Chem. Erde Bd. 37, S. 265–270 (1978)

Studies of Brazilian Meteorites XVI. Mineralogy, Petrology and Chemistry of the Ipiranga, Paraná, Chondrite

Studien Brasilianischer Meteoriten XVI. Mineralogie, Petrologie und Chemie des Chondriten Ipiranga (Staat von Paraná)

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With 2 Figures

Abstract

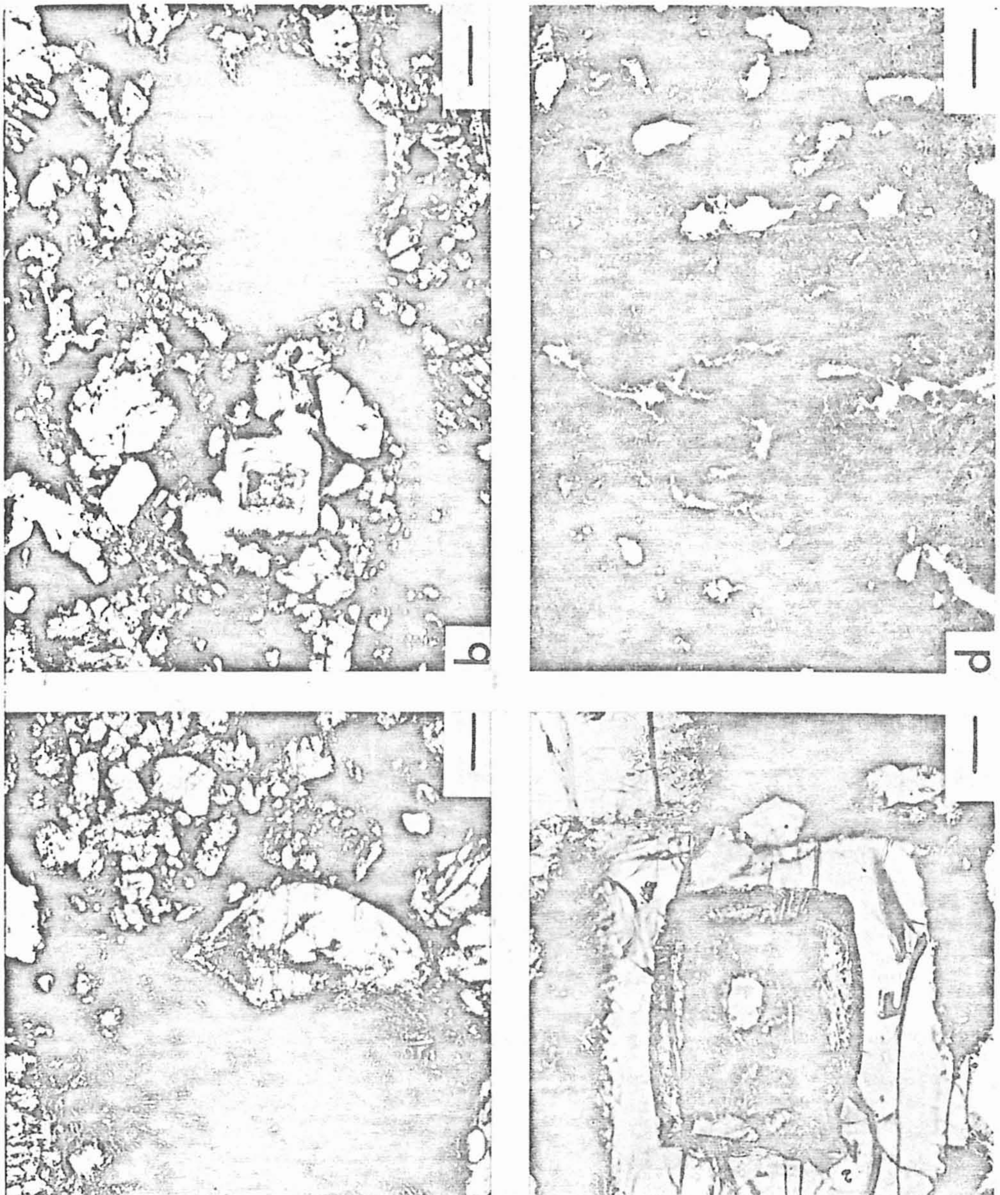
The Ipiranga, Paraná, Brazil chondrite fell at 10 : 30 a. m. on December 27, 1972. At least 30 stones were recovered, weighing over 7 kg. The meteorite has a recrystallized, chondritic texture and consists of major olivine ($Fa_{19.0}$), low-Ca pyroxene ($Fs_{16.8}$) and metallic NiFe; minor troilite and oligoclase ($Ab_{82.8}An_{12.2}Or_{5.0}$); and accessory chromite ($Cm_{77.9}Uv_{6.3}Pc_{3.0}Sp_{12.7}$). Mineral and bulk composition (Fe_{total}/SiO_2 0.71; Fe°/Fe_{total} 0.57; Fe°/Ni° 8.91; Fe_{total} 26.27 %; metallic NiFe 16.73 %) indicate H-group classification, and homogeneous, uniform mineral compositions; marked degree of recrystallization; and absence of igneous glass indicate that the stone is of petrologic type 5.

Zusammenfassung

Der Chondrit Ipiranga (Staat von Paraná, Brasilien) fiel 10^{30} morgens am 27. Dezember 1972. Mindestens 30 Steine wurden gesammelt, mit einem Gesamtgewicht von über 7 kg. Der Meteorit hat eine rekristallisierte, chondritische Textur und ist zusammengesetzt aus den Hauptbestandteilen Olivin ($Fa_{19,0}$), niedrig-Ca Pyroxen ($Fs_{16,8}$) und metallischem NiFe; den Nebenbestandteilen Troilit und Oligoklas ($Ab_{82,8}An_{12,2}Or_{5,0}$); und dem akzessorischen Chromit ($Cm_{77,9}Uv_{6,3}Pc_{3,0}Sp_{12,7}$). Mineral- und Gesamtzusammensetzung (Fe_{gesamt}/SiO_2 0,71; Fe°/Fe_{gesamt} 0,57; Fe°/Ni° 8,91; Fe_{gesamt} 26,27 %; metallisches NiFe 16,75 %) zeigen, daß der Meteorit zur H-Gruppe gehört. Die Klassifikation als petrologischer Typ 5 ist ersichtlich aus den homogenen Zusammensetzungen der Mineralien, dem hohen Grad der Rekristallisation sowie aus der Abwesenheit von Glas.

1. Introduction

The Ipiranga chondrite fell on December 27, 1972, at 10 : 30 a. m., at Lajeado do Ipiranga, Foz do Iguaçu County, State of Paraná, Brazil (25° 30′ S, 54° 30′ W). A fireball was observed passing through a cloudless sky from approximately east to west, leaving a smoke trail that lasted for more than 15 minutes. Two strong detonations were heard, followed by sound resembling machine-gun fire. The fall was observed by many eyewitnesses including an airline pilot flying the route from São Paulo to Foz do Iguaçu at an altitude of 2000 m, who noticed the fireball while the plane was flying over the Garapuava district, about 300 km from Foz do Iguaçu. Near Lajeado do Ipiranga, windows and doors of houses were shaken and cups and bookcases vibrated. At least two small impact pits were observed, the largest of which was 25 cm in diameter and 45 cm deep. A total of at least 30 individual meteorite specimens weighing over 7 kg were recovered. Individual specimens are highly variable in size and weight; apparently, the largest stone weighed 2.65 kg. Many of the samples were collected immediately after the fall and are said to have been hot. The estimated size of the strewnfield was at least 40 km in longest dimension.


b
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a
c

The meteorite was first described by CAVARRETTA et al. (1975) in a brief abstract that provided a bulk chemical analysis and a petrologic classification (H5) of the stone. A more detailed description of the mineralogy and texture of the chondrite was given by ANGELUCCI and FUNICIELLO (1975).

Here, we present additional data on the mineralogy and petrography of this meteorite in an effort to provide further support for its classification. Emphasis is given to electron microprobe analyses of constituent phases (olivine, low-Ca pyroxene, plagioclase, chromite), since no such data had previously been published on this stone. In addition, a new bulk chemical analysis was made.

2. Analytical Procedures

Polished thin sections of the meteorite were studied in transmitted and reflected light, and constituent minerals were analyzed with an automated ARL EMX-SM electron microprobe, using previously described analytical conditions, standards, and correction procedures (e. g. KEIL et al. 1978). Feldspar analyses were made using short integration times of 2 sec. to avoid excessive heat built-up and alkali loss during analysis. The bulk chemical analysis was performed according to modified procedures of JAROSEWICH (1966).

3. Mineralogy and Petrography

The meteorite has a chondritic texture, with round to elongate chondrules ranging in apparent diameter from 0.2–2.0 mm. Their textures are varied and include fibrous (Fig. 1 a), excentro-radial (Fig. 1 b), porphyritic (Figs. 1 a, b), poikilitic, barred and granular types. Some chondrules contain fine-grained, microcrystalline material (Fig. 1 b) and skeletal olivine crystals (Figs. 1 b, c), indicative of their crystallization from supercooled melts. The chondrules are embedded into a matrix consisting of mineral fragments of widely varying grain sizes, including some fine-grained, microcrystalline material.

The meteorite has been shocked by extraterrestrial impact collisions as is evidenced by the occurrence of wavy extinction and deformation of structural planes (cleavage, twinning) in minerals and of shock veins consisting of glass, mafic silicate relicts and remelted metallic nickel-iron-troilite intergrowths (Fig. 1 d). The meteorite is also recrystallized, with clear grains of plagioclase being readily discernible.

Major minerals are homogeneous olivine (avg. $Fa_{19.0}$, Table 1, Fig. 2), homogeneous low-Ca pyroxene (avg. $Fs_{16.8}$, Table 1, Fig. 2), and metallic nickel-iron. Minor minerals are troilite and homogeneous plagioclase of oligoclase composition (avg. $Ab_{82.8}An_{12.2}Or_{5.0}$, Table 1), and homogeneous chromite (avg. $Cm_{77.9}Uv_{6.3}Pc_{3.0}$ $Sp_{12.7}$, Table 1) is an accessory phase. Pentlandite and oldhamite were described on the basis of microscopic studies from this meteorite as accessory phases by ANGELUCCI and FUNICIELLO (1975). However, the occurrence of oldhamite is doubtful:

Fig. 1a. Chondrule consisting of fibrous pyroxene and idiomorphic olivine crystals (light). In the right corner is visible a porphyritic chondrule, consisting mainly of olivine, embedded into fine-grained material. Black is troilite. Transmitted, plane polarized light. Scale bar equals 0.12 mm.

Fig. 1b. Porphyritic chondrule (left) containing a skeletal crystal of olivine. Excentro-radial pyroxene chondrule (right). Black area is metallic nickel-iron and troilite. Transmitted, plane polarized light. Scale bar equals 0.18 mm.

Fig. 1c. Magnified image of skeletal olivine crystal of Fig. 1b. Transmitted, plane polarized light. Scale bar equals 0.04 mm.

Fig. 1d. Shock vein consisting of glass, silicates (olivine, pyroxene; different shades of gray), metallic nickel-iron and troilite (white). Black are cracks. Reflected light. Scale bar equals 0.13 mm.

Table 1. Average compositions, as obtained by electron microprobe techniques, of olivine, low-Ca pyroxene, plagioclase and chromite from the Ipiranga chondrite (in wt. %)

	Olivine	Low-Ca pyroxene	Plagioclase	Chromite
SiO_2	38.5	54,7	66.3	n. d.
TiO_2	n. d.	0.20	n. d.	2.43
Al_2O_3	<0.01	0.23	20.9	6.2
Cr_2O_3	n. d.	0.17	n. d.	57.4
FeO	17.9	11.5	0.69	30.4
MnO	0.48	0.60	n. d.	0.83
MgO	42.7	31.4	0.45	3.11
CaO	n. d.	0.73	2.39	n. d.
Na_2O	n. d.	<0.01	8.96	n. d.
K_2O	n. d.	n. d.	0.83	n. d.
Total	99.58	99.53	100.52	100.37
End-members (mol.%)				
	Fo 81.0	En 81.8	Ab 82.8	Cm 77.9
	Fa 19.0	Fs 16.8	An 12.2	Uv 6.3
		Wo 1.4	Or 5.0	Pc 3.0
				Sp 12.7

n. d. – not determined

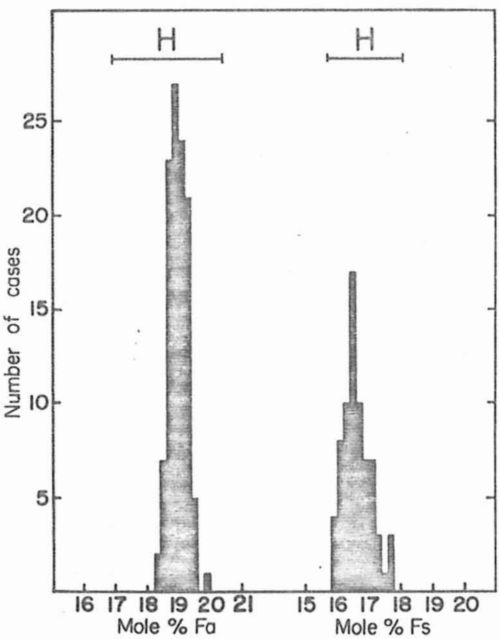

Fig. 2. Histograms illustrating the compositions of olivine (Fa; Fe_2SiO_4) and pyroxene (Fs; $FeSiO_3$) in the Ipiranga chondrite. For comparison, the ranges of the average olivine and pyroxene compositions in H-group chondrites are given (Keil and Fredriksson 1964, as revised by Fodor et al. 1976).

Table 2. Bulk-chemical analyses (in wt. %) and CIPW norms of the Ipiranga chondrite

	(1)	(2)			(1)	(2)
SiO_2	37.10	36.58	Olivine	Fo	26.4	30.0
TiO_2	0.12	0.26		Fa	0.9	13.3
Al_2O_3	2.17	2.94	Hypersthene	En	19.9	16.1
Cr_2O_3	0.52	0.10		Fs	6.1	6.5
FeO	9.90	12.68	Diopside	En	1.6	0.2
MnO	0.27	0.50		Fs	0.5	0.1
MgO	23.55	23.61		Wo	2.4	0.3
CaO	1.77	1.36	Plagioclase	Ab	7.7	7.1
Na_2O	0.90	0.84		An	0.7	3.8
K_2O	0.11	16.0		Or	1.6	0.9
P_2O_5	0.26	0.36	Apatite		0.6	0.8
H_2O^+	0.51	0.32	Chromite		0.8	0.1
H_2O^-	0.15	0.36	Ilmenite		0.2	0.5
Fe	14.96	14.51	Nickel-iron		16.9	16.4
Ni	1,68	1.75	Troilite		5.7	3.8
Co	0.09	0.09				
FeS	5.68	3.78				
C	0.11	0.08				
Total	99.85	100.29				
Fe_T	26.27	26.78				

(1) This work, (2) CAVARRETTA et al. (1975)

this mineral has not previously been found in the relatively highly-oxidized ordinary chondrites but appears to occur exclusively in the highly reduced enstatite chondrites and enstatite achondrites (e.g. KEIL 1968, RAMDOHR 1973, GRAHAM et al. 1977). Until electron microprobe data are presented of this phase in Ipiranga, its occurrence must be considered uncertain.

4. Bulk Composition

Our bulk chemical analysis is listed in Table 2, together with the earlier analysis by CAVARRETTA et al. (1975) as well as the CIPW norms. In general, the analyses agree well. Slight differences are noted in the higher TiO_2, Al_2O_3, FeO, MnO, and P_2O_5 and lower Cr_2O_3 and FeS in the analysis by CAVARRETTA et al. (1975) in comparison to ours.

5. Discussion and Conclusions

Composition of constituent minerals and the bulk composition of Ipiranga indicate that the meteorite, in agreement with the earlier work by CAVARRETTA et al. (1975), belongs to the H-group of chondrites. This classification is particularly indicated by the compositions of olivine ($Fa_{19.0}$, Table 1, Fig. 2) and low-Ca pyroxene ($Fs_{16.8}$, Table 1, Fig. 2) which are well within the ranges of average olivine and low-Ca pyroxene compositions for equilibrated H-group chondrites ($Fa_{16.9-20.4}$ and $Fs_{15.7-18.1}$, respectively; KEIL and FREDRIKSSON 1964, as modified by FODOR et al. 1976). H-group classification is also indicated by the compositions of chromite and plagioclase (Table 1) which are very close to the average compositions for these phases in equilibrated H-group chondrites (BUNCH et al. 1967, VAN SCHMUS and RIBBE 1968). H-group classification is further indicated by the bulk analyses (our data listed first, those by CAVARRETTA et al. 1975 are listed second), particularly by the ratios of Fe_{total}/SiO_2 (0.71, 0.73; avg. H-group 0.77 $\pm$ 0.07, VAN SCHMUS and WOOD 1967),

Fe°/Fe_{total} (0.57, 0.54; avg. H-group 0.63 ± 0.07, VAN SCHMUS and WOOD 1967), Fe°/Ni° (8.91, 8.29; avg. H-group 10.90, CRAIG 1964), as well as the contents of Fe_{total} (26.27 %, 26.78 %; avg. H-group 27.52 %, CRAIG 1964) and metallic nickel-iron (16.73 %, 16.35 %; avg. H-group 16.72 %, KEIL 1962a, b).

In agreement with the results of CAVARRETTA et al. (1975), we also conclude that the Ipiranga chondrite is of petrologic type 5 in the classification scheme proposed by VAN SCHMUS and WOOD (1967). Type 5 classification is indicated by the uniformity and homogeneity in composition of olivine, low-Ca pyroxene, chromite and plagioclase, the marked degree of recrystallization of the meteorite, and the absence of igneous glass.

Acknowledgments

This work is supported in part by the National Aeronautics and Space Administration, Grant NGL 32-004-064 (K. KEIL, Principal Investigator), and by grants from Fundação de Amparo à Pesquisa de Estado de São Paulo (Geologia 707/1975 and 405/1977) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (Proc. 1112. 0640/77) to C. B. GOMES.

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