

STUDIES OF BRAZILIAN METEORITES VI. MINERALOGY, PETROLOGY, AND CHEMISTRY OF THE PATRIMÔNIO, MINAS GERAIS, CHONDRITE

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ABSTRACT — A detailed microscopic (transmitted and reflected light), electron microprobe, and bulk chemical study of the previously undescribed Patrimônio, Minas Gerais, chondrite was carried out. The meteorite consists of major olivine (Fa_{24.8}), orthopyroxene (Fs_{20.7}), and plagioclase (Or_{6.6} Ab_{82.1} An_{11.3}), minor metallic nickel-iron and troilite, and accessory diopside (En_{47.6} Fs_{8.5} Wo_{43.9}), whitlockite, and chromite. Based on olivine, orthopyroxene, chromite and the bulk compositions, particularly the ratios of Fe_{total}/SiO₂ (0.54), Fe⁰/Fe_{total} (0.24), and Fe⁰/Ni⁰ (4.45), and bulk Fe_{total} (21.51%) and bulk metallic nickel-iron contents (6.25%), Patrimônio belongs to the L — group. Textural and mineralogical evidence, particularly the uniform and homogeneous compositions of olivine and orthopyroxene, the occurrence of only poorly defined chondrules, the extensive recrystallization, and the presence of clear, interstitial plagioclase, suggest that Patrimônio belongs to the petrologic class L6.

RESUMO — O meteorito Patrimônio, Minas Gerais, foi submetido a uma investigação minuciosa utilizando técnicas microscópicas (luz refletida e transmitida), análise por microsonda eletrônica e estudo da química global. O meteorito, um condrito típico, consiste essencialmente de olivina (Fa_{24.8}), ortopiroxênio (Fs_{20.7}) e plagioclásio (Or_{6.6} Ab_{82.1} An_{11.3}), aparecendo em proporções menores as fases metálicas (kamacita e taenita) e troilita; diopsídio (En_{47.6} Fs_{8.5} Wo_{43.9}), whitlockita e cromita constituem os acessórios mais importantes. Com base na química mineral (olivina, ortopiroxênio e cromita) e global, particularmente as razões Fe_{total} / SiO₂ (0,54), Fe⁰ / Fe_{total} (0,24) e Fe⁰ / Ni⁰ (4,45), o conteúdo de Fe_{total} (21,51%) e a concentração das fases metálicas (6,25%), o meteorito Patrimônio é enquadrado no Grupo L dos condritos. Evidências mineralógicas e texturais, em especial a composição uniforme e homogênea das olivinas e ortopiroxênios, a ocorrência rara de côndrulos perfeitamente definidos, a recristalização pronunciada e a presença de plagioclásio límpido intersticial, são sugestivas de que o meteorito pertence à classe petrológica L6.

INTRODUCTION

The Patrimônio meteorite (also referred to as Conceição Aparecida and Morro Cavado) fell in the district of Conceição Aparecida (approximate coordinates: latitude 19°32'S, longitude 48°34'W), State of Minas Gerais, Brazil, at 9.50 hours on Sunday morning, August 6, 1950. The place of fall, Fazenda do Morro Cavado, is situated in the small village of Patrimônio, about 11 miles from Conceição Aparecida. The fall was accompanied by light and sound phenomena; the sound was heard three times and lasted almost 10 minutes. According to witnesses, the body travelled from the SW to the NE. At least 20 stones fell, and pieces ranging in weight from 600 to 1800 grams were immediately recovered. Since many fragments were collected and taken away by residents from the nearby cities, some confusion has arisen as to the exact place of fall.

Brief references to the Patrimônio meteorite were made by Leonard (1956), Keil (1960), and Hey (1966). Mason (1963) measured the composition of its olivine by optical microscopy, and Santos (1972) published an abstract dealing with the petrography and chemistry of the stone. However, no comprehensive mineralogic, petrographic, and chemical study of this meteorite has yet been performed, and it is the main purpose of the present paper to provide these data and to classify the meteorite.

METHODS OF STUDY

The Patrimônio meteorite was studied microscopically in transmitted and reflected light, and its constituent phases were analyzed by electron microprobe techniques. Furthermore, its bulk chemical composition was determined following the procedures described by Jarosewich (1966). Electron microprobe analyses were made with an ARL EMX-SM instrument, using an accelerating voltage of 15 KeV, a sample current of about 0.02 μ Amp, and a spot size of $\leq 1 \mu$ m in diameter. Standards used were olivine

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(Marjalahti), augite (A-209), plagioclase (AC-362), and chromite (C53IN8). Intensity data were corrected for background, instrumental drift, and differential matrix effects using the method of Bence and Albee (1968).

TEXTURAL AND MINERALOGICAL DESCRIPTION

The Patrimônio meteorite has a poorly developed chondritic texture (Fig. 1), with only a few chondrules showing discernible boundaries with the matrix. The chondrules are round to elongate in shape and range in size from 0.3 to 1.8 mm (mean 1.2 mm). They are mostly poly-somatic, but some monosomatic types were also observed. Internal textures are variable and porphyritic, granular, and barred types were recognized.

Olivine, orthopyroxene and plagioclase are the major constituents of the chondrite, with metallic nickel-iron and troilite occurring in minor and high-Ca clinopyroxene, whitlockite, and chromite occurring in accessory amounts. Finely-crystalline (formerly glassy) material occurs as a very rare constituent of chondrules and of the matrix.

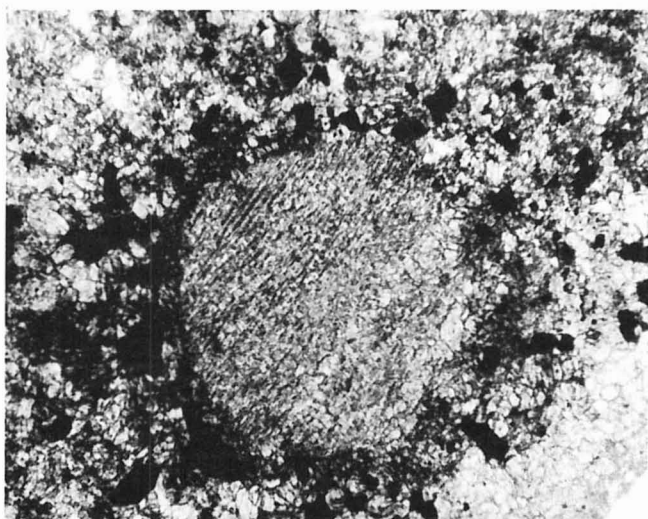


Fig. 1 Relict chondrule consisting mainly of olivine. Transmitted light. 45 X.

Olivine: This mineral occurs in relict chondrules, as granular or regular grains, or in the matrix as granoblastic crystals. In chondrules, olivine is commonly associated with pyroxene and occasionally poikilitically enclosed in it. Olivine in chondrules and in the matrix is identical and homogeneous in composition, averaging $Fa_{24.8}$ (Table 1). The homogeneity of the olivine is indicated by its narrow compositional range (Fig. 2), and its composition falls well within the range of Fa contents of L-group chondrites (Keil and Fredriksson, 1964; revised by Fodor et al., 1976).

Pyroxene: Orthorhombic pyroxene (bronzite in composition) is dominant, and only a few grains of high-Ca clinopyroxene were identified. Pyroxene occurs in relict chondrules, usually as prismatic to lamellar grains, or as crystals in the matrix. Polysynthetic twinning was observed in some of the high-Ca clinopyroxene grains. Orthopyroxene is very uniform in composition, averaging $Fs_{20.7} En_{77.6} Wo_{1.7}$ (Table 1). The limited compositional range (Fig. 2) is well within that for L-group chondrites (Keil and Fredriksson, 1964; revised by Fodor et al., 1976). High-Ca clinopyroxene

is diopside in composition (Table 1), averaging $Fs_{8.5} En_{47.6} Wo_{43.9}$.

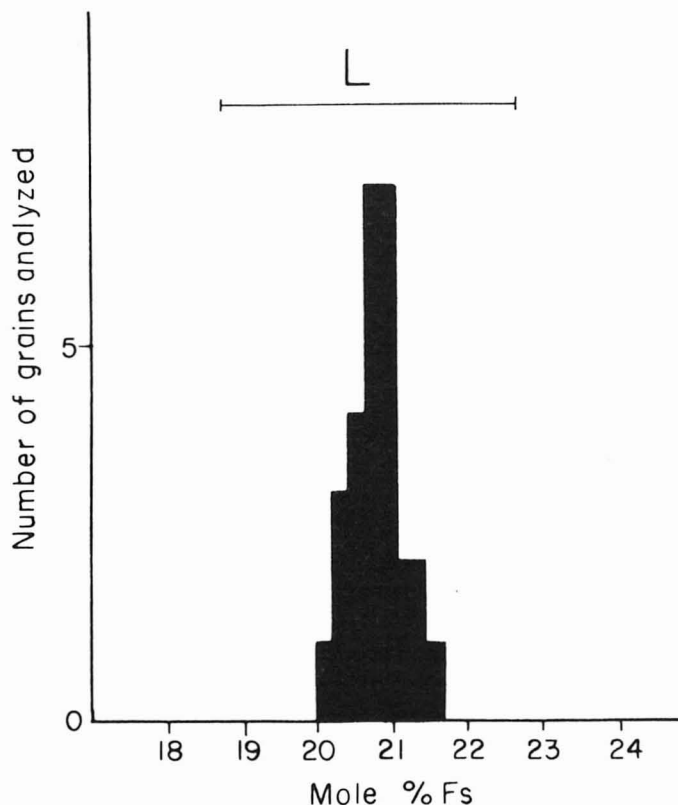
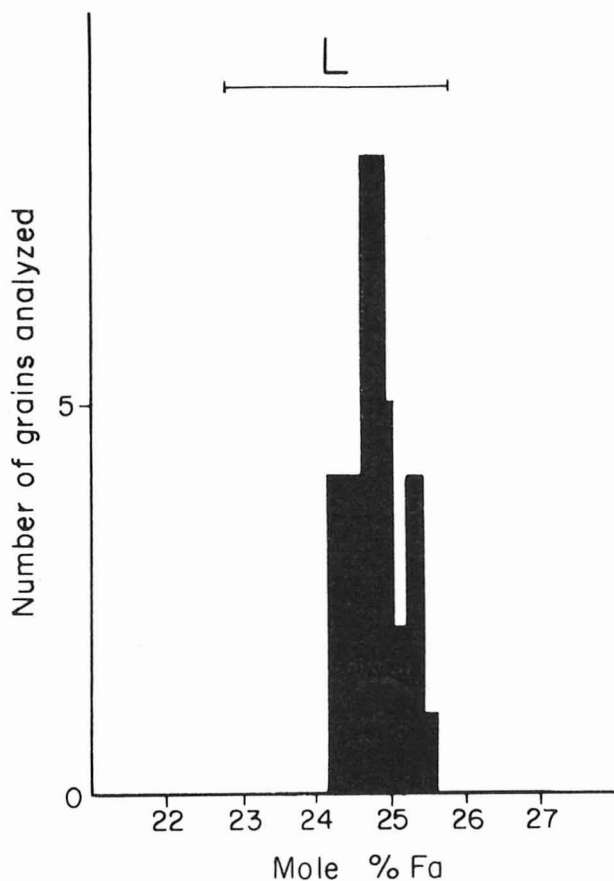


Fig. 2 Histogram showing the compositions (in mole %) of olivine ($Fa : Fe_2SiO_4$) and orthopyroxene ($Fs : FeSiO_3$). L-group classification is indicated for Patrimônio by comparison to the ranges of average olivine and orthopyroxene compositions in equilibrated H-group chondrites (Keil and Fredriksson, 1964; as revised by Fodor et al., 1976).

Table 1

Electron microprobe analyses (in weight percent) and structural formulae of olivine, bronzite, diopside, plagioclase, and chromite from the Patrimônio, Brazil, chondrite. Number of grains analyzed are shown in parentheses

	Olivine (28) S.D.		Bronzite (27) S.D.		Diopside (15) S.D.		Plagioclase (19) S.D.		Chromite (22) S.D.	
SiO ₂	38.5	0.3	55.9	0.3	54.3	0.5	65.3	0.4	0.18	0.03
TiO ₂	n.d.	—	n.d.	—	n.d.	—	n.d.	—	2.94	0.27
Al ₂ O ₃	0.07	0.03	0.23	0.05	0.63	0.06	21.4	0.2	5.7	0.2
Cr ₂ O ₃	n.d.	—	n.d.	—	n.d.	—	n.d.	—	54.5	0.4
V ₂ O ₃	n.d.	—	n.d.	—	n.d.	—	n.d.	—	0.72	0.04
FeO	22.7	0.3	13.9	0.3	5.2	0.5	0.75	0.16	32.3	0.4
MnO	0.45	0.03	0.47	0.02	0.21	0.02	n.d.	—	0.88	0.08
MgO	38.7	0.3	29.1	0.2	16.6	0.4	0.38	0.05	2.7	0.2
CaO	<0.02	0.02	0.87	0.10	21.3	0.5	2.24	0.04	n.d.	—
Na ₂ O	n.d.	—	0.05	0.03	0.71	0.06	9.0	0.3	n.d.	—
K ₂ O	n.d.	—	n.d.	—	n.d.	—	1.10	0.08	n.d.	—
Total	100.44		100.52		98.95		100.17		99.92	

Number of ions on the basis of

	O = 4	O = 6	O = 6	O = 32	O = 32
Si	0.999	1.990	2.005	11.516	0.051
Ti	—	—	—	—	0.631
Al	0.002	0.010	0.027	4.448	1.917
Cr	—	—	—	—	12.296
V	—	—	—	—	0.165
Fe	0.492	0.414	0.161	0.111	7.708
Mn	0.010	0.014	0.007	—	0.213
Mg	1.497	1.544	0.914	0.100	1.148
Ca	—	0.033	0.843	0.423	—
Na	—	0.003	0.051	3.077	—
V					—

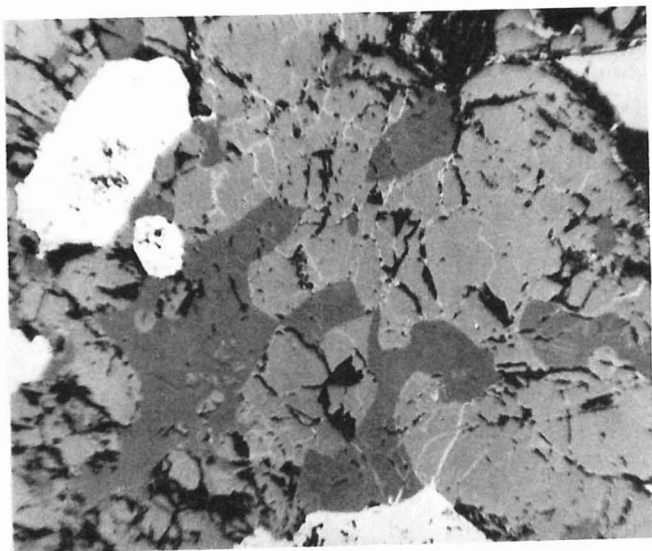


Fig. 3 Interstitial feldspar (dark gray), oligoclase in composition, surrounded by olivine grains (light gray) and metallic nickel-iron (white). Reflected light. 200 X.

Table 2

Chemical analysis and CIPW norm
of the Patrimônio chondrite

SiO ₂	39.84	Olivine	Fo	30.4
TiO ₂	0.11		Fa	16.3
Al ₂ O ₃	2.06	Hypersthene	En	16.3
Cr ₂ O ₃	0.47		Fs	8.0
FeO	16.11	Diopside	Wo	2.8
MnO	0.33		En	1.7
MgO	24.36		Fs	0.8

The analysis clearly indicates that the Patrimônio chondrite belongs to the L-group (Keil, 1969). This is evident, for example, from the $\text{Fe}_{\text{total}}/\text{SiO}_2$ ratio of 0.54 (average L-group 0.55; Van Schmus and Wood, 1967); the $\text{Fe}^0/\text{Fe}_{\text{total}}$ ratio of 0.24 (average L-group 0.33; Van Schmus and Wood, 1967); and the Fe^0/Ni^0 ratio of 4.45 (average L-group 6.87; Craig, 1964). Furthermore, L-group classification is also apparent from the total iron content of 21.51% (average L-group 21.82%; Craig, 1964) and the total metal content of 6.25% (average L-group 6.85%; Keil, 1962 a, b).

CONCLUSIONS

On the basis of the mineral compositions, particularly the Fe/Fe + Mg ratios in olivine, orthopyroxene, and chromite, and the bulk composition, particularly the ratios of $\text{Fe}_{\text{total}}/\text{SiO}_2$, $\text{Fe}^0/\text{Fe}_{\text{total}}$, and Fe^0/Ni^0 and the bulk total iron and bulk metallic nickel-iron contents, it is evident that the Patrimônio chondrite belongs to the L-group. Textural and mineralogical evidence, particularly the uniform and homogeneous compositions of olivine and orthopyroxene, as well as the occurrence of only poorly defined chondrules, the extensive recrystallization of the matrix, and the presence of clear interstitial plagioclase, suggest that the chondrite belongs to the petrologic class L6 of Van Schmus and Wood (1967).

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