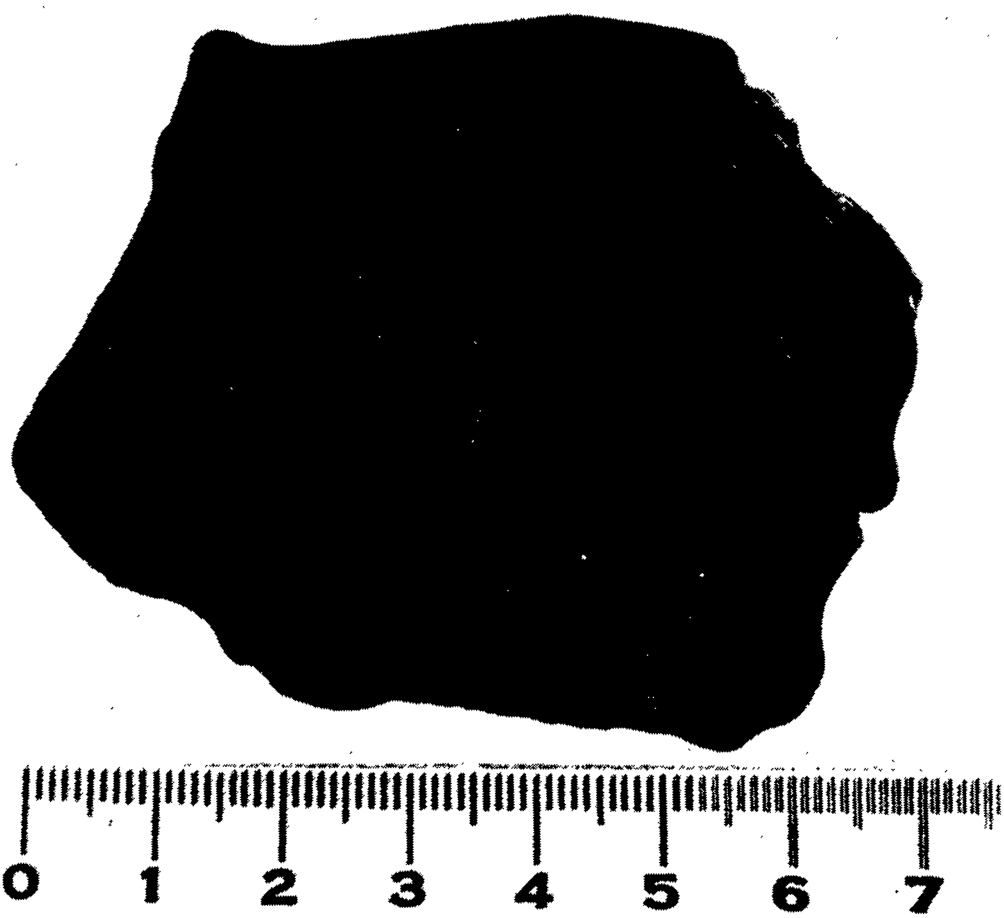

Fig. 1 **The Homewood chondrite.**

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Table 1
Homewood chondrite: average microprobe compositions of minerals (in weight percent). Number of grains analyzed is shown in parentheses.

	Olivine (6)	Ortho-pyroxene (6)	Maskelynite (6)	Chromite (6)	Whitlockite (6)
SiO_2	38.46	54.81	65.92		
TiO_2	*	0.18		2.17	
Al_2O_3	*	0.18	21.37	5.61	
Cr_2O_3	*			56.06	
FeO	22.59	14.81	0.49	32.91	1.79
MgO	38.39	28.01	*	2.29	2.62
CaO	*	0.82	1.91		46.62
MnO	0.37	0.68	*	0.65	0.03
Na_2O			9.51		2.78
K_2O			1.14		
P_2O_5					45.51
V_2O_3				0.79	
TOTAL	99.77	99.49	100.35	100.48	99.35
Si	1.00	1.98	2.90		
Ti		0.01		0.46	
Al		0.01	1.11	1.88	
Cr				12.61	
Fe	0.49	0.45		7.83	0.27
Mg	1.49	1.51		0.97	0.71
Mn	0.01	0.02		0.16	0.01
Ca		0.03	0.09		9.06
Na			0.81		0.98
K			0.06		
P					6.99
V				0.15	
O	4.00	6.00	8.00	32.00	28.00

Ranges and means of end-member compositions (mol %):
Olivine Fo 75.5-73.8, 74.6, Fa 24.5-26.2, 25.4
Orthopyroxene En 76.0-74.3, 75.1, Fs 22.4-24.1, 23.3

at ~ 110 °C for 8 hours. Elements were determined as follows: Si, Al, Fe, Ca, K, Ti and Mn on a ½-gram sample by X-ray fluorescence; Ni, Co, Cu, Mg and Na on a 0.1 gram sample by atomic absorption; P by a standard spectrophotometric technique; and S on a 0.1 gm and total H_2O and CO_2 on 0.4 gm of sample by respectively titrating and weighing the gases evolved during heating in an induction furnace. The results are reported in Table 2.

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Table 2
Homewood chondrite: bulk chemical analysis, normative composition (both in weight percent), and chemical parameters

	Bulk rock	Solute from dilute HCl	Analysis recalculated with respect to Fe
SiO_2	38.50	–	38.50
MgO	25.20	(Mg 7.19)	25.20
FeO	27.30*	–	14.70
Al_2O_3	2.80	–	2.80
CaO	2.30	–	2.30
Na_2O	0.82	–	0.82
K_2O	0.06	–	0.06
Cr_2O_3	0.53	–	0.53
MnO	0.31	–	0.31
TiO_2	0.07	–	0.07
P_2O_5	0.31	–	0.31
Fe	–	15.30	6.17
Ni	1.18	0.907	1.18
Co	0.06	0.06	0.06
Cu	0.27+	0.01	–
S	2.08	0.066**	–
FeS	–	–	5.70
H_2O^+	0.20+	–	–
H_2O^-	2.13+	–	–
C	0.35+	–	–
TOTAL			98.71

CHEMICAL PARAMETERS		NORMATIVE COMPOSITION++	
Fe_{total}	21.22	Olivine	45.9 wt %
Fe_{total}/SiO_2	0.55	Orthopyroxene	29.9
SiO_2/MgO	1.53	Kamacite/Taenite	7.9
Fe°/Fe_{total}	0.29	Troilite	5.9
		Maskelynite	8.7
		Chromite	1.0
		Whitlockite	0.7
			100.0

*Total iron (in silicate + free metal + sulfide) as FeO.
**S in residue from HCl leach.
+See text.
++Calculated using the microprobe analyses of the minerals.

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MINERALOGY AND PETROGRAPHY

Microprobe analyses of the minerals are given in Table 1, and a bulk chemical analysis of the meteorite in Table 2. Both olivine ($Fa_{25.4}\,Fo_{74.6}$) and orthopyroxene ($En_{75.1}Fs_{23.3}Wo_{1.6}$) occur as single large grains of 1-2 mm diameter, as constituents of the fine-grained matrix and in chondrules; both minerals are unzoned and of uniform composition. Olivine is moderately to intensely fractured and shows undulatory extinction; however, no kink bands or other planar deformation features are present. Calcic pyroxene was identified by electron microprobe as some very fine-grained Ca-rich silicate patches in the matrix, none of which was large enough to give a reliable analysis. Maskelynite ($Ab_{84.1}An_{9.3}Or_{6.6}$) occurs in evenly-distributed patches, along some chondrule-matrix boundaries, around some kamacite/taenite grains, and along a major fracture through the meteorite. Kamacite and taenite are intimately associated, and occur as anhedral grains up to 2 mm across; fine inclusions distributed uniformly throughout the meteorite may also be kamacite/taenite. It was not possible to differentiate the two metal phases in the microscope of the microprobe, and hence the identification was based on the microprobe analyses. Kamacite is fairly uniform in composition ($Fe_{0.93}Ni_{0.06}Co_{0.01}$) at the centres of the grains, with a decrease in the Ni content at the margin of the grains, while taenite has a much more variable composition (average composition $Fe_{0.745}Ni_{0.251}Co_{0.004}$). Many metal grains are partially rimmed by maskelynite, troilite and/or chromite. Trolite occurs as anhedral polycrystalline grains containing abundant inclusions that are generally too fine-grained to identify; larger inclusions prove to be globules of silicate material. Chromite occurs as subhedral grains; its chemical composition $[Fe^{2+}_{6.88}Mg_{0.97}Mn_{0.16}]\ [Cr_{12.61}Al_{1.88}V_{0.15}Ti_{0.46}Fe^{2+}_{0.96}]O_{32}$ is in the range of compositions found for chromite in L-group chondrites (Bunch *et al.*, 1967). A cell edge of 8.20A was derived from a Gandolfi photograph of this chromite. Whitlockite $Ca_{9.06}(Mg_{0.71}Fe^{2+}_{0.27}Mn_{0.01})Na_{0.98}P_{6.99}O_{28}$ occurs as small anhedral crystals dispersed throughout the matrix.

Thin sections show three types of chondrules with poorly-defined outlines set in a fine-grained, recrystallized matrix exhibiting indistinct grain boundaries and some polycrystalline grains (Fig. 2). The chondrules constitute approximately one-fifth of the meteorite, and their linear arrangement results in a weakly foliated appearance. Barred olivine chondrules are the most abundant, and they exhibit two variations: (i) parallel skeletal olivine crystals that form monosomatic grains, and (ii) an orthogonal net of skeletal olivine crystals optically continuous with the outer rim of the chondrule. Porphyritic chondrules are the next most abundant, and consist of masses of granular subhedral olivine and pyroxene. Radiating pyroxene chondrules occur in small amount, and consist of radiating laths of orthopyroxene with interstitial microcrystalline silicate material.

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BULK COMPOSITION

A whole rock analysis, the chemical parameters and the normative composition are given in Table 2. The analysis shows high Cu, C and $H_2O\pm$. Cu is normally present in the range ~ 0.01 wt %, and the slight excess was thought to be due to slight contamination of the sample from the saw blade on which the diamond teeth were mounted in brass; in support of this, an analysis showed 0.01 wt % Zn (not shown in the Table). Similarly, the somewhat high C is attributed to the saw blade. The high $H_2O\pm$ value was completely incompatible with the small amount of secondary iron hydroxides observed in the meteorite, and was presumed to result from absorbed water. Thus Cu, C and $H_2O\pm$ were excluded from the recalculated values given in Table 2.

Recalculation of Fe into its different states as given in Table 2 was done by subtracting from the total Fe as FeO (1) sufficient Fe to combine with S to form troilite, and (2) the FeO equivalent to the metallic Fe found in the solute, to leave the remainder as FeO occurring in the silicates and chromite which is the amount reported in the recalculated column as FeO. The recalculated analysis in Table 2 is close to that of other L-type chondrites (Jarosewich 1966, 1967; Jarosewich and Mason 1969; Dube *et al.*, 1975).

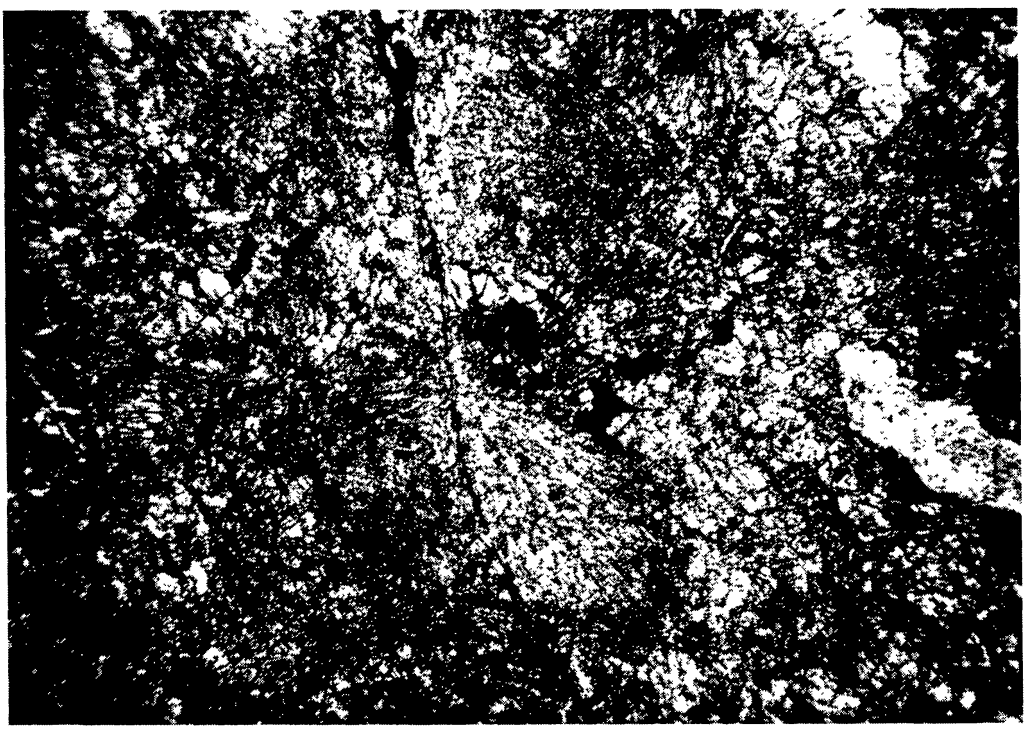

Fig. 2 Thin section of the Homewood chondrite showing poorly-defined outlines of the chondrules. The elongated chondrule in the right center is ~ 2 mm long.

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The normative composition given in Table 2 was calculated using the initial bulk chemical analysis and the electron microprobe mineral compositions. The amounts of components due to whitlockite, chromite, maskelynite and troilite were calculated and subtracted from the total composition. The remaining amounts of SiO_2 and MgO were used to calculate the amounts of olivine and orthopyroxene, and then the FeO contribution from these two minerals was subtracted from the total remaining FeO to give the amount of FeO equivalent to the metallic Fe in the analysis.

DISCUSSION

The presence of only small amounts of secondary iron oxides and hydroxides suggests that the terrestrial age of the meteorite is only a few decades; this view is supported by the good preservation of the glassy fusion crust. The chemical parameters listed in Table 2 show the Homewood meteorite to belong to the L group of Van Schmus and Wood (1967). The uniformity of the compositions of the olivines and pyroxenes, the clear interstitial feldspar (maskelynite) and the absence of igneous glass, the recrystallized matrix and the poorly defined outlines of the chondrules are all characteristic of a type 6 chondrite in the petrologic classification of Van Schmus and Wood (1967) even though the presence of fine inclusions suggests type 5. Thus the Homewood meteorite is an L6 (hypersthene) chondrite.

The complete lack of crystalline feldspar is indicative of shock pressures from 300-350 kb (M.R. Dence, pers. comm. 1975). In agreement with this, olivine is moderately to intensely fractured with pervasive mosaicism and undulatory extinction; however, no kink bands or other planar deformation features are present. These textural features indicate a heavy shock event (Carter *et al.*, 1968; Van Schmus and Ribbe, 1968).

ACKNOWLEDGMENTS

This work constitutes part of an M.Sc. thesis submitted by W.K. Mysyk to the Department of Earth Sciences, University of Manitoba.

The authors wish to thank A.G. Plant, Geological Survey of Canada, Ottawa for microprobe analyses of olivine and for valuable discussions; and M.R. Dence of the Earth Physics Branch, Ottawa, E.I. Leith, G.S. Clark and A.C. Turnock of the University of Manitoba, and D.G.W. Smith of the University of Alberta for comments and discussions during this study. Financial assistance was provided by the National Research Council of Canada (grant to R.B. Ferguson).

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Manuscript received 12/20/78

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