A PRELIMINARY MINERALOGICAL EXAMINATION OF THE YAMATO-74 ACHONDRITES

Hiroshi TAKEDA,
Mineralogical Institute, Faculty of Science, University of Tokyo, Hongo 7-chome, Bunkyo-ku, Tokyo 113

Masamichi MIYAMOTO,
Department of Earth Sciences, Kobe University, Rokkodai-cho, Nada-ku, Kobe 657

Keizo YANAI
National Institute of Polar Research, Kaga 1-chome, Itabashi-ku, Tokyo 173

and

Hiroshi HARAMURA
Geological Institute, Faculty of Science, University of Tokyo, Hongo 7-chome, Bunkyo-ku, Tokyo 113

Abstract: Seven diogenites, two eucritic polymict breccias and one pallasite have been identified in the Yamato-74 meteorites by the electron microprobe and single crystal X-ray diffraction techniques. The texture of Yamato-74010, -74011, -74013, -74037, -74097, -74136 and -74648 is unlike those of the other diogenites. It is not brecciated and texturally the pyroxene seems to have recrystallized to a granoblastic texture with small change in mineral composition. The chemical composition of the orthopyroxenes in these diogenites falls in the range $Ca_{1.9}$ $Mg_{75.1}$ $Fe_{23.0}$ to $Ca_{3.0}$ $Mg_{71.0}$ $Fe_{26.0}$. The chemistry and textures of these diogenites are the same as those of the Yamato-6902 (b) diogenite previously reported. These Yamato diogenites may represent fragments of the same fall. Yamato-74159 is a polymict breccia which contains mineral and lithic clasts common to eucrites. The Yamato-74450 eucrite shows a variolitic texture, indicating a rapid solidification near the surface of its parent body. A brecciated part containing a pigeonite crystal with augite lamellae is also found in small amounts. The pyroxene trends of Yamato-74450 resemble those of the Pasamonte eucrite. The Yamato-74044 pallasite is the only stony-iron meteorite among the Yamato collection. A preliminary examination of the Yamato-75 meteorites identified one iron-rich diogenite and two eucritic polymict breccias. Yamato-75032 is the most Fe-rich of any known diogenite.

1. Introduction

In the light of a lunar model of crust formation and surface regolith breccia, the apparent genetic relationship among achondrites, such as diogenites, howardites, eucrites, and silicate inclusions in mesosiderites, have been suggested to have constituted a part of the crust formed by a single step melting and differentiation on a asteroid-like parent body very early in the history of the solar system (*e.g.* REID, 1974; BUNCH, 1975; DYMEK *et al.*, 1976; MATSON *et al.*, 1976; TAKEDA *et al.*, 1976; DRAKE and CONSOLMAGNO, 1977). A model crust of the achondrite parent body is difficult to reconstruct in large part because the achondrites are very rare. The Yamato meteorites (YANAI, 1977) provide a new source of meteoritic material, in which several unusual achondrites have been found. Two unique achondrites, Yamato-6902 (OKADA, 1975; TAKEDA *et al.*, 1975) and Yamato-7307 (TAKEDA *et al.*, 1976b) have been reported in the Yamato meteorites. The discovery of unique achondrites may require some revisions of the proposed model.

The petrochemistry of the achondrites has been summarized by MOORE (1962), and DUKE and SILVER (1967) emphasize the brecciated structure of many specimens, especially the difference between monomict and polymict breccias. MCCARTHY *et al.* (1973) interpreted the chemistry of eucrites in terms of an igneous fractionation model. TAKEDA *et al.* (1976b) delineated the pyroxene crystallization trends of the achondritic crust. Based on his melting experiments, STOLPER (1977) demonstrated that the eucritic liquid can be generated by low pressure partial melting of olivine-pyroxene-anorthite mixtures. FREDRIKSSON *et al.* (1976) summarized bulk and major phase composition of eight hypersthene achondrites.

Pyroxene chemistry and crystallography of eight new Yamato achondrites collected in 1974 and three other Yamato achondrites (YANAI, 1976) have been investigated by the electron microprobe and X-ray diffraction techniques. The results have been interpreted in light of the above recent developments concerning the parent body model (MATSON *et al.*, 1976; TAKEDA *et al.*, 1976b; DRAKE and CONSOLMAGNO, 1977). Detailed studies of two polymict breccias found in the Yamato meteorites will be given in our accompanying paper (MIYAMOTO *et al.*, 1978). The non-metallic portion of the Yamato-74044 pallasite is also described in this paper.

2. Experimental Techniques

Samples supplied from the National Institute of Polar Research are Yamato-74011, -74037, -74097, -74648, -75011 and -75015 as small chipped fragments weighing less than 0.01 g and Yamato-74010, -74013, -74044, -74136, -74450 and -75032 as between 0.5 to 2.0 g of chips. Several grains of the small fragments were mounted in araldite resin, and polished grain mounts were prepared for microprobe analyses. Very small fragments were chipped from the original samples larger than 0.5 g. Single crystals of pyroxenes were separated for X-ray diffraction studies, and the rest of the fragments were mounted for microprobe analyses. About one half of the larger original samples were cut and mounted in epoxy resin. One to three sawn slices of 0.25 mm thick were cut from these potted butts. Polished sections cemented by araldite and for some samples by Lakeside 70 were prepared for microprobe analyses. The sections cemented by Lakeside 70 were finished to about 0.1 mm thick so that single crystals of particular compositions could be separated after microprobe analyses.

The quantitative chemical analyses were made with a JOEL JXA-5 electron probe X-ray microanalyzer with a 40° take-off angle. The method is the same as that of NAKAMURA and KUSHIRO (1970). The pyroxene crystals were mounted approximately along the *c*-axis, and were aligned with spindle axis parallel to the c^* direction. Precession photographs of $h0l$ and $0kl$ nets were taken using Zr-filtered Mo$K\alpha$ radiation. Yamato-74159, -74450 and -75032 have been analyzed by the standard wet chemical method.

3. Diogenites

3.1. Results

Yamato-74010, -74011, -74013, -74037, -74097, -74136 and -74648 show chemistry and textures the same as those of the Yamato-6902 diogenite (TAKEDA *et al.*, 1975). These meteorites were originally described as resembling a terrestrial dunite. These very hard meteorites are surrounded by a smooth surface, but no fusion crust was observed. The meteorites consist almost entirely of pyroxene. The sample is olive yellow in color, with patches of black euhedral

Fig. 1. Photomicrographs of the Yamato-74136 diogenite in transmitted light. Upper one third represents a part of the coarse grained network of clear orthopyroxene crystals with small number of coarse angular inclusions. Lower portion composed of fine-grain orthopyroxene with numerous droplet-like fine inclusions. Width is 3 mm.

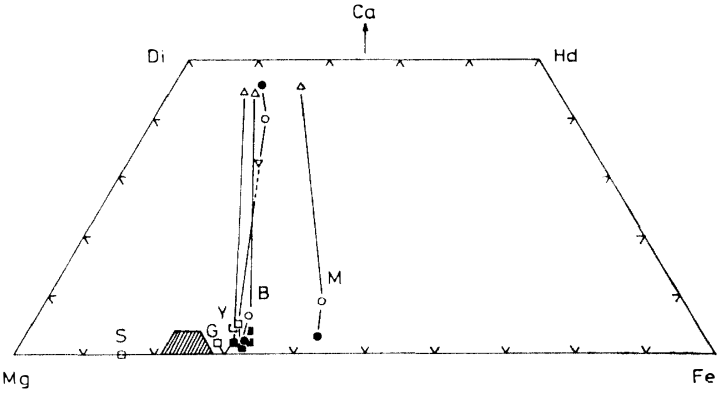

Fig. 2. Pyroxene compositions of diogenites and magnesium-rich cumulate eucrites. Open circles and squares: bulk composition; others: exsolved pairs. Most of the diogenite pyroxenes fall within the shaded area except Garland (G), and are enlarged in Fig. 3. S: Steinbach, Y: Yamato-75032, B: Binda, and M: Moama.

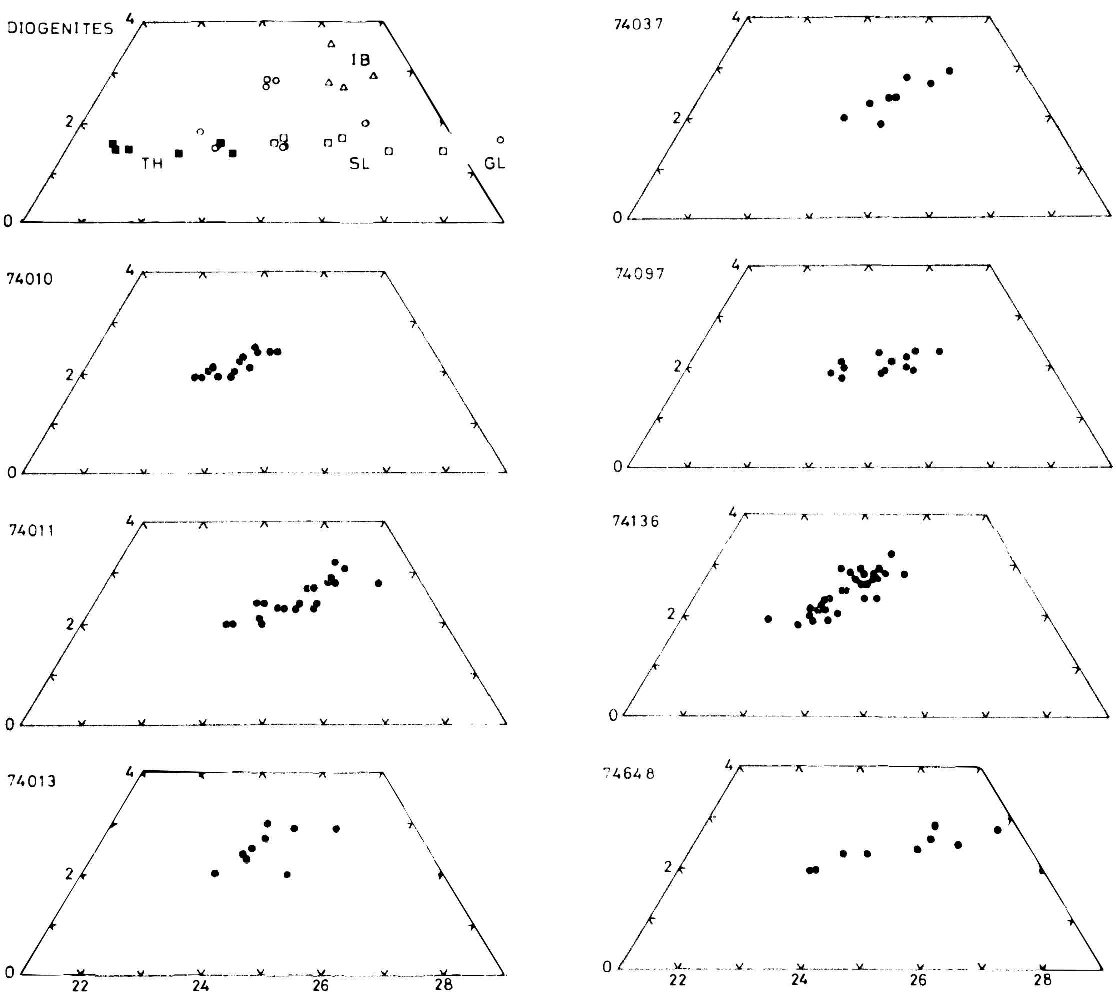

Fig. 3. Pyroxene compositions of diogenites. Open circles: known diogenites (after FREDRIKSSON *et al., 1976). GL: Garland. Squares and triangles represent range circles: Yamato-74 recrystallized diogenites. Compositional areas are enlargement of shaded area in Fig. 2.*

chromite crystals up to 2.5 mm in diameter. The sizes of the pyroxenes are less than 1 mm.

As was noted previously for Yamato-6902, the texture of these meteorites is unlike that of the other diogenites known to date. It is not brecciated and texturally the pyroxene seems to have recrystallized to a granoblastic texture with small change in mineral composition.

The characteristic texture of this diogenite can best be seen on the section with thickness of about 0.1 mm. A light-colored band forming a complex network can be observed, along which pyroxene crystals are coarse grained, transparent and free from inclusions. The largest crystal we observed is 1.1×0.7 mm in size (Fig. 1). Opaque minerals in this region are also coarse (up to 0.01 mm in diameter) and are mostly euhedral or angular but their numbers are small. This coarse-grained structure includes islands of fine-grained dark yellowish-green colored crystals of pyroxene (0.05 to 0.1 mm in diameter) with numerous minute

Table 1. Ranges of pyroxene compositions of the Yamato-74 diogenites.*

Sample	Ca	Mg	Fe	Remarks (No.)
Yamato-74010	1.9	75.2	22.9	Min.
	2.5	73.9	23.6	Max.
	2.2	74.3	23.5	Ave. (15)
74011	2.0	74.6	23.4	Min.
	3.0	72.1	24.9	Max.
	2.5	73.1	24.4	Ave. (21)
74013	2.0	74.8	23.2	Min.
	2.9	72.3	24.8	Max.
	2.6	73.6	23.8	Ave. (10)
	2.4	73.4	24.3	Bulk
74037	2.0	74.4	23.6	Min.
	2.9	72.2	24.8	Max.
	2.4	73.4	24.2	Ave. (7)
	2.7	72.6	24.7	Bulk
74097	1.8	74.5	23.6	Min.
	2.0	73.7	24.2	Max.
	1.9	74.1	23.9	Ave. (12)
	2.0	74.4	23.7	Bulk
74136	1.8	74.2	24.0	Min.
	2.9	72.3	24.8	Max.
	2.4	73.2	24.4	Ave. (6)
	2.7	72.3	25.0	Bulk
74648	2.0	74.8	23.2	Min.
	2.8	71.3	25.9	Max.
	2.4	73.2	24.4	Ave. (9)
6902(b)	2.2	74.0	23.8	Ave. (15)

* Atomic %.

Table 2. Selected pyroxene compositions of the Yamato-74 diogenites.

Sample No.	Yamato-6902* (b)	Yamato-74010		Yamato-74011		Yamato-74013		Yamato-74037	
Remarks		L	H	L	H	L	H	L	H
SiO_2	55.0	54.0	53.6	54.2	53.2	54.1	54.4	53.8	53.2
Al_2O_3	0.60	0.65	0.64	0.58	1.10	0.52	0.88	0.46	1.17
TiO_2	0.07	0.07	0.08	0.06	0.11	0.23	0.23	0.06	0.06
Cr_2O_3	0.66	0.74	0.78	0.78	1.02	0.62	0.88	0.71	0.97
FeO	15.50	15.37	15.52	15.86	16.49	15.58	15.91	15.75	15.97
MnO	0.54	0.55	0.62	0.57	0.58	0.58	0.59	0.58	0.60
MgO	27.1	26.9	26.6	26.4	25.2	27.7	26.5	27.0	25.8
CaO	1.10	1.13	1.15	1.07	1.56	0.85	1.18	1.04	1.44
Na_2O	—	0.02	0.02	0.02	0.02	0.00	0.00	0.02	0.01
Total	100.57	99.43	99.01	99.54	99.28	100.18	100.57	99.42	99.22
Ca**	2.2	2.2	2.3	2.1	3.2	1.6	2.4	2.1	2.9
Mg	74.0	74.0	73.6	73.2	70.8	74.8	73.0	73.7	72.1
Fe	23.8	23.8	24.1	24.7	26.0	23.6	24.6	24.2	25.0

* TAKEDA *et al.*, 1975. "—": not analyzed. L: low Ca, H: high Ca.
** Atomic %.

Sample No.	Yamato-74097		Yamato-74136				Yamato-74648		Yamato-75032
Remarks	L	H	L	M	H	HE	L	H	host
SiO_2	53.8	54.1	54.4	54.2	54.0	54.4	53.5	53.6	52.2
Al_2O_3	0.46	0.55	0.61	0.57	0.93	0.90	0.58	1.02	0.64
TiO_2	0.07	0.06	0.13	0.14	0.29	0.09	0.06	0.09	0.37
Cr_2O_3	0.65	0.79	0.74	1.02	1.08	1.04	0.75	0.92	0.26
FeO	15.49	15.21	15.95	16.03	16.09	15.92	15.80	16.52	21.5
MnO	0.60	0.55	0.52	0.54	0.53	0.67	0.60	0.59	0.63
MgO	26.4	26.6	27.2	26.7	26.1	26.4	27.1	26.3	23.2
CaO	1.00	1.06	1.03	1.12	1.32	1.31	1.17	1.47	0.95
Na_2O	0.02	0.02	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Total	98.49	98.94	100.58	100.32	100.34	100.77	99.56	100.51	99.75
Ca**	2.0	2.1	2.0	2.2	2.6	2.6	2.3	2.9	1.9
Mg	73.7	74.1	73.8	73.1	72.4	72.8	73.7	71.8	64.5
Fe	24.3	23.8	24.2	24.7	25.0	24.6	24.0	25.3	33.6

** Atomic %. M: intermediate.

inclusions. The inclusions resemble dust and their shape is droplet-like. Some pyroxene crystals along the area between the coarse-grained band and the inclusion-rich islands contain inclusions only within the central portion of the crystal; the outer rim is clear. Pyroxene crystals around the large chromite grains

Table 3. Representative electron microprobe analyses of olivines from the Yamato-74044 pallasite and plagioclase from the Yamato-75032 diogenite.

Sample	Yamato-74044		Yamato-75032
	Large	Small	
SiO_2	39.0	39.6	45.6
Al_2O_3	0.05	0.05	34.8
TiO_2	0.01	0.00	0.17
Cr_2O_3	0.04	0.06	0.00
FeO	12.37	12.25	0.06
MnO	0.35	0.37	0.00
MgO	48.5	46.9	0.06
CaO	0.00	0.02	18.49
Na_2O	0.04	0.01	1.03
K_2O	—	—	0.03
NiO	0.21	0.01	—
Total	100.57	99.27	100.24

Table 4. Chemical data on chromites in the Yamato diogenites and the Yamato-74044 pallasite.

Sample	Yamato-6902	Yamato-74013	Yamato-74136	Yamato-75032	Yamato-74044
SiO_2	—	—	—	—	0.05
Al_2O_3	7.97	7.30	13.17	7.14	3.93
TiO_2	0.83	0.69	0.56	2.28	0.11
FeO	25.47	24.3	25.1	31.9	22.4
MnO	0.49	0.54	0.57	0.62	0.74
MgO	5.83	5.73	6.06	1.80	6.10
CaO	—	0.0	0.01	0.02	0.01
SO_3	—	0.03	0.03	0.02	—
V_2O_3	—	0.59	0.33	0.56	0.51
Cr_2O_3	60.09	59.8	50.6	53.9	65.7
CoO	—	0.0	0.01	0.01	—
NiO	—	0.0	0.00	0.00	0.11
Total	100.68	98.98	96.44	98.25	99.66

are also coarse grained.

The chemical composition of the orthopyroxenes in these Yamato diogenites falls in the range between $Ca_{1.9}Mg_{75.1}Fe_{23.0}$ and $Ca_3Mg_{71}Fe_{26}$. This compositional range is within that of the known diogenites (Fig. 2). The lower limit of iron-calcium content of the orthopyroxenes in the Yamato recrystallized diogenites is close to that of Tatahouine, and the upper limit is beyond the Ibbenbuhren pyroxene (Fig. 3). The chemical compositions of orthopyroxenes in the individual Yamato-74 diogenites are given in Fig. 3 and Tables 1 and 2. The compositional

Table 5. Chemical data on troilites in the Yamato diogenites and the Yamato-74044 pallasite.

Sample	Yamato-74013			Yamato-74136			Yamato-74044		Yamato-75032
Remarks*	Chromite	Fe	Opx chromite	Fe	Large	Fine	Chromite	Olivine	
Fe	61.6	62.9	64.4	63.0	63.0	62.7	63.9	64.2	62.2
S	35.1	35.9	35.8	36.1	35.9	35.8	35.5	35.6	35.9
Cr	1.87	0.21	0.47	0.23	0.24	0.24	0.08	0.13	0.07
Co	0.08	0.07	0.05	0.06	0.05	0.04	0.08	0.04	0.07
Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
Total	98.65	99.08	100.72	99.39	98.19	98.78	99.56	99.97	98.33

* Mineral names indicate that troilite analyzed occurs within or adjacent to that mineral.

Table 6. Metallic irons in the Yamato diogenites and the Yamato-74044 pallasite.

Sample	Yamato-74013		Yamato-74136	Yamato-74044		
Remarks*	S	L		k	p	t
Co	0.73	0.70	0.72	0.65	0.43	0.16
Ni	0.30	0.29	0.00	6.43	18.9	46.9
Ti	0.00	0.01	0.00	0.00	0.00	0.01
Fe	97.9	98.4	98.4	93.0	79.5	52.1
S	0.03	0.01	0.02	0.00	0.00	0.00
Cr	0.03	0.02	0.04	0.02	0.00	0.01
Total	98.99	99.43	99.18	100.10	98.83	99.18

* k: kamacite, p: plessite, t: taenite, S: small, L: large.

variation of all seven Yamato-74 diogenites is considered to be identical. The composition within one crystal is uniform, but the calcium and iron contents in the large clear orthopyroxenes (H in Table 2) appear to be slightly higher than those of inclusion-rich small ones (L in Table 2). The X-ray diffraction study indicate that a coarse-grained pyroxene is orthopyroxene with no exsolved augite.

The opaque mineral inclusions in the pyroxenes are troilite, Co-rich Ni-poor metallic iron and chromite. Two of these minerals coexist within one inclusion. These inclusions are also present within the large chromite crystals. A silica mineral and plagioclase were found together with coarse-grained troilite. The chemical data of these opaque minerals are given in Tables 4, 5, and 6. The chemical compositions of large, euhedral chromites and small chromite inclusions within recrystallized orthopyroxenes are different, although the analysis of the latter chromite is poor due to its small size. The compositional differences between the large angular inclusions and the fine dust-like inclusions are difficult to detect because of the very small size of the latter inclusions.

Table 7. Bulk compositions of selected achondrites.*

	Yamato-74159	Yamato-74450	Yamato-75032
SiO_2	49.04	49.36	51.92
TiO_2	1.09	1.04	0.40
Al_2O_3	10.35	10.82	2.28
FeO	19.23	18.26	18.85
FeS	0.15	0.64	0.30
MnO	0.53	0.51	0.55
MgO	8.29	8.06	20.99
CaO	9.48	9.52	3.31
Na_2O	0.58	0.51	0.12
K_2O	0.07	0.06	0.04
$H_2O(-)$	0.00	0.00	0.00
$H_2O(+)$**	0.32	0.35	0.32
P_2O_5	0.07	0.10	0.03
NiO	0.003	0.003	0.003
Cr_2O_3	0.44	0.33	0.72
Co	<0.003	<0.003	<0.003
Total	99.64_6	99.56_6	99.83_8

* Analysis by H. HARAMURA.
** Including volatile components released up to 1100°C.

Yamato-75032 is a pyroxene-rich achondrite collected in 1975 (MATSUMOTO, 1977). The bulk chemistry of the Yamato-75032 achondrite obtained by the wet chemical analysis (Table 7) indicates that it is the most iron-rich diogenite. This diogenite is a monomict breccia with orthopyroxene (Table 2), minor augite, rare fragments of calcic plagioclase (Table 3), and minute grains of troilite and chromite in the matrix. The Fe/(Mg+Fe) ratio of this orthopyroxene is the highest of the known diogenites and close to that of the most Mg-rich eucrite, Binda. The bulk calcium contents of many Yamato-75032 orthopyroxenes are also high due to presence of the blebby inclusions of augite within the host orthopyroxene. This pyroxene might have been originally a low-calcium pigeonite. This meteorite is distinctly different from the Yamato-6902 diogenite type and common known diogenites.

3.2. *Discussion*

For most hypersthene achondrites the original crystallization was followed by mechanical brecciation without substantial recrystallization. The evidence of recrystallization found for the Yamato diogenites indicates their unique nature as was pointed out by us for Yamato-6902 (TAKEDA *et al.*, 1975). The texture is totally unlike that of Tatahouine, which appears to be the only other unbrecciated diogenite (A. M. REID, private communication, 1975). In order to explain the event which caused this recrystallization, more detailed studies on the relationship between the texture and chemistry, and isotopic dating of these diogenites have to be carried out. At any rate it is apparent that some diogenites may have had a quite complex thermal history involving reheating and, in some cases, almost complete recrystallization. Autometamorphism recrystallization during original cooling as was proposed for lunar rock 76535 (R. BRETT, private communication, 1977) may have to be considered.

Without knowing the recrystallization age, it is difficult to deduce whether this change in texture was developed by autometamorphism at an early stage or by thermal metamorphism by a radiogenic heat source after impact brecciation at a later second high temperature stage.

One clue may be to correlate the chemical trends of the orthopyroxenes and the textures. The coarse grain-size of orthopyroxenes free from dust inclusions along the network-forming lobate band within the meteorite would suggest that recrystallization might have been extensive along the band. The distribution of the bands within these meteorites may indicate that this portion was the original matrix of the brecciated diogenite filling the interstices between the brecciated pyroxene clasts. The Ca-rich materials may be more concentrated in the matrix. However, it is difficult to explain the numerous dust-like inclusions within the original pyroxene fragments.

The difference in chemical composition between large euhedral chromites and minute chromite inclusions in the recrystallized orthopyroxene indicates that they crystallized at different stages. The composition of the large chromite is close to that of pallasitic chromite, while the small one is similar to that of eucritic chromite. The large grain size of the euhedral chromite and the above facts indicate that the large chromites may be a remnant formed during the initial crystallization of the diogenites.

The presence of metallic iron, rich in cobalt and poor in nickel confirms that these unusual diogenites do not have terrestrial origin. A similarity of textures and compositions of all the Yamato-6902 and -74 diogenites strongly suggests that all or at least some of these meteorites are the fragments of one and the same fall. The shapes of Yamato-74013, -74097 and -74136 also match one another (K. YANAI, private communication).

The Yamato-75032 achondrite is the only unrecrystallized monomict Yamato diogenite. This diogenite is composed of the most iron-rich orthopyroxene among the known diogenites, and has some affinity to magnesian eucrites such as Binda. Many fragments of orthopyroxene with blebby augite might originally have been low-calcium pigeonites. The significance of this achondrite has been discussed in conjunction with the crystallization trends of pyroxenes in the genetically related achondrites (TAKEDA *et al.*, 1977). Yamato-75032 chromite also shows intermediate chemical characteristics between diogenites and eucrites. If the calcium-rich orthopyroxenes were inverted low-calcium pigeonites, we would have to reconsider the definition of diogenites.

4. Eucrites and Eucritic Polymict Breccias

4.1. Results

Yamato-74159 is a polymict breccia (98.2 g) with the bulk chemistry of eucrites (Table 7). It contains a variety of pyroxene fragments common to eucrites, calcic plagioclase, and lithic clasts a few mm in diameter in a fine grained matrix. One clast is gabbroic and the other shows ophitic texture similar to that of Pasamonte. The chemical zoning of the pyroxenes is also similar to that of Pasamonte. A detailed description and its significance to surface regolith formation on its parent body are given in our accompanying paper (MIYAMOTO *et al.*, 1978).

Yamato-74450 is a 235 g meteorite covered with a thin black-shiny fusion crust. The large portion of a fragment we examined shows a variolitic texture of white and grayish minerals, which in polished thin section proves to be radiated lath-shaped or needle-like calcic plagioclase and pyroxenes (Fig. 4). The chemical trends and zoning of the pyroxenes detected by the microprobe analyses (Fig. 5) resemble those of the Pasamonte eucrite (TAKEDA *et al.*, 1976a). These trends represent both the chemical variation of different grains and the zoning within one crystal. Large pyroxenes with ophitic texture are frequently found in the variolitic matrix. The core of such pyroxenes has uniform chemical composition but the rims of such grains show chemical zoning. The most magnesium-rich pyroxene observed has the composition $Ca_{4.6}Mg_{68.3}Fe_{27.1}$. The pyroxene composition distributes towards more iron- and calcium-rich direction up to $Ca_{31}Mg_{17}Fe_{52}$. The tie lines drawn in Fig. 5 indicate chemical zoning. The

Fig. 4. Photomicrographs of Yamato-74450 with a variolitic texture in transmitted light. Width is 4.5 mm. Note that a brecciated matrix is present between the variolitic clasts.

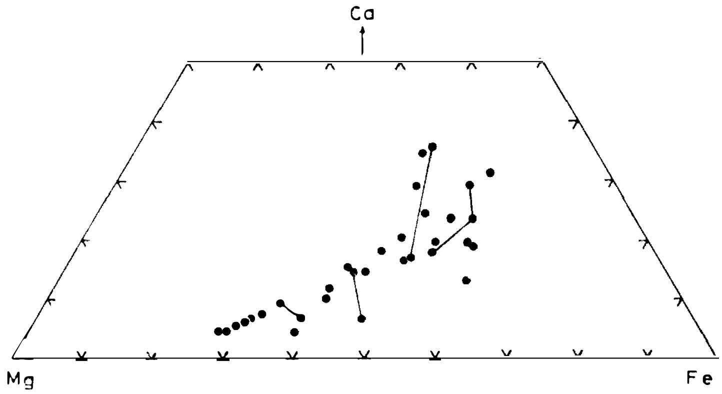

Fig. 5. Pyroxene compositions from Yamato-74450. The tie lines indicates chemical zoning.

host-lamellae relation has not been detected except in one grain in a small brecciated portion of the meteorite. The exsolution pattern of this pyroxene resembles that of Juvinas. No coarse-grained diogenitic orthopyroxene has been found within the thin section examined. The bulk chemistry (Table 7) is also that of eucrite.

A reconnaissance microprobe study on pyroxenes in Yamato-75011 and -75015 indicates that these achondrites are similar to the Yamato-74159 eucritic polymict breccia in that they contain pyroxenes common to various eucrites, and that some pyroxenes exhibit extensive zoning as was found in the Pasamonte eucrite. Yamato-75015 contains a coarse-grained orthopyroxene crystal with blebby augites, which may originally have been a pigeonite with Fe/(Mg+Fe) ratio intermediate between those of Binda and Moama (YANAI *et al.*, 1977).

4.2. Discussion

Common crystalline monomict eucrites such as Juvinas (DUKE and SILVER, 1967) with pigeonites of uniform composition have not been found among the Yamato achondrites. The typical eucritic pigeonites were unmixed to a host low-Ca pigeonite or clinohypersthene and lamellae of augite, with (001) in common. The pigeonites with chemical zoning appear to be common in the Yamato eucritic polymict breccias (Yamato-74159, -74450, -75011 and -75015). Subophitic, ophitic to variolitic texture is also common in the clasts of these meteorites. Such texture and the pyroxene chemical trend are similar to those of the unusual eucrite, Pasamonte. Chemical zoning of that type may be explained by crystallization conditions which involve rapid growth from a supercooled melt. Such conditions may be compatible with cooling in a surface lava or impact melt. The Pasamonte-like component is rare in common howardites, in which diogenitic pyroxenes derived from the deeper crust (MIYAMOTO *et al.*, 1977) are dominant. The facts that the Pasamonte-like clasts and pyroxenes are dominant in eucritic polymict breccias support an idea that they are derived from near the surface.

Although variolitic texture appears to be common in Yamato-74450, such portion may well be a part of a larger clast. The presence of the exsolved pyroxene in a brecciated matrix suggests that Yamato-74450 is polymict in strict sense. More detailed studies of known eucrites would indicate that eucrites are more or less polymict. It is interesting to note that the bulk chemistry of Yamato-74159 and -74450 is the same in spite of their difference in texture.

5. Pallasite

During the course of searching for achondrites in the Yamato-74 meteorites, one small (52 g) pallasite-like meteorite, Yamato-74044, was found. The surface is very much weathered and olivine crystals up to 1 cm in diameter occur within the oxidized products of metallic iron. This is the only stony-iron meteorite found in the Yamato collection.

Olivine crystals with uniform chemical composition (Table 3), chromite (Table 4) and troilite (Table 5) are enclosed in the iron-nickel alloy. The composition of the olivine $Fa_{12.3}$ is common for pallasites. The nickel content of olivine appears to be low for the small sized crystal in kamacite, and high for a large crystal. Further studies will be required to be sure of this difference.

The Fe-Ni metal exhibits Widmanstätten texture. The microprobe traverse of a taenite portion 0.2 mm thick exhibits the characteristic M-shaped pattern. The chemical compositions given in Table 6 are the value of the center of the M-shaped pattern (plessite in Table 6) with the lowest Ni content, that of kamacite around taenite, and that of taenite with the highest Ni content (46.9% Ni). This value corresponds to an absolute cooling rate of 0.8°C/100 m.y. after BUSECK and GOLDSTEIN (1969).

6. Discussion

Although expectation that some previously unrecognized varieties of meteorites would be found has not been realized, many achondrites found in 1974 and 1975 are unique in their texture or chemistry. The Yamato-74 diogenites show recrystallized texture, and the Yamato-75032 achondrite fills the compositional gap between diogenites and cumulate eucrites. The Yamato eucritic polymict breccias or eucritic howardites without diogenitic components contain clasts of various eucrite-types. The detailed studies of these Yamato achondrites will contribute to setting constraints on the proposed model of the achondrite parent body or bodies.

The fall frequency of howardites and eucrites is about five time larger than that of diogenites (WASSON, 1974). The find frequency of diogenites in the Yamato meteorites is double that of the Yamato howardites and eucrites. This discrepancy may be explained by our suggestion that all or many of the recrystallized diogenites are the same fall although the flux could have been different at the time of fall of Yamato meteorites. It is well known that finds of pallasites are very much greater than falls. The frequency estimated from the Yamato pallasite (one out of six hundreds) also supports the view that pallasites are a rare meteorite group. The catalogue of Yamato-74 and -75 meteorites including those achondrites described here will be published by one of the authors (K. YANAI) from the National Institute of Polar Research in near future.

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