DAVIES

Meteoritics 1975, Vol. 10, No. 4, 289 to 511. Arrowhead Press, Inc., Phoenix, Arizona

THE IJOPEGA CHONDRITE: A NEW H6 FALL

A.L. Jaques and P.L. Lowenstein

Geological Survey of Papua New Guinea,
Box 778, Port Moresby, Papua New Guinea

D.H. Green, E. Kiss, W.B. Nance, S.R. Taylor and N.G. Ware

Australian National University
Canberra, Australia

THE IJOPEGA CHONDRITE: A NEW H6 FALL

A.L. Jaques and P.L. Lowenstein

Geological Survey of Papua New Guinea,
Box 778, Port Moresby, Papua New Guinea

D.H. Green, E. Kiss, W.B. Nance, S.R. Taylor and N.G. Ware

Australian National University
Canberra, Australia

The Ijopega (Papua New Guinea) meteorite is a new H6 group chondrite fall which contains olivine (Fa 19.9 mole %), bronzite (Fs 17.8 mole %), plagioclase (An 12.1 Or 6.3 Ab 81.6 mole %), diopside, kamacite, taenite, troilite, chromite and whitlockite. The meteorite is extensively recrystallized and brecciated, and shows evidence of moderate shock deformation. Examination of Fe^{2+} and Mg partitioning between ortho- and clinopyroxene indicates a high equilibration temperature (940° or 880 °C). Chemical analysis shows the meteorite to be rich in S, containing about twice the average H-group abundance. Trace elements, including REE, are in accord with established H-group chondrite abundances.

INTRODUCTION

The Ijopega chondrite fell at 0745 Tuesday 3 March 1975 local time (2145 Monday 3 March GMT) in the Asaro Coffee Estate near Ijopega village in the Asaro Valley, 8 km northwest of Goroka in the Eastern Highlands of Papua New Guinea, latitude 06°02′S, longitude 145°22′E. The meteorite fall was witnessed by several people who report that it came from the northeast, making a noise like a helicopter or light aircraft with engine trouble, and spiralled down emitting a smoke trail to land within 25 m of one of the observers. It made a rectangular hole in soft ground 10 cm × 13 cm × 50 cm deep, the impact causing the ground to shake in the immediate vicinity. When excavated a few minutes after landing the stone was reported to be still too hot to handle. The orientation of the hole indicates that the meteorite impacted from the northwest and penetrated the ground at angle of 70 degrees. The apparent discrepancy between the observed direction and that obtained from the hole suggests a spiral descent.

The Ijopega chondrite was a single stone, 18 cm in diameter, Fig. 2, weighing 7.33 kg with a density of 3.66 g/cc. The meteorite has a thin fusion crust 1 to 1.5 mm thick transected by "bread crust-like" cooling fractures. In some places, fragments had been torn off in flight and a fusion crust partly redeveloped.

Half of the stone is held by the finders as it is considered a sacred object. Specimens are currently held at the Australian National University,

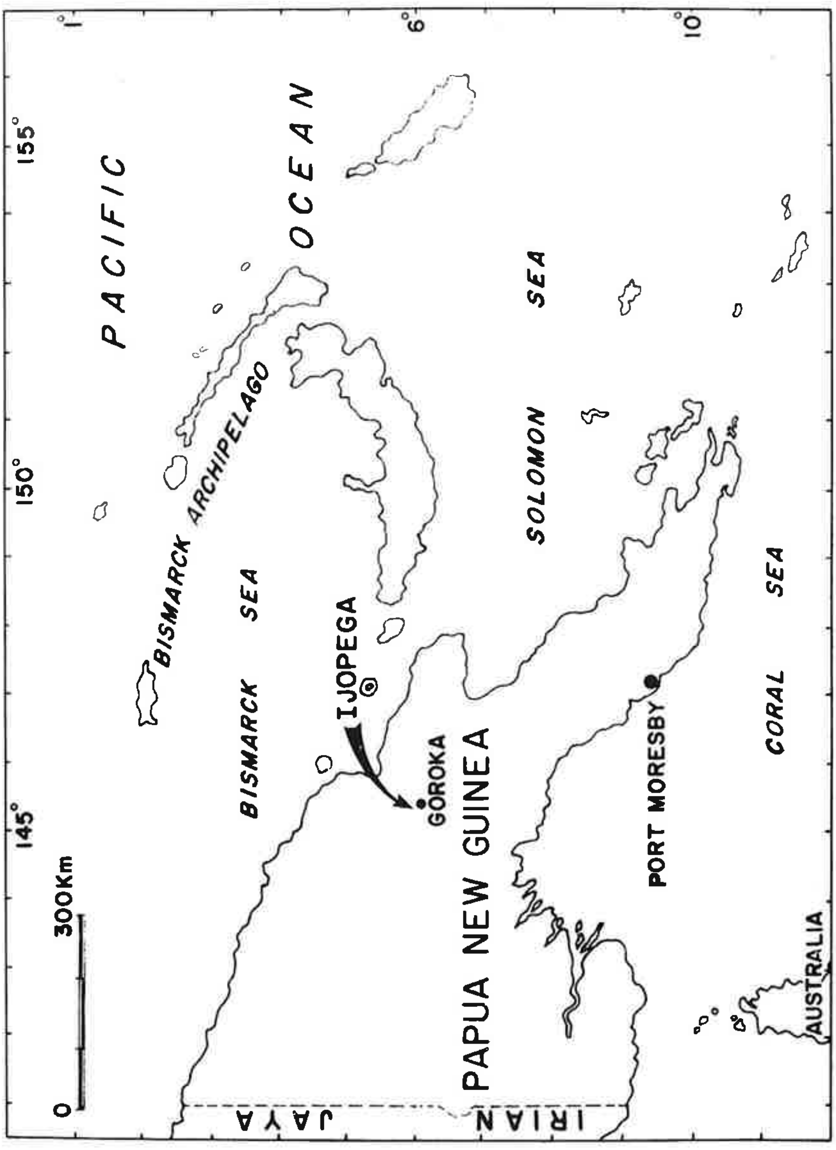

Fig. 1 **Locality map showing place of fall of Ijopega chondrite.**

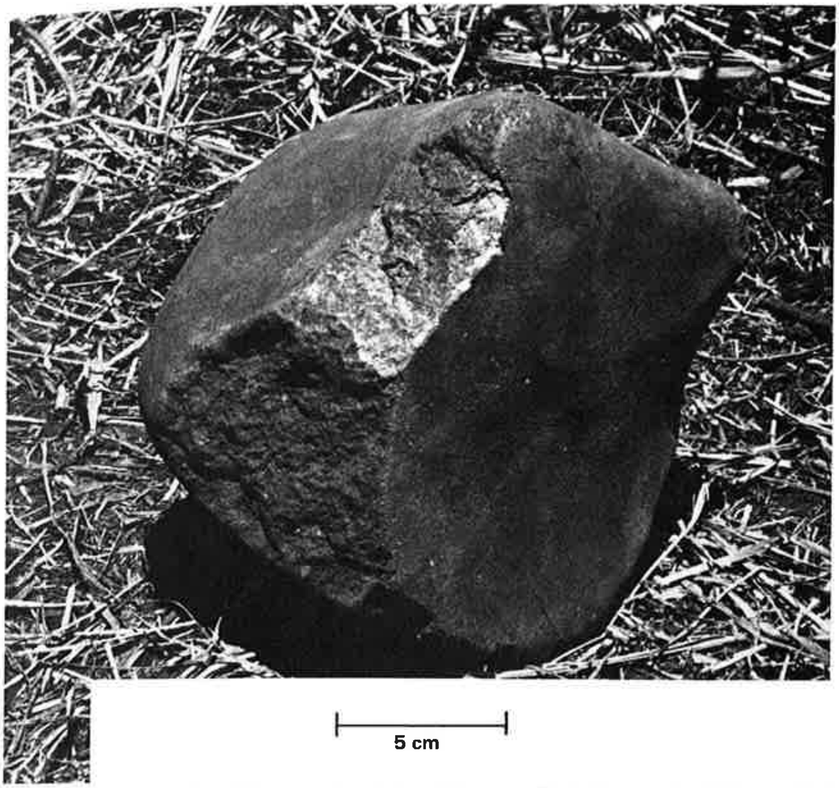

Fig. 2 **Photograph of Ijopega chondrite. Note smooth fusion crust 1-1.5 mm thick with minor cooling fractures and broken edges where fragments have been torn off.**

the Australian Bureau of Mineral Resources, the Geological Survey of Papua New Guinea and the remainder by the Papua New Guinea National Museum. The material used for this study came from a near-central slab.

PETROGRAPHY AND CLASSIFICATION

Ijopega is a brecciated, highly recrystallized chondrite comprised of homogeneous olivine, bronzite, plagioclase, diopside, kamacite, taenite, troilite, chromite and whitlockite.

The thin fusion crust consists of metal and fractured silicate grains intensely veined by black, opaque, non-reflecting "glassy" material, probably produced by shock-induced melting (electron probe analyses indicate it is an inhomogeneous Mg-Fe silicate). A strong veined, shocked, layer about 1 cm thick lies underneath the fusion crust. Thin veins, fractures and breccia zones of comminuted silicate grains, "glass" and Ni-Fe anhedra pervade the remainder of the meteorite producing an overall fractured texture. Clasts within the breccia range from chondrule size up to 2.5 cm.

Extensive pre-fracturing recrystallization of the chondrite has taken place and the overall texture is granoblastic, xenomorphic granular with many polygonal grains. However, relict chondrules – mostly olivine, some bronzite – of the barred, radiating, porphyritic and lithic types (Van Schmus, 1969) occur throughout, Fig. 3. Chondrule boundaries are not well defined and the interchondrule material has completely recrystallized, mainly to sodic plagioclase. A conspicuous white chondrule larger than most (3 mm diam) contained radiating olivine with interstitial plagioclase and accessory chromite. Bronzite plates poikilitically enclose olivine in places.

Many silicate grains show evidence of deformation; undulose extinction is common, some grains exhibit deformation lamellae and kink bands occur in some diopside exsolution lamellae. These features, together with the extensive fracturing of silicate grains, suggest moderate shock deformation (Carter *et al.*, 1968).

Ijopega is classified as a bronzite chondrite (H-group) on the basis of mineral compositions (see later) and abundance of Ni-Fe metal. The absence of glass, abundance of crystalline sodic plagioclase, paucity of clinopyroxene and degree of recrystallization indicate that it belongs to petrologic class 6 of Van Schmus and Wood (1967).

MINERALOGY

Olivine, orthopyroxene, clinopyroxene, plagioclase, chromite and whitlockite were analysed by TPD electron probe using a Li-drifted silicon detector following the energy dispersive techniques described by Reed and Ware (1973). The analytical conditions employed an electron beam accelerating voltage of 15 kv, an electron beam diameter of <0.5 microns, and a

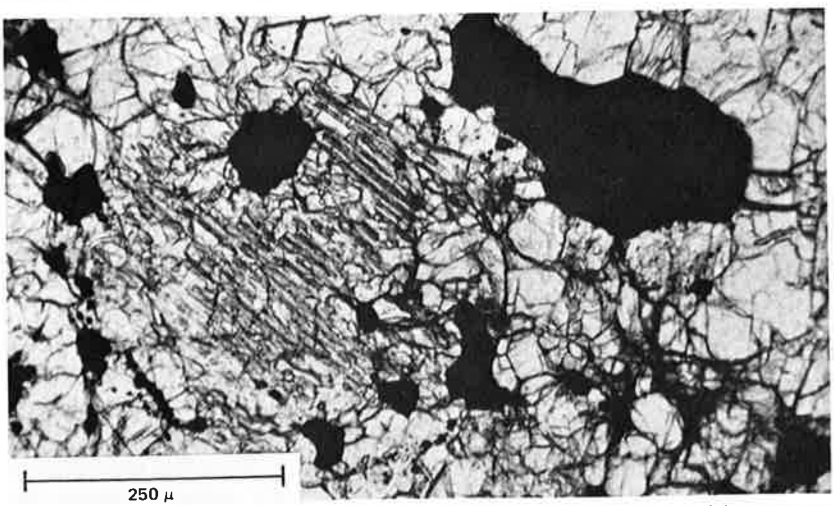

Fig. 3 **Photomicrograph of relict olivine chondrule. Interstitial material now recrystallized to sodic plagioclase. Note fracturing of silicate grains (bronzite and olivine mainly, some interstitial plagioclase). Opaques are kamacite (large grain), troilite and chromite (smallest grains).**

specimen current of 3 nanoamps. Average compositions are presented in Table 1. Full details of all mineral analyses are given elsewhere (Jaques *et al.*, 1975).

Ni-Fe determinations were made on an ARL-EMX microprobe following wavelength dispersive methods described by Lovering and Ware (1970). Average Ni-Fe contents are shown in Table 2.

Olivine

Olivine occurs in relict chondrules and as granoblastic matrix grains and ranges in size from about 750 μ to less than 50 μ. Compositions of both chondrule and groundmass olivines are homogeneous over the range Fa 19.2 to Fa 20.5 mole percent. The average composition, Table 1, of Fa 19.9 indicates an H-group classification for the meteorite. The low Ca, mostly <0.1 wt %, and low Ni, <200 ppm, contents are typical of equilibrated chondritic olivine. Olivines from the white chondrule contained slightly higher amounts of Ca, 0.1 wt %, which may be a relic feature of an earlier higher temperature (high Ca) olivine phase (Dodd, 1969).

Pyroxenes

Bronzite comprises most of the granoblastic matrix. It also occurs in relic chondrules and forms poikilitic grains about olivine. Compositions, Table 1, are uniform, average Ca 1.3 Mg 80.9 Fe 17.8 mole %, and consistent with an H-group classification. Some grains exhibit traces of (100) striations and others have small extinction angles; these features suggest recrystallization from a low-Ca clino-form (Binns, 1970). The Ca content of Ijopega bronzites averages 0.70 weight percent which is higher than for H6 group chondrites listed by Dodd (1969) suggesting a high equilibration temperature.

Diopside is not abundant and occurs as small (< 100 μ, many < 50 μ) platelets and granoblastic grains. Many contain very fine (001) exsolution lamellae not resolved by the microprobe. Compositions, Table 1, average Ca 44.9 Mg 48.1 Fe 7.0 mole percent and are slightly poorer in Ca and richer in Fe than most H6 group diopside analysed by Bunch and Olsen (1974).

The distribution coefficient K_D for Ijopega is 0.66 where

$$K_D = \left[\frac{Fe^{2+}}{Mg}\right]^{cpx} \times \left[\frac{Mg}{Fe^{2+}}\right]^{opx}$$

which indicates a higher equilibration temperature than that suggested by both Van Schmus and Koffman (1967) and Bunch and Olsen (1974). An equilibration temperature of 940 °C is obtained using the Kretz (1963) curve, and a lower temperature, 880 °C, obtained using an alternate curve by McCallum (data from Bunch and Olsen, 1974). Calculated mineral cation sum indicates negligible Fe^{+++} content.

Table 1

Average compositions of olivine, bronzite, plagioclase, diopside, chromite and whitlockite. All data in weight percent. Number of grains analysed shown in brackets.

	Olivine [20]	Bronzite [16]	Plagioclase [10]	Diopside [16]	Chromite [9]	Whitlockite [8]
SiO_2	39.11	56.37	64.60	54.53	0.11	0.28
TiO_2		0.09		0.37	2.32	
Al_2O_3			21.59	0.30	6.48	1.22
Cr_2O_3		0.09		0.95	57.45	
FeO*	18.59	11.90	0.50	4.40	29.59	0.56
MnO	0.42	0.45		0.09	0.58	
MgO	41.88	30.39	0.43	16.94	3.19	4.31
CaO		0.70	2.49	22.02	0.26	45.50
Na_2O			9.30	0.39		2.65
K_2O			1.09			0.10
P_2O_5						45.33
TOTAL	100.00	99.99	100.00	99.99	99.98	99.95
	Number of cations on the basis of					
	0 = 4	**0 = 6**	**0 = 32**	**0 = 6**	**0 = 32**	**0 = 8**
Si	1.000	1.997	11.434	1.992	0.030	0.014
Ti		0.003		0.010	0.491	
Al			4.503	0.013	2.154	0.074
Cr		0.004		0.027	12.798	
Fe	0.397	0.352	0.074	0.135	6.973	0.024
Mn	0.009	0.014		0.003	0.139	
Mg	1.595	1.602	0.114	0.923	1.339	0.328
Ca		0.026	0.472	0.860	0.078	2.488
Na			3.189	0.039		0.131
K			0.247			0.003
P						1.958
TOTAL	3.001	3.998	20.033	4.002	24.002	5.020
	Atomic ratios					
	Mg 80.1	Mg 80.9	K 6.3	Mg 48.1	Mg 15.8	
	Fe 19.9	Fe 17.8	Na 81.6	Fe 7.0	Fe 82.5	
		Ca 1.3	Ca 12.1	Ca 44.9	Mn 1.6	

*Total iron.

Table 2

Average compositions of Ni-Fe metal from the Ijopega chondrite. Data in weight percent. Number of grains analysed shown in brackets.

	Kamacite [19]	Taenite [7]	Ni-rich Taenite [1]
Ni	5.81	31.29	40.30
Fe	93.70	68.60	60.44
Co	0.49	0.10	0.03
TOTAL	100.00	100.00	100.76

Plagioclase

Crystalline plagioclase, commonly twinned, is abundant and occurs as granoblastic grains up to 350 μ in the matrix and in recrystallized chondrules. Compositions are uniform averaging Or 6.3 Ab 81.6 An 12.1 mole percent, in accord with plagioclase compositions from H-group chondrites (Van Schmus and Ribbe, 1968). Abundant crystalline sodic plagioclase is diagnostic of petrologic group 6 chondrites (Van Schmus and Wood, 1967). Virtually no maskelynite was observed, which is surprising in view of the extent of veining in the meteorite.

Chromite and troilite

Chromite occurs as irregular interstitial grains mainly less than 200 μ. Compositions are variable with respect to Ti, Al, Mn and to a much smaller extent with respect to Cr, Mg and Fe. The average composition is shown in Table 1. The composition is in accord with H6 group chondrite chromite compositions (Bunch *et al.*, 1970) although Al and Mg contents are slightly higher and Fe and Mn slightly lower in the Ijopega chondrite.

Troilite was observed as abundant anhedral irregular grains up to 750 μ in size commonly in association with Ni-Fe. Grains within breccia zones are either globular or extremely irregular in outline. No other sulphide phase was observed.

Whitlockite

Whitlockite occurs as anhedra up to 100 μ in size. Scanning by electron probe with the aid of the ratemeter audio output and the detector set for Phosphorus K_α radiation revealed no other phosphate phases. The average composition given in Table 1 is in accord with whitlockite compositions determined by Van Schmus and Ribbe (1969).

Kamacite and Taenite

Ijopega contains 16.46 percent by weight Ni-Fe which is present as irregular interstitial grains up to 750 μ. Kamacite and taenite occur in close association, kamacite being by far the more abundant. Average compositions shown in Table 2 indicate a Ni content of 5.8 weight percent and 0.5 percent Co in kamacite. Taenite averages 31.3 weight percent Ni within the range 28-33 weight percent with the exception of one Ni-rich taenite grain which contained 40.3 percent Ni. A number of grains of both kamacite and taenite are zoned. The cores of kamacite grains are richer in Ni than the rims whereas in taenite the rims appear to be the more Ni-rich.

BULK CHEMICAL ANALYSIS

Bulk chemical analysis of the Ijopega meteorite was carried out by methods described below and confirmed by separate analysis of the magnetic and non-magnetic fractions by wet methods (mainly spectrophotometry) and electron probe (after fusion on an iridium strip) respectively. In the bulk analysis major and minor constituents were determined following techniques described by Easton and Lovering (1963) after selective extraction of metal with Hg (II) Cl. Fe was determined by spectrophotometry of chloroferrate ion (Sandell, 1959) after oxidative extraction of metal and sulphide phases by the bromide-ethanol method (Sant and Prasad, 1968, modified as follows: 4% vol. Br_2 in ethanol for 4 days, at 80 °C); results were checked using 2, 2′ – dipyridyl as chromogen. Ni, Al, Co and V were determined by methods described by Sandell (1959) and Kiss (1967, 1973, in press); appropriate corrections were applied in the Al determination. The C content was not determined but traces of grey-black matter remaining insoluble after solution of the bulk sample in HCl + HNO_3 + H_2SO_4 + HF were possibly carbon. Excellent agreement obtained between sulphide – sulphur of Fe and Ni determined by the bromine – ethanol method, 4.22 wt %, and total S determined independently, 4.26 wt %, confirms the high S content of the meteorite and suggests that the bromine method may be an adequately precise approach in determination of simple sulphides.

Chemical composition and norm for the Ijopega chondrite are given in Table 3. The composition generally accords with H-group, high Fe, chondrite compositions but the FeS content is notably higher. Ijopega contains 4.22 weight percent S which is about twice the normal H-group abundance (Mason, 1971) and more in line with enstatite chondrite values. The total Fe content, 27.56 wt %, accords with H-group values but the FeO content is lower because of the high S content. The Mg/Si ratio for Ijopega is slightly lower than for many H-group chondrites but other elements lie within established H-group ranges.

TRACE ELEMENTS

Elemental abundances for 22 trace elements were measured by spark source mass spectrometry (Taylor 1965, 1971) on a metal-free portion of the meteorite. In order to provide "whole meteorite" data, the analytical results on the silicate portion analysed were reduced by a factor of 0.835 to account for the 16.46 percent metal contained in the meteorite. The analytical data so

Table 3
Chemical analysis and CIPW norm of the Ijopega chondrite.

SiO_2	36.91	Hypersthene	En	25.70
			Fs	6.05
TiO_2	0.07	Olivine	Fo	20.03
Al_2O_3	2.76		Fa	5.20
Cr_2O_3	0.21	Diopside	En	1.13
FeO	6.97		Wo	1.54
MnO	0.30		Fs	0.27
MgO	22.26	Albite		7.87
CaO	1.70	Anorthite		3.09
Na_2O	0.93	Orthoclase		0.56
K_2O	0.09	Apatite		0.60
P_2O_5	0.25	Chromite		0.31
CoO	0.02	Ilmenite		0.14
Fe	14.90	Nickel-iron		16.46
Ni	1.48	Troilite		11.42
Co	0.08			
FeS	11.42			
NiS	0.15			
TOTAL	100.50			

adjusted are given in Column 1 of Tables 4 and 5 with the limits of precision of the data also given. The rare earth data, normalised to the average chondritic data listed in Table 4 (Column II) are plotted in Fig. 4. Average trace element data for H-group chondrites, taken from Mason (1971), are listed in Table 5 (Column II).

Of the elements determined, lead is present at a level, 0.66 ppm, which is about twice the chondritic average. The sample was ground in a tungsten carbide grinding vial and this, or prior handling, may have introduced lead contamination of the order of 0.30 ppm. However, lead in chondrites is contained mainly in troilite, and Ijopega contains about twice the normal sulphur abundance of chondrites. The lead isotope ratios as measured by spark source mass spectrography for the whole rock sample are 2.150 ± 0.029 for $^{208}Pb/^{206}Pb$ and 0.888 ± 0.014 for $^{207}Pb/^{206}Pb$. As these ratios are within the range observed for H-group chondrites (Mason, 1971) the lead content

Table 4
Rare Earth element abundances in the Ijopega chondrite. Data in ppm(wt).

	I	II	III
La	0.27 ± 0.016	0.30	0.27
Ce	0.81 ± 0.024	0.84	0.76
Pr	0.11 ± 0.01	0.12	0.11
Nd	0.51 ± 0.026	0.58	0.52
Sm	0.19 ± 0.005	0.21	0.19
Eu	0.061 ± 0.006	0.074	0.067
Gd	0.21 ± 0.017	0.26	0.23
Tb	0.042 ± 0.0004	0.049	0.044
Dy	0.28 ± 0.028	0.31	0.28
Ho	0.067 ± 0.0007	0.073	0.066
Er	0.19 ± 0.009	0.21	0.19
Tm	0.029 ± 0.0018	0.030	0.027
Yb	0.18 ± 0.005	0.20	0.18
Lu	0.028 ± 0.002	0.031	0.028
Σ REE	2.98	3.29	2.96

I Ijopega chondrite. Data from spark source mass spectrometry.

II Chondrite average values from Haskin *et al.* (1966, 1968) and Hubbard and Gast (1971).

III Chondrite average values (Col. II) × 0.9.

Table 5
Trace element abundance data in Ijopega chondrite. Data in ppm(wt).

	I	II	III
Rb	2.7	2.5	2.3
Sr	8.6	9.5	8.6
Ba	3.3	3.5	3.15
Pb	0.66	0.37	0.33
Y	2.2	2.1	1.90
Zr	6.5	6.4	5.8
Hf	0.16	0.17	0.15

I Ijopega chondrite. Data from spark source mass spectrometry. Precision < ± 5%.

II Average H-group chondrite values from Mason (1971).

III Average chondrite values (Col. II) × 0.9.

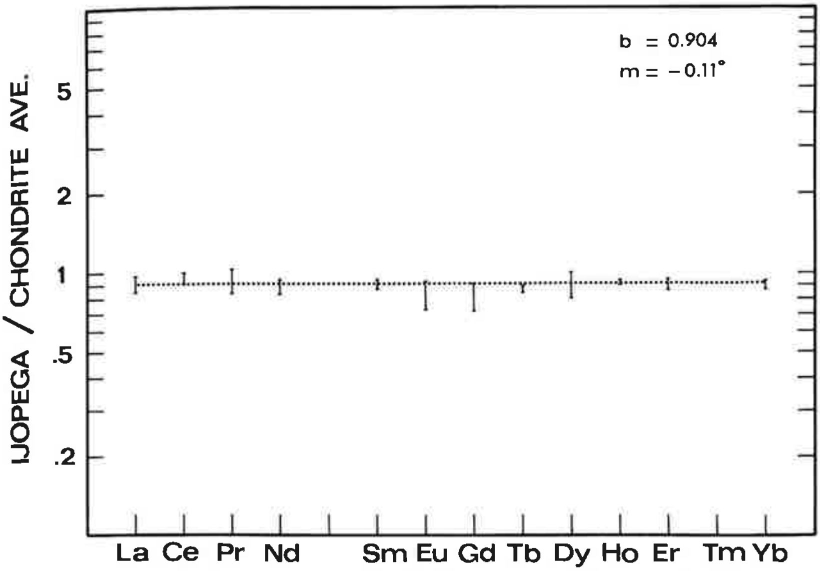

Fig. 4 **Rare earth element pattern for the Ijopega chondrite normalized to average chondrite values. Data from Table 4. Note that the pattern is parallel to those of ordinary chondrites but the abundance levels are 10 percent systematically lower. There are no individual REE anomalies, relative to chondrites.**

may be indigenous. The use of the tungsten carbide grinding vial precluded the determination of W and Nb. The latter monoisotopic element, ^{93}Nb, suffered intereference from $^{186}W^{2+}$ at levels (5 ppm) estimated to be about 10 times the natural abundance of Nb in chondrites.

The trace element data given in Tables 4 and 5 show very close resemblances to the abundances in H-group chondrites. The rare earth element (REE) pattern, normalised to average chondritic abundances, is flat ($m = -0.11°$) and parallel to the chondritic pattern. The abundances are about 10 percent lower ($b = 0.904$ in Fig. 4). This comparison is shown in Table 4, Column III, where the average chondrite data are reduced by 0.9. The correspondence between Cols. I and II is very close. Such variations among chondrite REE abundances are well established (*e.g.* Masuda *et al.*, 1973).

The abundances of the other trace elements measured here (Rb, Sr, Ba, Y, Zr and Hf) follow the same pattern. They compare most closely with 0.9 times the average abundances for H-group chondrites, given in Column III, Table 5. These comparisons confirm the identification of this meteorite as an H-group chondrite, with REE and other trace element abundances slightly lower (10%) than average.

ACKNOWLEDGMENTS

We are grateful to the people of Ijopega village, particularly S. Kimoi, the finder, and to P. Leahy, Manager of the Asaro Coffee Estate, for making the meteorite available for study. We also thank N. Wilson (Assistant District Commissioner, Goroka), R. Giddings (District Officer, Planning) and B. Miller (Science Lecturer, Goroka Teachers College) for their help in liaising with the Ijopega villagers. R. Rudowski, N. Pederson and W. Hibberson (ANU) are thanked for technical assistance and advice. B. Mason kindly read the manuscript.

The study was supported by the Papua New Guinea Government and publication is by permission of the Director, Office of Minerals and Energy.

REFERENCES

Binns, R.A., 1970. Pyroxenes from non-carbonaceous chondritic meteorites. *Mineral Mag.* **37**, 649-669.

Bunch, T.E., K. Keil and K.G. Snetsinger, 1967. Chromite composition in relation to chemistry and texture of ordinary chondrites. *Geochim. Cosmochim. Acta* **31**, 1569-1582.

Bunch, T.E. and E. Olsen, 1974. Restudy of pyroxene – pyroxene equilibration temperatures for ordinary chondrite meteorites. *Contr. Mineral. Petrol.* **43**, 83-90.

Carter, N.L., C.B. Raleigh and P.S. Decarli, 1968. Deformation of olivine in stony meteorites. *J. Geophys. Res.* **73**, 5439-5461.

Dodd, R.T., 1969. Metamorphism of the ordinary chondrites: a review. *Geochim. Cosmochim. Acta* **33**, 161-203.

Easton, A.J. and J.F. Lovering, 1963. The analysis of chondritic meteorites. *Geochim. Cosmochim. Acta* **27**, 753-767.

Haskin, L.A., F.A. Frey, R.A. Schmitt and R.H. Smith, 1966. Meteoritic, Solar and terrestrial rare-earth distributions, in *Physics and Chemistry of the Earth* **7**, (L.H. Ahrens, F. Press, S.K. Runcorn and H.C. Urey, eds.) Permagon Press, 169-321.

Haskin, L.A., M.A. Haskin, F.A. Frey and T.R. Wildeman, 1968. Relative and absolute terrestrial abundances of the rare earths, in *Origin and Distribution of the Elements* (L.H. Ahrens, ed.), Pergamon Press, 889-912.

Hubbard, N. and P.W. Gast, 1971. Chemical composition and origin of nonmare lunar basalts. *Proc. Second Lunar Sci. Conf. Geochim. Cosmochim. Acta, Suppl. 2, Vol. 2*, 999-1020.

Jaques, A.L., P. Lowenstein, D.H. Green, E. Kiss, W.B. Nance, S.R. Taylor and N.G. Ware, 1975. The Ijopega meteorite. *Papua New Guinea Geol. Surv. Rep.* 75/7 (unpub.).

Kiss, E., 1967. Chemical determination of some major constituents in rocks and minerals. *Anal. Chim. Acta* **39**, 223-234.

Kiss, E., 1973. Pyridylazo – diaminobenzenes as reagents for cobalt. Spectrophotometric determination of cobalt in silicates and meteorites. *Anal. Chim. Acta* **66**, 385-396.

Kiss, E., in press. Selective spectrophotometric determination of vanadium with a new pyridylazophenol in the presence of hydrogen peroxide. *Anal. Chim. Acta.*

Kretz, R., 1963. Distribution of magnesium and iron between orthopyroxene and calcic pyroxene in natural mineral assemblages. *J. Geol.* **71**, 773-785.

Lovering, J.F. and N.G. Ware, 1970. Electron probe microanalysis of minerals and glasses in Apollo 11 lunar samples. *Proc. Apollo 11 Lunar Sci. Conf. Geochim. Cosmochim. Acta, Suppl. 1, Vol. 1*, 633-654.

Mason, B., 1971. *Handbook of elemental abundances in meteorites.* Gordon and Breach, N.Y., 555 pp.

Masuda, A., N. Nakamura and T. Tanaka, 1973. Fine structures of mutually normalised rare-earth patterns of chondrites. *Geochim. Cosmochim. Acta* **37**, 239-248.

Reed, S.J.B. and N.G. Ware, 1973. Quantitative electron microprobe analysis using a Li-drifted silicon detector. *X-Ray Spectrom.* **2**, 69-74.

Sandell, E.B., 1959. *Colorimetric determination of traces of metals.* Interscience, N.Y. 3rd Ed. 1032 pp.

Sant, B.R. and T.P. Prasad, 1968. Determination of metallic iron, iron (11) oxide and iron (111) oxide in a mixture. *Talanta* **15**.

Taylor, S.R., 1965. Geochemical analysis by spark source mass spectrometry. *Geochim. Cosmochim. Acta* **29**, 1243-1261.

Taylor, S.R., 1971. Geochemical application of spark source mass spectrometry, 11 photoplate data processing. *Geochim. Cosmochim. Acta* **35**, 1187-1196.

Van Schmus, W.R., 1969. The mineralogy and petrology of chondritic meteorites. *Earth Sci. Rev.* **5**, 145-184.

Van Schmus, W.R. and D.M. Koffman, 1967. Equilibration temperatures of iron and magnesium in chondritic meteorites. *Science* **155**, 1009-1011.

Van Schmus, W.R. and P.H. Ribbe, 1968. The composition and structural state of feldspar from chondritic meteorites. *Geochim. Cosmochim. Acta* **32**, 1327-1342.

Van Schmus, W.R. and P.H. Ribbe, 1969. Composition of phosphate in ordinary chondrites. *Geochim. Cosmochim. Acta* **33**, 637-640.

Van Schmus, W.R. and J.A. Wood, 1967. A chemical petrologic classification for the chondritic meteorites. *Geochim. Cosmochim. Acta* **31**, 747-765.

Manuscript received 8/26/75