MINERALOGICAL EXAMINATION OF THE YAMATO-79 ACHONDRITES: POLYMICT EUCRITES AND UREILITES

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***Abstract*:** Mineralogical examination of the first one-third of the Yamato-79 achondrites collected by the JARE party in 1979 and 1980 seasons revealed that eight of them are polymict eucrites similar to the Antarctic polymict eucrites reported previously, and that Y-790727 is a howardite and Y-790981 is a ureilite. The following Yamato-79 eucrites show features different from the known types. Y-790122 and Y-790266 are rich in lithic clasts. A thin section of Y-790122 consists of four different clast types joined together face to face with little matrix between them. Almost one-third of Y-790266 is a medium-grained subophitic basalt with pyroxene chemical zoning trends which simulate the host pigeonite and exsolved augite pair of the ordinary eucrites such as Juvinas. Y-790007 contains abundant cumulate eucrite clasts identical to Binda in their pyroxene exsolution texture and chemistry.

1. Introduction

This study was carried out as a part of the Preliminary Examination of the Yamato-79 Meteorite Collection with sample numbers less than 1000. Because polymict eucrites are the most common achondrites found in this sample number range, we report the results on polymict eucrites. Polymict achondrite Y-790727 reported in 'Photographic Catalog of the Selected Antarctic Meteorites' (YANAI, 1981) turned out to be a howardite rich in eucrite component. Because a preliminary inspection of the next one-third of the collection indicates that howardites are common in this portion, we will not report the results on Y-790727 in this paper. The seventh Antarctic ureilite, Y-790981, is included in this report.

The phrase 'polymict eucrite' has been defined as polymict breccias of eucritic composition or howardites with less than 10% diogenitic component (TAKEDA *et al.*, 1980). The term 'eucritic polymict breccia' was used to describe Yamato-74159, the first recognized meteorite of this kind, which contains both compositionally-zoned pyroxenes similar to Pasamonte and exsolved pigeonites similar to Juvinas within one brecciated eucrite (TAKEDA *et al.*, 1978; MIYAMOTO *et al.*, 1978). Subsequently Y-75011, Y-75015 (TAKEDA *et al.*, 1979) and Allan Hills-765 (MIYAMOTO *et al.*, 1979) were recognized to be of this type. The Yamato eucrites (except Y-74356) are unlike previously-described eucrites and howardites in that they contain a series of fragments covering a range of eucrite types from the Pasamonte-type, the Juvinas-type, to cumulate eucrite of the Binda-type in various proportions and are thus polymict, but they do not appear to contain a diogenitic component as in typical howardites.

Subsequently, seven polymict eucrites have been found in the Yamato collection. New findings of many polymict eucrites have been one of the great contributions of the recoveries of a large number of meteorites from the Yamato Mountains, Antarctica, by Japanese (JARE) teams in 1974 and 1975 (YANAI, 1979). Similar polymict eucrites, 7 in total, have also been recovered by a joint U.S.-Japan team from 1976 to 1978 from Allan Hills, Antarctica, almost 3000 km from the Yamato Mountains. Comparison of lists of Antarctic and non-Antarctic achondrites (MASON *et al.*, 1979) shows that polymict eucrites are more abundant in the Antarctic region. Macibini (REID,

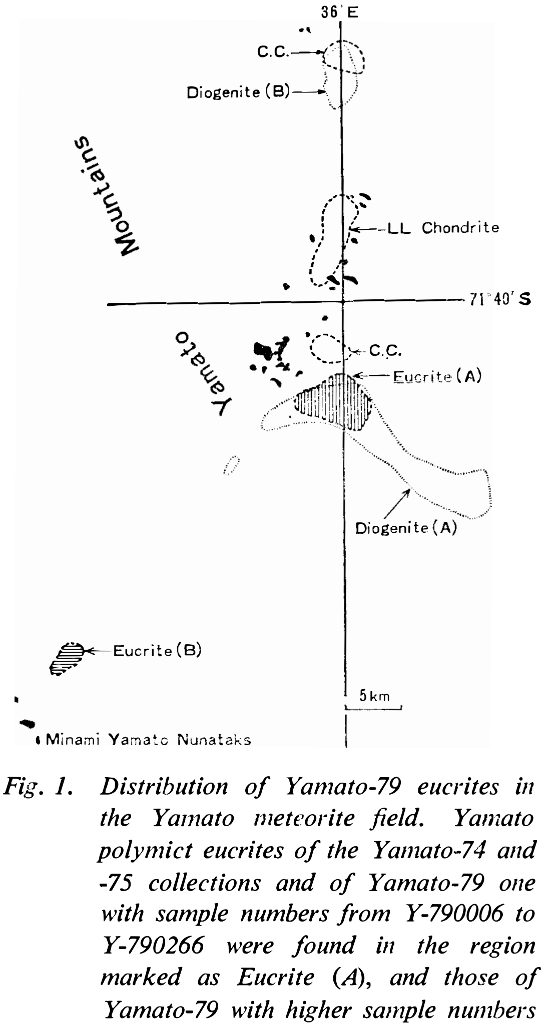


Fig. 1. Distribution of Yamato-79 eucrites in the Yamato meteorite field. Yamato polymict eucrites of the Yamato-74 and -75 collections and of Yamato-79 one with sample numbers from Y-790006 to Y-790266 were found in the region marked as Eucrite (A), and those of Yamato-79 with higher sample numbers were found in the Eucrite (B) region. Diogenite (A): recrystallized granoblastic diogenites, Diogenite (B): Y-75032 type diogenites. CC and LL: other meteorite groups.

Table 1. Yamato-79 polymict eucrites (Y-790001–Y-790990).

Sample No.	Dimensions (cm)	Weights (g)	Clasts*
Y-790006	3.8×3.0×2.2	29.4	
Y-790007	5.6×5.0×2.6	80.4	
Y-790020	7.1×4.6×3.4	86.3	
Y-790113	3.3×2.6×1.6	19.0	
Y-790114	2.0×1.6×1.4	23.9	
Y-790122	5.7×5.0×3.1	109.5	××
Y-790260	9.2×6.7×5.0	433.9	×
Y-790266	7.4×5.0×5.9	208.0	×××
Y-790447	1.8×1.3×1.0	3.03	××

* Many × indicate it is rich in clast.

1974) shows similarities to polymict eucrites and MASON *et al.* (1979) pointed out that Bialystok and Nobleborough are polymict achondrites with dominant pigeonite and in common with Macibini contain small amounts of diogenitic orthopyroxene.

Because polymict eucrites are rare among the known eucrites, the new findings of many polymict eucrites from Antarctica suggest that they could be pieces from a single fall, especially for the Yamato ones. The polymict eucrites identified in the early sample numbers of the Yamato-79 collection in Table 1 were recovered from the same bare ice area as that of the previous Yamato polymict eucrites (Fig. 1). There is another group of polymict eucrites of sample number between 1960 and 2769, which were found in different area (Fig. 1). It is of interest to see how the Yamato-79 polymict eucrites resemble the Yamato-74 and -75 ones. To give better understanding of this problem, and their origin and evolution, we will report in this paper mineralogy of the Yamato-79 polymict eucrites with sample number up to Y-790266. A part of the study on a large lithic clast in Y-790266 has been carried out as a part of the Polymict Eucrite Consortium study.

2. Samples and Experimental Techniques

After the preliminary processing (KOJIMA and YANAI, 1981) and physical description (NATL INST. POLAR RES., 1982), 1 to 3 g samples of Yamato-790006, Y-790007, Y-790020, Y-790113, Y-790114, Y-790122, Y-790260, Y-790266, Y-790727 and Y-790981 were chipped near the surface of the meteorites. A portion of each sample except Y-790113 and Y-790114 was used to make thin sections. After removal of fusion crusts, oxidized portions, and some crystalline clasts, aliquots for bulk chemical analysis were prepared. The bulk chemical analyses were made by the standard wet-chemical method by Mr. H. HARAMURA of the Geological Institute, University of Tokyo. Y-790447 was recognized as a polymict eucrite (Table 1) in hand specimen observation by KOJIMA and YANAI (1981).

Ten polished thin sections, Y-790006,80, Y-790007,91, Y-790020, 80, Y-790113,82, Y-790114,80, Y-790122,80, Y-790260,71, Y-790266,61 (crystalline clast), Y-790266,92 (matrix portion) and Y-790981,80 prepared at the National Institute of Polar Research (NIPR), were examined by an optical microscope. Chemical zoning and unmixed phases by exsolution in pyroxenes were recorded by measuring Ca, Mg and Fe concentrations at 5 to 50 μm intervals or by scanning with JEOL 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 quantitative chemical analyses were made with JEOL 733 Super Probe by employing the same parameters as those used with JXA-5.

3. Results

3.1. *Bulk chemical compositions*

The bulk chemical compositions of the Yamato-79 polymict achondrites are listed in Table 2a. They are plotted in the silica-olivine-anorthite pseudoternary diagram (Fig. 2) according to STOLPER's (1977) method. This diagram and the Al_2O_3-CaO diagram (Fig. 3) revealed that Yamato-79 polymict breccias except Y-790727

*Table 2a. Bulk chemical compositions (wt %) of Yamato-79 polymict eucrites and a howardite.**

	0006	0007	0020	0122	0260	0266	0727	2769
SiO_2	48.72	48.43	48.66	47.39	48.24	48.06	48.79	48.26
TiO_2	0.83	1.00	0.83	1.00	0.86	0.98	0.38	0.93
Al_2O_3	11.45	11.16	11.44	10.59	13.72	11.51	7.66	11.96
Fe_2O_3	0.67	0.87	1.72	1.77	—	—	2.87	0.21
FeO	18.36	16.24	17.68	15.84	17.56	19.15	13.69	19.78
MnO	0.54	0.54	0.55	0.54	0.51	0.55	0.49	0.59
MgO	8.10	8.13	7.99	7.81	7.36	7.53	17.65	6.11
CaO	10.08	10.14	10.22	9.99	10.37	9.39	5.76	10.92
Na_2O	0.51	0.51	0.46	0.46	0.50	0.61	0.21	0.52
K_2O	0.06	0.07	0.05	0.07	0.06	0.09	0.02	0.05
$H_2O(-)$	0.0	0.13	0.03	0.55	0.07	0.05	0.27	0.0
$H_2O(+)$	0.40	0.5	0.47	2.1	0.23	1.07	0.85	0.56
P_2O_5	0.21	0.20	0.17	0.17	0.07	0.11	0.15	0.09
Cr_2O_3	0.40	0.39	0.37	0.37	0.37	0.41	0.75	0.28
FeS		2.18		1.86	0.51	0.32	0.77	
Fe								
Total	100.33	100.49	100.64	100.51	100.43	99.83	100.31	100.26
NiO (ppm)		203		137	38	66	239	31
Ni (ppm)	76		66					
Co (ppm)	<30	<30	<30	<30	<30	<30	<30	<30

* Analysis by HARAMURA.

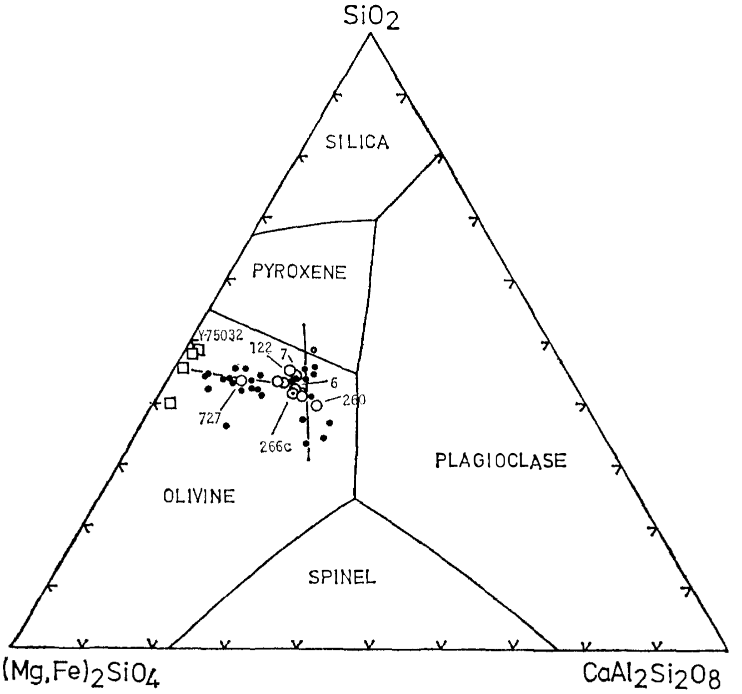


Fig. 2. Bulk chemical compositions of selected Yamato-79 polymict eucrites and howardites plotted in the silica-olivine-anorthite pseudoternary diagram of STOLPER (1977). Solid circles are data from MASON et al. (1979). Squares: diogenites, open circles: polymict eucrites and howardites from Yamato Mountains. Numbers are the last one to three digits of the Y-79 collection. c: clast. Mineral phase boundaries are those of the lunar KREEP. Scales are mol %.

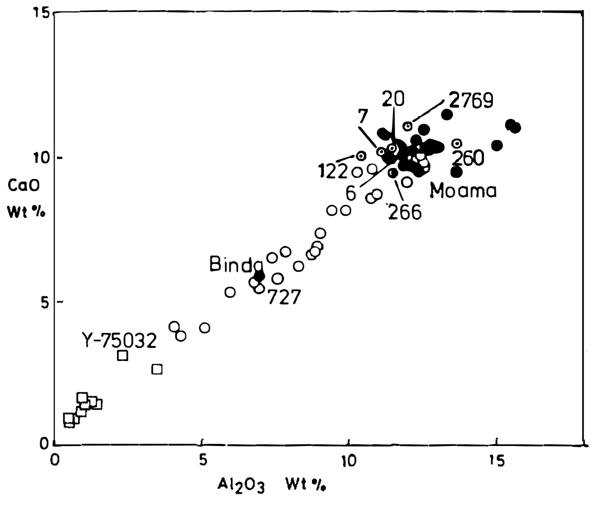


Fig. 3. The Al_2O_3/CaO diagram of diogenites (squares), howardites (open circle), eucrites (solid circles) and polymict eucrites (open circle with a dot). Data other than Antarctic meteorites are from MASON *et al. (1979).*

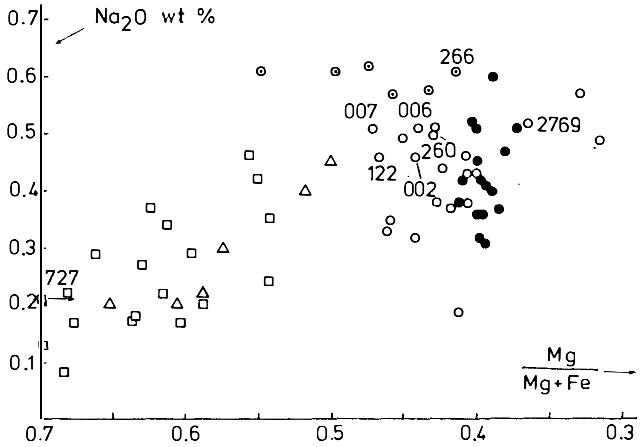


Fig. 4. Na_2O vs. $Mg/(Mg+Fe)$ diagram of howardites (squares), cumulate eucrites (triangles), eucrites (solid circles) and polymict eucrites (open circles with a number). Data other than Antarctic meteorites are from MASON *et al. (1979). The bulk compositions of clasts in polymict eucrites (open circles with a dot) are partly after* WOODEN *et al. (1981).*

Table 2b. Bulk chemistry (wt %) of Yamato ureilites.

	Y-74659	Y-74123	Y-790981	Y-74130
SiO_2	42.91	33.21	36.60	42.12
Al_2O_3	1.07	0.90	0.52	0.83
TiO_2	0.14	0.08	0.11	0.12
Cr_2O_3	0.64	0.73	0.59	0.75
Fe_2O_3	1.47	3.33	3.12	5.09
FeO	8.83	17.34	15.13	12.52
MnO	0.42	0.37	0.35	0.35
MgO	38.78	37.29	34.47	32.34
CaO	1.71	0.55	0.99	1.98
Na_2O	0.07	0.03	0.07	0.20
K_2O	<0.02	<0.02	<0.02	<0.02
$H_2O(-)$	0.17	0.38	0.30	0.25
$H_2O(+)$*	3.65	3.73	5.41	3.19
P_2O_5	0.14	0.61	0.09	0.08
FeS	0.49	0.82	1.95	0.41
Fe	—	—	0.21	—
Ni	0.14	—**	0.21	0.12
Total	100.65	99.57	100.14	100.37

* Including volatile compositions such as C released up to 1100°C. Analyses by H. HARAMURA.
** NiO 0.18.

Table 3a. Selected pyroxene compositions (wt%) of Yamato-790007 (BD, BC) and -790020 (MC).

	BD host Opx.	BC core Pig.	BC rim Aug.	MC host Opx.
SiO_2	52.2	52.4	49.7	52.5
Al_2O_3	0.73	1.69	1.32	0.53
TiO_2	0.26	0.16	0.61	0.21
Cr_2O_3	0.26	0.75	0.35	0.31
FeO	20.9	18.80	26.83	23.6
MnO	0.78	0.54	0.85	0.83
MgO	22.6	22.3	9.25	21.1
CaO	1.65	3.03	11.53	1.06
Na_2O	0.00	0.00	0.03	0.00
Total	99.65	99.78	100.47	100.13
Si	1.954	1.945	1.957	1.974
Al	0.032	0.074	0.061	0.023
Ti	0.007	0.005	0.018	0.006
Cr	0.014	0.022	0.011	0.009
Fe	0.655	0.583	0.884	0.740
Mn	0.025	0.017	0.028	0.027
Mg	1.263	1.235	0.543	1.181
Ca	0.066	0.120	0.487	0.043
Na	0.000	0.000	0.002	0.000
Total*	4.016	4.001	3.991	4.003
Ca**	3.3	6.2	25.4	2.2
Mg	63.7	63.7	28.4	60.1
Fe	33.0	30.1	46.2	37.7

* Cations per 6 oxygens. ** Atomic %.

Table 3b. Selected pyroxene compositions (wt%) of Yamato-790122 (CC) and -790260 (GC, PX).

	CC host Pig.	CC bulk Pig.	GC bulk Pig.	PX core Pig.	PX rim Pig.
SiO_2	50.3	50.9	49.2	52.2	51.1
Al_2O_3	0.79	0.87	0.56	1.31	1.15
TiO_2	0.31	0.33	0.33	0.20	0.20
Cr_2O_3	0.77	0.27	0.27	0.59	0.31
FeO	28.1	26.8	31.9	18.29	28.3
MnO	0.99	0.88	0.96	0.68	0.86
MgO	14.53	14.69	11.95	23.7	16.15
CaO	3.86	5.32	4.55	3.03	2.12
Na_2O	0.02	0.00	0.02	0.02	0.02
Total	99.71	100.06	99.72	99.99	100.21
Si	1.964	1.971	1.962	1.932	1.970
Al	0.036	0.040	0.026	0.057	0.052
Ti	0.009	0.010	0.010	0.006	0.006
Cr	0.024	0.008	0.009	0.017	0.009
Fe	0.919	0.869	1.064	0.566	0.912
Mn	0.033	0.029	0.032	0.021	0.028
Mg	0.846	0.848	0.711	1.305	0.928
Ca	0.161	0.221	0.194	0.120	0.088
Na	0.001	0.000	0.002	0.002	0.001
Total*	3.993	3.996	4.010	4.026	3.994
Ca**	8.4	11.4	9.9	6.0	4.5
Mg	43.9	43.8	36.1	65.6	48.1
Fe	47.7	44.8	54.0	28.4	47.3

* Cations per 6 oxygens. ** Atomic %.

Table 3c. Selected pyroxene compositions (wt%) of Yamato-790266.

	MG core Pig.	MG rim Pig.	SP rim Pig.	SP rim Aug.
SiO_2	52.3	49.6	48.7	49.6
Al_2O_3	1.14	0.44	0.61	1.19
TiO_2	0.16	0.14	0.27	1.02
Cr_2O_3	0.79	0.28	1.32	0.35
FeO	21.1	34.0	33.6	23.2
MnO	0.52	1.09	0.82	0.78
MgO	21.6	12.89	11.61	10.77
CaO	2.30	1.41	2.66	12.66
Na_2O	0.01	0.00	0.02	0.00
Total	99.92	99.90	99.54	99.68
Si	1.954	1.975	1.955	1.946
Al	0.050	0.021	0.029	0.055
Ti	0.005	0.004	0.008	0.030
Cr	0.023	0.009	0.042	0.011
Fe	0.658	1.133	1.129	0.761
Mn	0.016	0.037	0.028	0.026
Mg	1.204	0.766	0.695	0.629
Ca	0.092	0.060	0.114	0.532
Na	0.001	0.000	0.001	0.000
Total*	4.003	4.005	4.001	3.990
Ca**	4.7	3.1	5.9	27.7
Mg	61.6	39.1	35.9	32.7
Fe	33.7	57.8	58.2	39.6

* Cations per 6 oxygens. ** Atomic %.

Table 4. *Selected plagioclase compositions (wt%) of Yamato-790007, -790122, -790260 and -790266.*

	007 BD —	007 BC core	007 BC rim	122 CC —	260 PC —	266 XL Na-rich
SiO_2	44.7	47.6	49.5	47.7	44.3	48.4
Al_2O_3	36.1	33.0	31.1	33.0	35.3	32.4
TiO_2	0.00	0.01	0.02	0.00	0.00	0.01
Cr_2O_3	0.00	0.00	0.02	0.02	0.00	0.05
FeO	0.21	0.63	0.60	0.91	0.23	0.27
MnO	0.06	0.03	0.02	0.05	0.04	0.00
MgO	0.05	0.12	0.08	0.02	0.03	0.03
CaO	17.99	17.64	15.88	16.26	18.08	15.88
Na_2O	0.64	1.38	1.97	1.74	0.91	2.18
K_2O	0.03	0.10	0.21	0.14	0.04	0.20
Total	99.78	100.51	99.40	99.84	98.93	99.42
Si	2.061	2.181	2.280	2.195	2.066	2.229
Al	1.965	1.783	1.688	1.792	1.938	1.760
Ti	0.000	0.000	0.001	0.000	0.000	0.000
Cr	0.000	0.000	0.001	0.001	0.000	0.002
Fe	0.008	0.024	0.023	0.035	0.009	0.010
Mn	0.003	0.001	0.001	0.001	0.002	0.000
Mg	0.003	0.008	0.005	0.002	0.002	0.002
Ca	0.888	0.865	0.783	0.802	0.902	0.783
Na	0.057	0.123	0.176	0.155	0.083	0.195
K	0.002	0.006	0.012	0.008	0.003	0.012
Total*	4.987	4.991	4.970	4.991	5.005	4.993
Ab**	6.1	12.3	18.1	10.1	8.4	19.7
An	93.8	87.1	80.7	83.0	91.4	79.1
Or	0.2	0.6	1.2	0.9	0.3	1.2

* Cations per 8 oxygens. ** Mol%.

are within the eucrite field in their chemical compositions. The Y-790727 meteorite is a howardite with the Al_2O_3/CaO value close to that of the most Mg-rich eucrite, Binda, and is richer in eucrite component than the Yamato-7308 howardite.

The compositions of Y-790266 given in Table 2a is that of the largest clast in this clast-rich breccia. The Na_2O *vs.* Mg/(Mg+Fe) plot (Fig. 4) of the Y-790266 clast is in the region of clasts in other Antarctic polymict eucrites (WOODEN *et al.*, 1981) and is more Na-rich than the analyses of the other polymict eucrites, which represent the compositions of matrices.

The chemical composition of Y-790981 (Table 2b) is within the range of ureilites. High Fe_2O_3 content is one of common features of the weathered Antarctic ureilites reported to date (TAKEDA *et al.*, 1979).

3.2. *Polymict eucrites*

Microscopic observations of the Yamato-79 polymict eucrites indicate that their textures and component minerals resemble those of Y-74159, the first polymict eucrite found from Antarctica (TAKEDA *et al.*, 1978). They are complex mixtures of basaltic rock fragments and mineral grains in a matrix of comminuted pyroxene and plagioclase.

Basaltic fragments have textures including ophitic, subophitic, variolitic, and vitric types, with grain sizes generally less than 1–2 mm.

The pyroxene variations for several rock fragments are similar to those of Pasamonte, which is the first and the only non-Antarctic eucrite with distinct Fe-Mg-Ca zoning of pyroxene (TAKEDA *et al.,* 1976). Pigeonite fragments show exsolution lamellae of augite with (001) in common, as was found in Juvinas. Rare fragments of inverted pigeonite similar to that in Binda are also detected in some of these meteorites.

Y-790006, Y-790113 and Y-790114 are polymict eucrites less than 30 g in weight. Y-790006,80 contains a vitric clast 3 mm in diameter with skeletal pyroxene phenocrysts and a small coarse-grained basaltic clast. Y-790113,82 contains fragments of inverted pigeonite and a coarse-grained basalt rich in mesostasis. Y-790114,80 has a clast of granulitic basalt among other types.

Y-790007,91

This meteorite is different from the above polymict eucrites in that it has abundant fragments of inverted pigeonite with blebby exsolved augites like that of the pyroxene cumulate eucrite Binda. Their host composition $Ca_3Mg_{64}Fe_{33}$ (BD in Table 3a) is identical to those in Binda. In addition to many fragments of inverted pigeonite, there is a clast (BD) of this cumulate eucrite (Figs. 5 and 6a), in which an inverted pigeonite and a plagioclase are in direct contact, exhibiting a coarse-grained crystalline texture. The composition of the plagioclase (BD in Table 4) is the most calcic (An_{94}) among those found in polymict eucrites (Fig. 7). Small fragments of pyroxene as Mg-rich as that in diogenites were rarely detected. Pigeonites with fine exsolution lamellae similar to those in ordinary eucrites (*e.g.* Juvinas) were occasionally found (Fig. 6b), but no clast of such rock has been detected. The pyroxene compositions are given in Fig. 8.

In spite of the predominance of the slowly-cooled eucrite components, this breccia

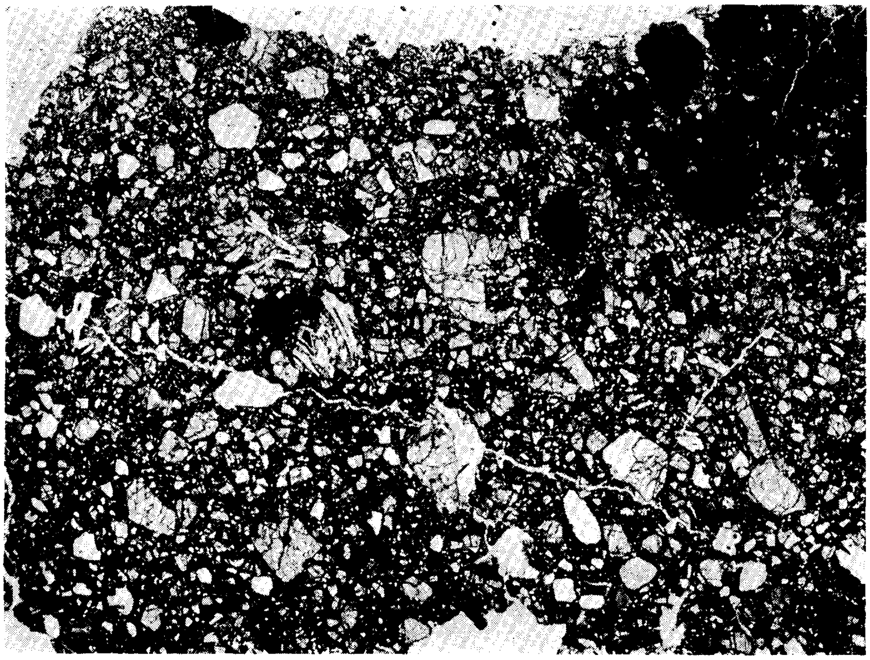
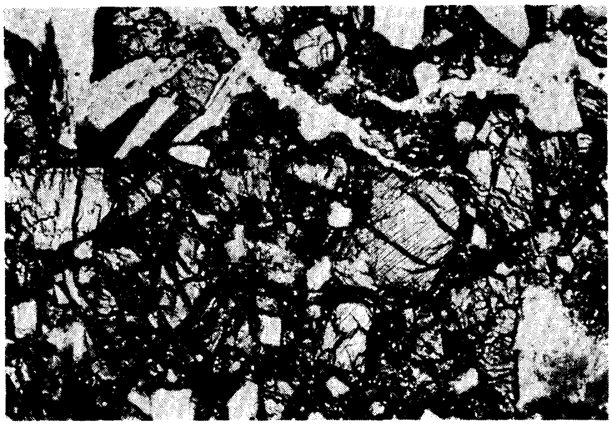


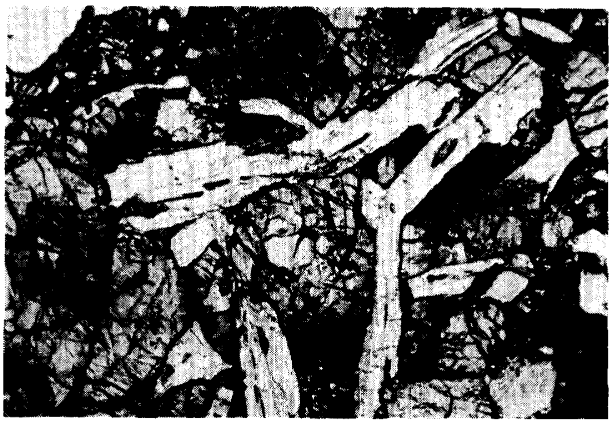
Fig. 5. Photomicrograph of thin section of Y-790007, 91, Width 7.5 mm.

Fig. 6. Photomicrographs of selected portions of Y-790007,91:

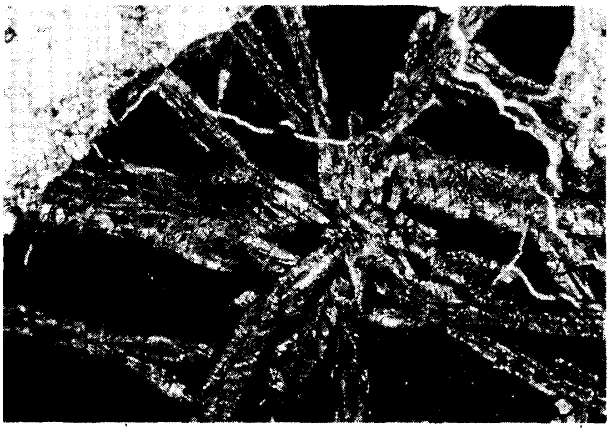
a. Cumulate eucrite clast (BD) composed of inverted pigeonites with blebby augites and plagioclases. Width 0.9 mm. Cross polarized light.



b. Matrix pyroxenes with exsolution lamellae. Open.



c. Basaltic clast (BC) with chemically zoned pyroxenes. Open.



d. Feathery pyroxenes in dark glassy matrix clast (VT). Open.

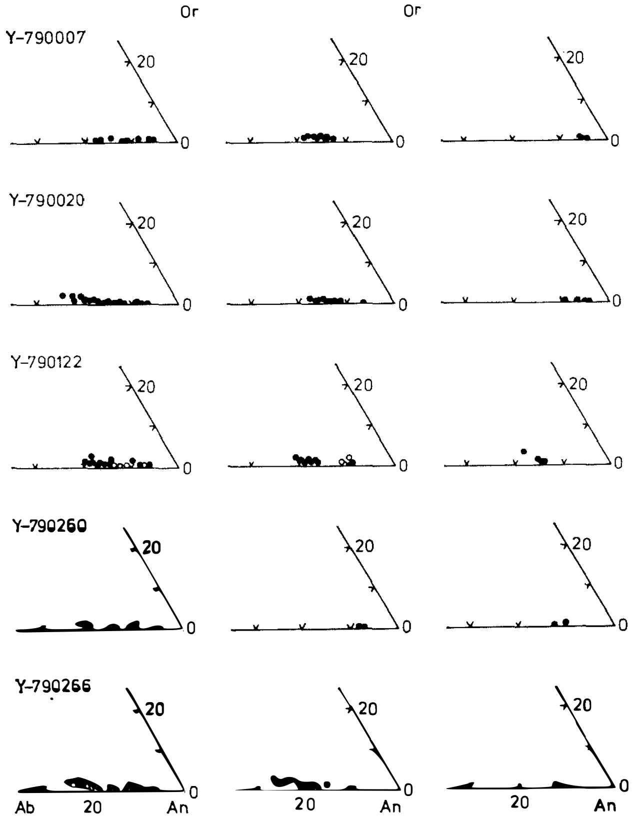


Fig. 7. Chemical compositions of plagioclases in Yamato-79 polymict eucrites plotted in the Ab-An-Or diagram. Or towards top and Ab towards left. Left column: matrix plagioclases; center: plagioclases in basaltic clasts, BC clasts in Y-790007, Y-790020, Y-790260, S clast in Y-790122, MG in Y-790266; right: other clasts, BD in Y-790007, MC in Y-790020, E clast in Y-790122, recrystallized granoblastic clasts (GC) in Y-790260 and Y-790266.

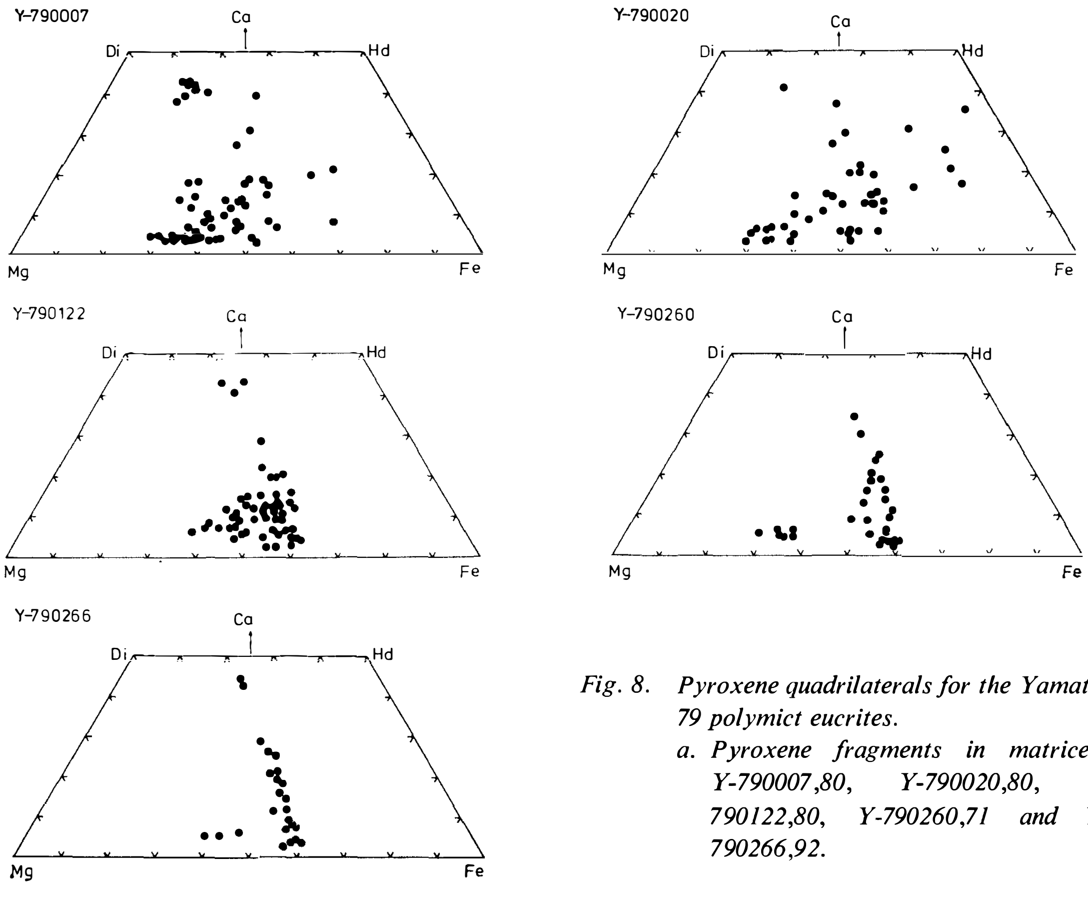


Fig. 8. Pyroxene quadrilaterals for the Yamato-79 polymict eucrites.

a. Pyroxene fragments in matrices: Y-790007,80, Y-790020,80, Y-790122,80, Y-790260,71 and Y-790266,92.

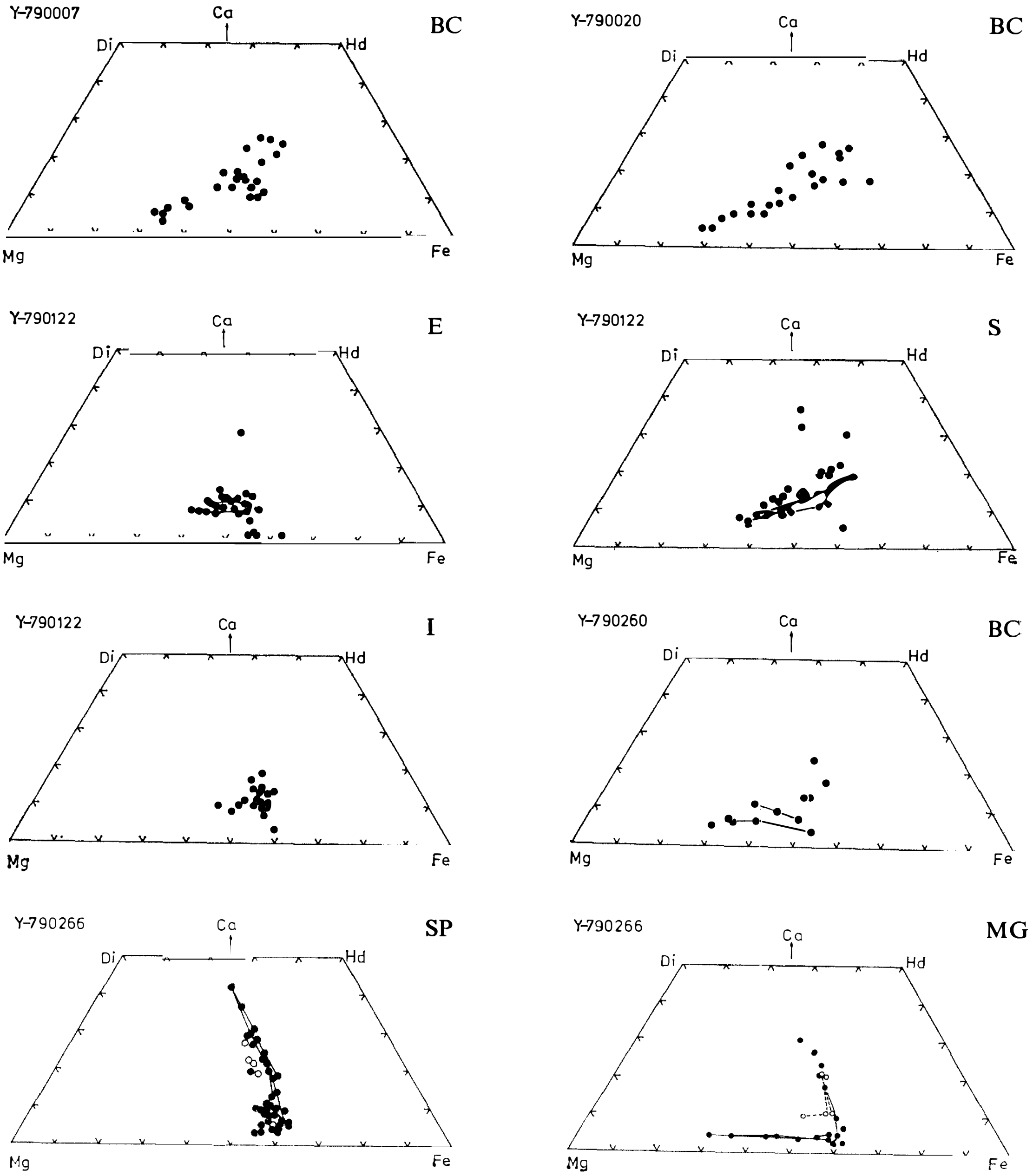


Fig. 8b. Chemically-zoned pyroxenes in ophitic, subophitic and intersertal basalts in these meteorites.

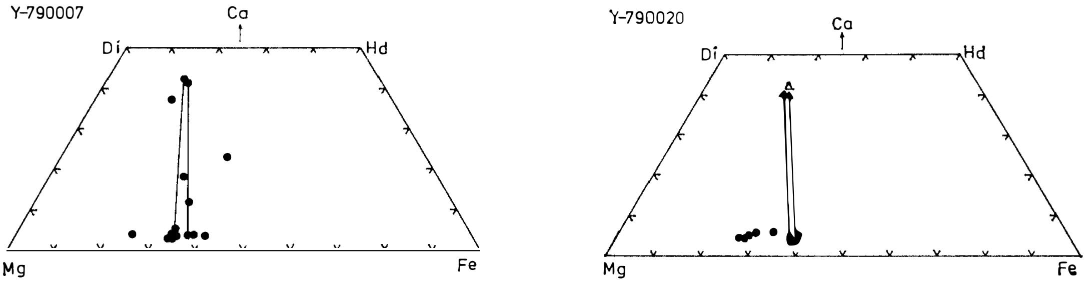


Fig. 8c. Cumulate eucrite pyroxenes in clast BD of Y-790007 and clast MC of Y-790020. Tie-lines connect the host and exsolved augite pair.

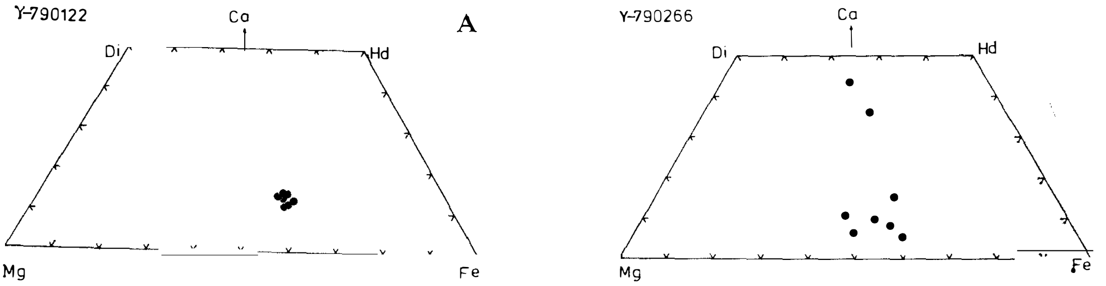


Fig. 8d. Pyroxene fragments in aphanite-like dark clasts (A).

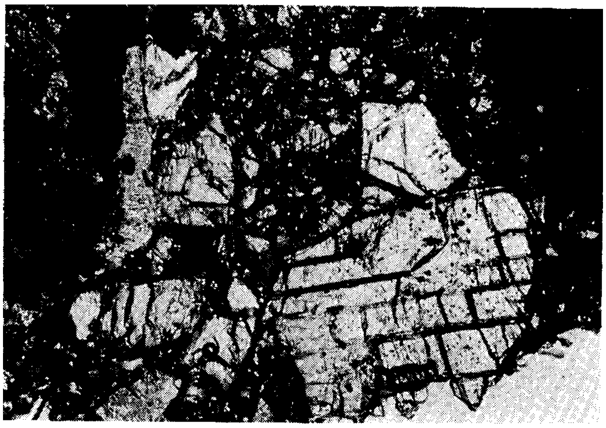


Fig. 9. Photomicrographs of Y-790020,80. Width 0.9 mm. Open. Pyroxenes in the matrix, and partly inverted pigeonite (MC) with coarse exsolution lamellae.

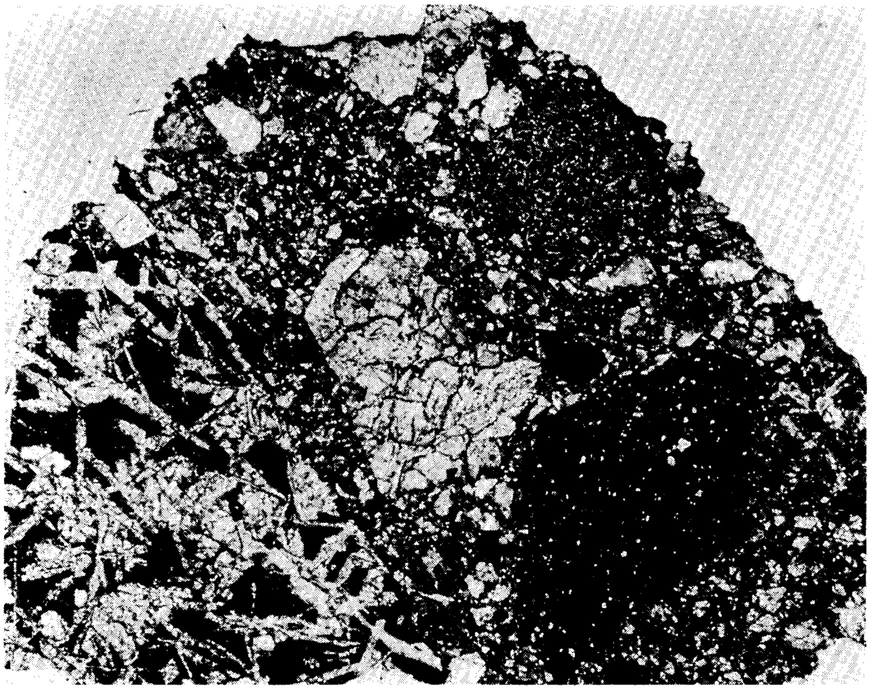
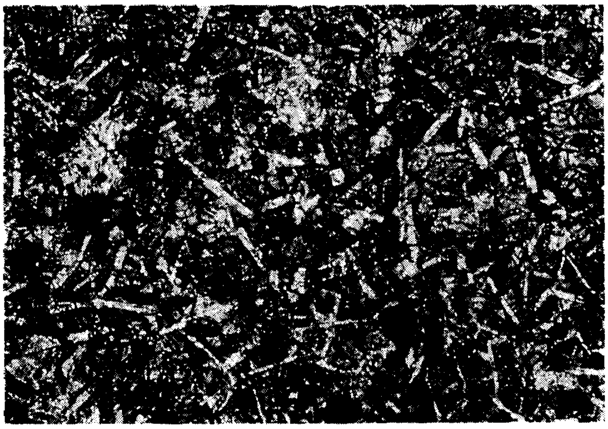
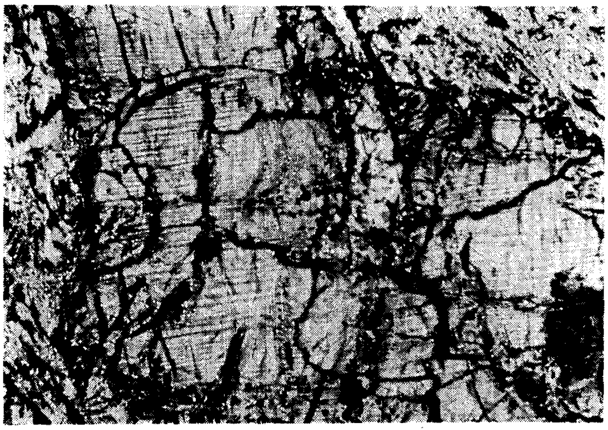


Fig. 10. Photomicrograph of thin section of Y-790122; four different clasts (see Fig. 11) can be seen. Width 1 cm. S: left, I: upper right, E: center and A: lower right.

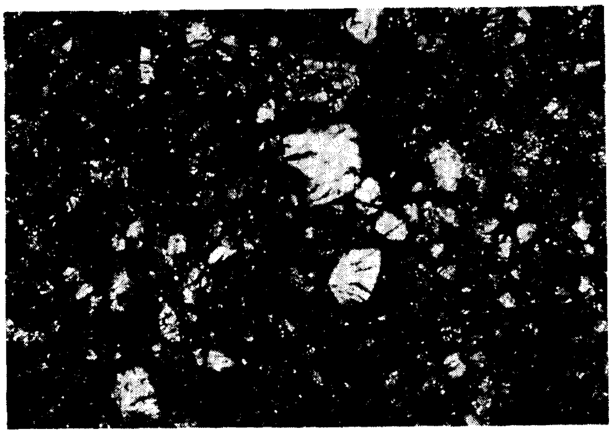
Fig. 11. Photomicrograph of selected portions of Y-790122. Width 0.9 mm.
a. Medium-grained subophitic basalt clast (S).



b. Fine-grained intersertal basalt clast (I).



c. Coarse-grained equigranular clast (E).



d. Aphanitic clast (A) or compacted regolith clast.

contains round vitric clasts (VT) with radiating feathery phenocrysts (Fig. 6d). The largest vitric clast is 6 mm in the longest dimension. A few basaltic clasts with an ophitic texture (BC) were found (Fig. 6c). Their pyroxenes show chemical zoning (Fig. 8b) and their plagioclase is more Na-rich than the cumulate eucrite ones (Table 4).

Y-790020,80

This breccia is characterized by an occurrence of a partly inverted pigeonite (Fig. 9), 0.5 mm in diameter, with coarse exsolution lamellae of augite $Ca_{40}Mg_{41}Fe_{19}$ with (001) in common with the host pyroxene $Ca_3Mg_{59}Fe_{38}$ (MC in Table 3a). It is similar to partly inverted pigeonite from Moore County (MORI and TAKEDA, 1981). Small fragments of this type are also found in the matrix. Inverted pigeonites with blebby inclusions (Binda type) have not been detected, but a lithic clast with pyroxene $Ca_{2.8}Mg_{63.7}Fe_{33.5}$ and plagioclase $An_{93.4}$ is present. The most Mg-rich pyroxene has a composition $Ca_{4.2}Mg_{70.0}Fe_{25.8}$.

Basaltic clasts with pyroxene showing chemical zoning are abundant (Fig. 8b). Large pigeonite crystals with chemical zoning are similar to those found in Y-75011 clast (TAKEDA *et al.*, 1982).

Y-790122

Two sides of the meteorite are broken, and one side is covered with black fusion crust. It is a polymict eucrite with abundant crystalline clasts. Some basaltic clasts show laths of plagioclase and others are brown to dark brown coarse lithic clasts about 1 cm in diameter.

This meteorite is rich in various clasts. The thin section examined (Y-790122,80) consists of four different clasts ranging in size from 2 mm to 4.5 mm, with narrow veins of brecciated matrix between them (Fig. 10). S: a medium-grained subophitic

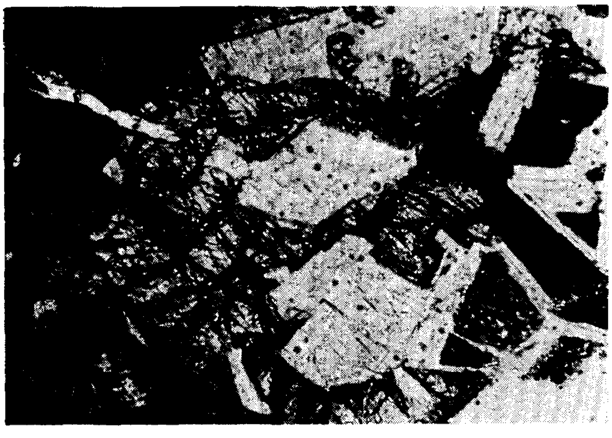
Fig. 12. Photomicrographs of thin section of Y-790260; large pyroxene clast (PX) in lower left. Width 1.0 cm.

basalt with dark troilite-rich mesostasis contains chemically zoned pyroxenes (Fig. 11a); I: a very fine-grained subophitic to intersertal basalt (Fig. 11b) with slightly zoned pigeonites ($Ca_{12}Mg_{38}Fe_{50}$) and plagioclase (An_{89}); E: a coarse-grained equigranular clast with slightly zoned pigeonites; A: an aphanitic clast includes subrounded fine-grained pyroxene $Ca_{14}Mg_{35}Fe_{51}$ and plagioclase clasts (An_{89}-An_{93}) in a dark matrix (Fig. 11d). No inverted pigeonite from cumulate eucrites is found in the matrix. This polymict eucrite is a clast-rich type.

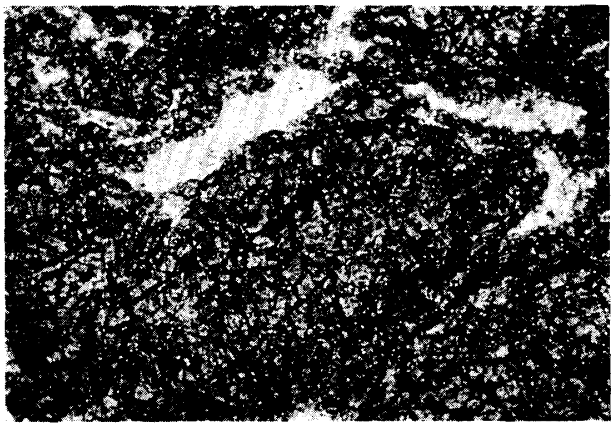
The chemical compositions of pyroxenes in the matrix and the four different clasts are given in Fig. 8. Pyroxenes in clast E look like that of some eucrites, but they show slight compositional zoning and their bulk chemical composition is slightly more Mg-rich than those in the ordinary eucrites (CC in Tables 3b and 4).

Fig. 13. Photomicrographs of selected areas of thin section of Y-790260; width 0.9 mm. Open.

a. Pyroxene clast (PX) with dark fractures filled with olivines.



b. Subophitic basalt clast (BC).



c. Shock-recrystallized clast with deformed plagioclase (GC).

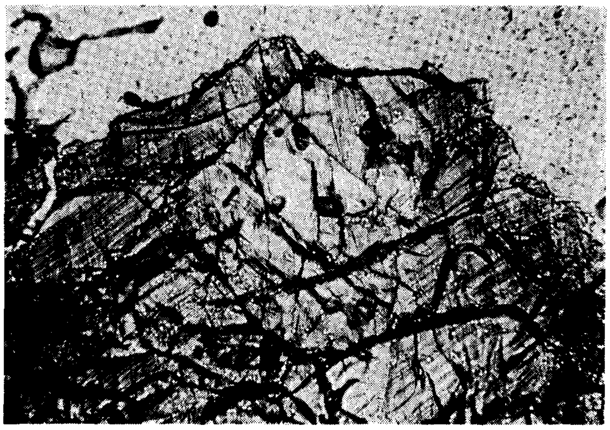
Y-790260

An oblong almost complete stone with considerable fusion crust covering most of the meteorite. Two sides have less fusion crust, where abundant lithic and mineral clasts can be seen. The textures of clasts range from fine-grained, variolitic to coarse-grained, ophitic to subophitic. The largest clast reaches 1.5 cm in diameter. Mineral clasts include white angular plagioclases and honey brown pyroxenes.

The single thin section (Y-790260,71) reveals a breccia with plagioclase and pyroxene fragments in a dark matrix which appears to be partly shock-recrystallized (Fig. 12). Many pyroxene fragments do not show distinct outer shape and their rims merge into the matrix, making angular plagioclase fragments more prominent. One large plagioclase clast in the center of Fig. 12 reaches 3 mm in the longest dimension

Fig. 14. Photomicrographs of thin section of Y-790266. Width 0.9 mm. Open.

a. Pyroxene phenocryst with augite rims (SP).



b. Pyroxenes with Mg-rich core (MG).

c. A shock-recrystallized granoblastic portion (GC).

(PC in Table 4). Very large pyroxene fragments (PX in Table 3b) up to 5 mm in diameter (Fig. 13a) are common. They have uniform cores rich in Mg ($Ca_7Mg_{64}Fe_{29}$) and dark brown rims ($Ca_9Mg_{45}Fe_{46}$) (Table 3b), and reveal many dark fractures filled with Fe-rich olivines (Fa_{66}). These pyroxenes filled with olivine veins resemble those of the Y-75011 clast. Pyroxene with exsolution textures are rare. One clast (GC) consists of fine-grained irregular aggregates of pyroxene rich in opaque inclusions and elongated patches of plagioclase, which do not show well-defined outer shape (Fig. 13c). One basaltic clast 1 mm in diameter shows a subophitic texture and contains chemically zoned pyroxenes of the Pasamonte type (Fig. 13b).

Y-790266

An angular stone covered with thin fusion crust, which is partly lost. The interior is difficult to see but it is rich in clasts. About half of this meteorite consists of a medium-grained crystalline eucrite clast, but it is essentially polymict with a small amount of matrix, because some small clasts show coarse-grained texture and the others fine-grained ophitic texture. Mineral fragments are not abundant.

The thin section of a matrix-rich portion (Y-790266,92) shows a fine-grained breccia of angular fragments of pyroxene and plagioclase, in a matrix of comminuted pyroxene and plagioclase with accessary opaque minerals. However, some portions may be brecciated medium-grained basalt, which is the most common clast (Fig. 14a) in this eucrite. Pyroxenes in strongly shocked areas shows fine-grained granoblastic texture with elongated or deformed plagioclase (Fig. 14c). Vitric clasts with zoned pyroxene phenocrysts and dark aphanitic clasts are also present.

The thin section of a medium-grained basalt (Y-790266,61) with subophitic to intergranular texture consists of stubby plagioclase laths with intergranular pyroxenes (Fig. 14a and Fig. 15). Microprobe analyses show pyroxene (SP) ranging in composi-

Fig. 15. Photomicrograph of a medium-grained basalt in Y-790266. Width 1 cm.

tion from core pigeonite $Ca_6Mg_{36}Fe_{58}$ to rim augite $Ca_{28}Mg_{32}Fe_{40}$ (Fig. 8b) and plagioclase (XL) $Ab_{15}An_{84}Or_1$ to $Ab_{23}An_{75}Or_2$ (Tables 3c and 4). A few large pyroxenes (MG) have an Mg-rich core $Ca_5Mg_{67}Fe_{28}$ (Fig. 14b) zoned toward Fe-rich pigeonite (Figs. 8b and 14b; Table 3c). Fragments of this type basalt are common in the brecciated matrix.

3.3. Ureilite

Y-790981 is about 1/8 fragment bound by three intersecting flat fracture faces and one round face with partly weathered black fusion crust, which shows polygonal fractures characteristic of ureilites. Round dark crystals, relatively coarse-grained, can be seen on the fracture surfaces, with some spaces between the crystals. White

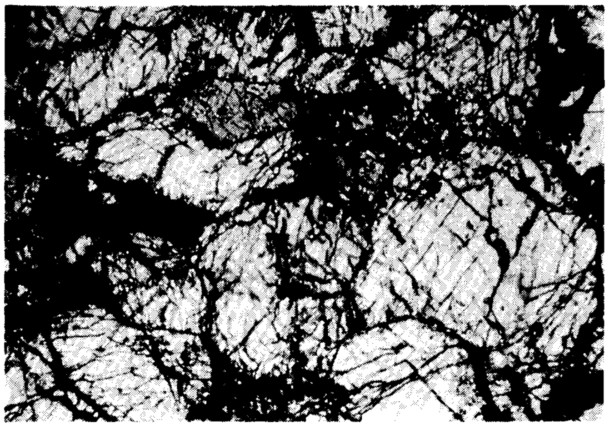
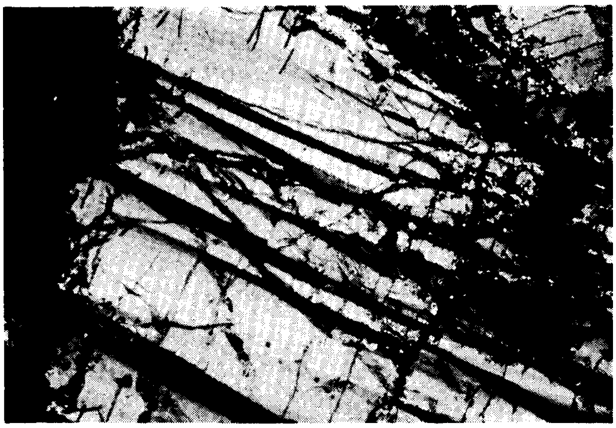
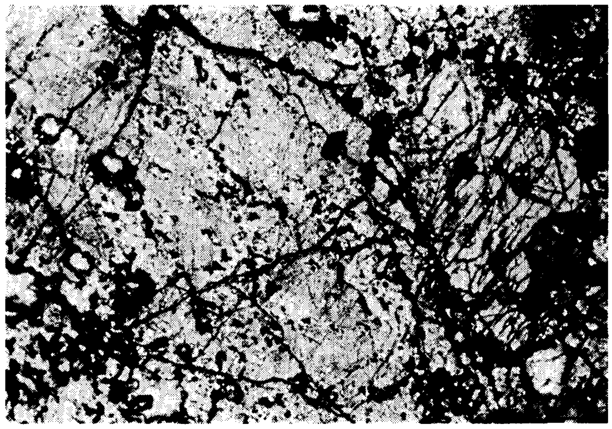


Fig. 16. Photomicrographs of the Y-790981 ureilite. Width 0.9 mm.

a. Olivine crystals with carbonaceous matrix. Open.



b. Olivine crystals showing wavy extinction. Cross polarized light.



c. Pyroxenes with glass inclusions. Open.

Fig. 17. Pyroxene quadrilateral of the Y-790981 ureilite. The tie-lines connect the three-pyroxene assemblage of Y-74130.

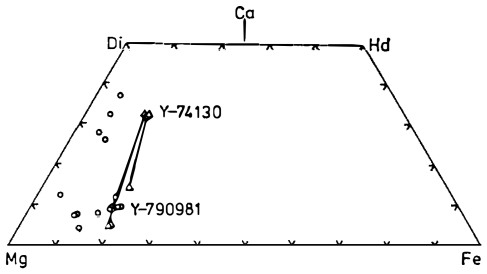


Table 5. Pyroxene compositions (wt %) of Yamato ureilites.

Samples	Y-790981			Y-74130			
	Pig. P28	Pig. P34	Aug. P35	Aug. N2	Opx. N3	Pig. N6	Aug. N5
SiO_2	54.8	56.0	53.4	52.9	54.7	54.0	52.8
Al_2O_3	1.13	0.54	0.54	2.76	1.81	1.89	2.72
TiO_2	0.06	0.05	0.30	0.29	0.16	0.16	0.23
Cr_2O_3	1.14	1.02	1.39	1.88	1.08	1.15	1.83
FeO	11.34	6.90	3.36	7.27	11.91	11.38	8.02
MnO	0.46	0.38	0.36	0.50	0.50	0.48	0.48
MgO	27.0	30.4	20.7	18.12	28.18	23.9	18.92
CaO	4.13	3.72	18.51	14.89	2.26	6.34	13.99
Na_2O	0.05	0.07	0.23	0.88	0.14	0.46	0.75
Total	100.11	99.08	98.79	99.49	100.74	99.76	99.74
Si	1.962	1.981	1.921	1.939	1.941	1.955	1.931
Al (IV)	0.038	0.019	0.079	0.061	0.049	0.045	0.059
Al (VI)	0.010	0.003	0.014	0.058	0.027	0.036	0.058
Ti	0.002	0.001	0.008	0.008	0.004	0.004	0.006
Cr	0.032	0.028	0.040	0.055	0.030	0.033	0.053
Fe	0.339	0.204	0.101	0.223	0.354	0.345	0.245
Mn	0.014	0.011	0.011	0.015	0.015	0.015	0.015
Mg	1.439	1.602	1.108	0.991	1.492	1.290	1.032
Ca	0.158	0.141	0.713	0.585	0.086	0.246	0.548
Na	0.004	0.005	0.016	0.063	0.010	0.032	0.053
Total*	3.998	3.995	4.011	3.998	4.008	4.001	4.000
Ca**	8.2	7.2	37.1	32.5	4.4	13.1	30.0
Mg	74.3	82.3	57.6	55.1	77.2	68.6	56.5
Fe	17.5	10.5	5.3	12.4	18.3	18.3	13.4

* Cations per 6 oxygens. ** Atomic percent.

needle-like crystals are found in cavities on the surface. The bulk composition is given in Table 2b.

Y-790981 is predominantly composed of anhedral to euhedral olivine (87%) and pigeonite (8%) with dark carbonaceous (C) matrix (5%) at the grain boundaries. The olivine crystals display fracturing and undulatory extinction (Fig. 16b) and subgrain boundaries. Average olivine core composition is Fa_{21}, and in contact with C matrix the composition is enriched in Mg by reduction, and sometimes a Fe-free pigeonite is produced at the rim. The pigeonites have some tiny inclusions. The pigeonite composition $Ca_8Mg_{74}Fe_{18}$ are similar to those of Y-74123 and are rich in

Al_2O_3 (1.1 wt%) and Cr_2O_3 (1.1 wt%). In some crystals there are inclusions of diopside $Ca_{37}Mg_{58}Fe_5$, more Mg-rich than that expected from the coexisting pair. The most notable texture of the pigeonite is the first occurrence of unmixed augite in ureilites. ATEM examination by H. MORI (priv. commum., 1982) revealed that the thickness of the exsolved augite lamellae is a few hundred Å, and that spherical Al-rich augite inclusions coexist with glass. The pyroxene compositions are given in Fig. 17 and Table 5.

Y-791538 is another ureilite found in the Y-79 collection (B. MASON, priv. commun., 1982), and is similar to Y-74659. However, a sample for the preliminary examination has not been available at this investigation.

4. Discussion

4.1. Origin of polymict eucrites and the howardite parent body

Comparative studies of pyroxenes in polymict breccias of the howardite parent body and of the lunar highland (LABOTKA and PAPIKE, 1980; TAKEDA *et al.,* 1980) have been providing us with information on the nature and evolution of planetary regoliths. We proposed that the polymict eucrites contain essentially the entire range of pyroxene components within the primitive eucrite crust. In spite of the extensive studies of individual meteorites, few comprehensive comparative studies on this primitive planet have been undertaken to elucidate a general model of breccia formation. Comparison of pyroxene mineralogy of many polymict eucrites between the Yamato-79 collection and those recovered previously from Antarctica (TAKEDA *et al.,* 1978, 1979; WOODEN *et al.,* 1981; DELANEY *et al.,* 1982), revealed that more diverse clast types were found. Especially, Y-790122 and Y-790266 are rich in crystalline clasts and Y-790007 contains abundant inverted pigeonites from cumulate eucrites.

The variety of Antarctic polymict eucrites and howardites were interpreted in terms of a simple model involving various depths of excavation by impacts of various-sized meteorites into a layered crust of the howardite parent body (TAKEDA, 1979). The Yamato-79 polymict eucrites can also be interpreted in terms of this model, but regional differences in breccia-unit distribution on the parent body should be considered to explain the diversity of the clast types.

Similarity in their textures, mineral compositions and clast types common in the suite of achondrites collected from Antarctica suggests that at least some of them could even be pieces of a single fall. On the other hand, some of the polymict eucrites containing different types of cumulate eucrite may represent pieces of another fall. However, the difference can be attributed to local difference within a single meteorites, since new thin sections of different portions of Y-74450 are different from the first chip we investigated (TAKEDA *et al.,* 1978), in that it contains fragments of inverted pigeonite from a cumulate eucrite. Y-790007 contains similar inverted pigeonites.

The question why polymict eucrites are common only in Antarctica requires further studies by different disciplines. The differences between the Antarctic polymict eucrites and non-Antarctic eucrites can be summarized as:

(1) The differences are an artifact produced by inadequate sampling.

(2) There is some factor that results in the achondrite flux in the Antarctic region

of the earth being different from elsewhere.

(3) The distribution of achondrite meteorites reaching the earth has changed with time and the Antarctic collection represents an average over a much longer time interval or during a certain period in the distant past (REID, priv. commun., 1980).

(4) The meteorites on specific ice field represent falls in the local area during a certain period.

(5) Monomict eucrites are derived from large hard crystalline clasts and polymict eucrites are small fragments with fragile matrix. Soft landing of fragile polymict eucrites on a soft snow field can protect them from fragmentation.

(6) There was a large shower of a polymict eucrite over the entire Antarctic Continent.

At present, we do not have solid evidence to support any one of the above hypotheses, but the present results at least are not against hypotheses (4) and (5).

Variability of pyroxene zoning can be explained by the difference in the degree of supersaturation of a pigeonite component that relates to nucleation and growth rate, their bulk chemical composition, fractionation in the melt pocket and the interaction with plagioclase growth in the melt. However, the bulk chemistries of the clasts are not known due to their small size, except that of Y-790266. It is anticipated that a small difference in bulk chemistry may result in nucreation and crystallization of pyroxene before plagioclase in one case. Phenocrysts of Mg-rich pigeonite have been found in basaltic clasts of Y-74450, which is rich in normative pyroxene. In ophitic or subophitic clasts, laths of plagioclase may have developed before the major growth stage of pigeonite. Simultaneous nucleation of pigeonite and plagioclase may have taken place in basalts with variolitic texture. The trend of the Y-790266 clast is difficult to produce by such simple crystal growth. Growth of crystals from partly shock-melted eucrites or thermal annealing processes should be considered. The evidence that the zoning trend of Y-790266 is similar to that for the variolitic matrix of the pigeonite porphyritic basaltic clast in ALH-77302 suggests that simultaneous growth of plagioclase and pigeonite may produce such chemical trend. At any rate further dynamic crystallization experiments are required to test these hypotheses.

The chemical composition of the Y-790266 clast is close to the peritectic liquid. The bulk composition including the matrix is difficult to obtain because the meteorite is rich in clasts, but that of Y-790260 which is similar to Y-790266 but rich in matrix is close to the peritectic composition towards the plagioclase side. Na_2O (0.61 wt%) *vs.* Mg/(Fe+Mg) (=0.41) plot of Y-790266 clast (Fig. 4) is in the region of clasts in other Antarctic polymict eucrites (WOODEN *et al.*, 1981), and is more Na-rich than other Yamato-79 polymict eucrites (Na_2O 0.50 wt%). The plagioclase in the Y-790266 clast is also Na-rich (An_{80}), but a more Na-rich one (An_{73}) was found in plagioclase fragments in the matrices of other polymict eucrites and in the non-polymict Antarctic eucrite Y-74356, whose common plagioclase is more calcic (An_{92}). Statistics of the compositions of plagioclase in the matrix of many polymict eucrites (Fig. 8) suggest that the more calcic plagioclases are abundant in the matrices. Such calcic plagioclases were identified in the cumulate-eucrite clasts of Y-790007.

The presence of three different pyroxene-zoning types (TAKEDA *et al.*, 1982) suggests that there may be diversity of lava units on the surface of the eucrite or howardite

Table 6. Polymict eucrites and howardites arranged in order of excavation by hypothetical impacts. C: clast, M: matrix.

Excavation	Meteorite samples	Weight (g)	References
Polymict eucrites rich in surface type	Y-74450 C		
	Pasamonte	—	a
	Y-74159 C		
	ALH-765	1435	c
	ALH-77302	235.5	i
	ALH-78040	211.7	h, j
	ALH-78132	656.0	h, j
	ALH-78165	20.9	h, j
	Nobleborough	—	k
(unidentified)	Y-75259	8.8	i
	Y-75296	8.6	i
	Y-75307	7.9	i
	Y-790122	109.5	l
	Y-790260	433.9	l
	Y-790266	208.0	l
Shallow polymict eucrites with minor cumulate eucrites	ALH-78158	15.1	h, i
	Y-74159 M	98.2	a, b
	Y-74450 M	235.6	a, b
	Y-75011	121.5	e
	Y-75015	166.6	e
	Y-790007	80.4	l
	Y-790020	86.3	l
Intermediate, polymict eucrites with minor diogenites	ALH-78006	8.0	h, i
	Macibini	—	d
	Bialystok	—	k
Deep, howardites (known samples	Y-790727	120.4	l
excluded except new one)			f
Diogenite-rich polymict breccias	Frankfort	—	g
	Y-7308	480	b, g

a. Takeda *et al.*, 1978
b. Miyamoto *et al.*, 1978
c. Miyamoto *et al.*, 1979
d. Reid, pers. commun., 1974
e. Takeda *et al.*, 1979
f. Wilkening *et al.*, 1971
g. Takeda *et al.*, 1976
h. Takeda *et al.*, 1980
i. Takeda and Yanai, 1981
j. Sato *et al.*, pers. commun., 1981
k. Mason *et al.*, 1979
l. This study

parent body. The identification of different basalt types may be useful in classifying the polymict eucrites on the basis of the genesis of the basaltic lava units on the parent body.

All polymict breccias found to date except ordinary howardites are tabulated in Table 6. In this table, several meteorites of the 1980 U.S. collection are not included because of a lack of information. They are grouped into four subgroups and are arranged in order of depths of excavation by hypothetical impacts as:

(1) Near surface (polymict eucrites). Yamato-74159 was the first polymict eucrite described from Antarctica (Miyamoto *et al.*, 1978; Takeda *et al.*, 1978). Similar meteorites were also found in the Allan Hills region, Antarctica (Miyamoto *et al.*, 1979; Grossman *et al.*, 1981). The recognition of this type of meteoritic breccia is based on our finding of chemically-zoned pyroxenes with a Mg-rich core in Pasamonte (Takeda *et al.*, 1976). This surface-type eucrite was called an unequilibrated eucrite

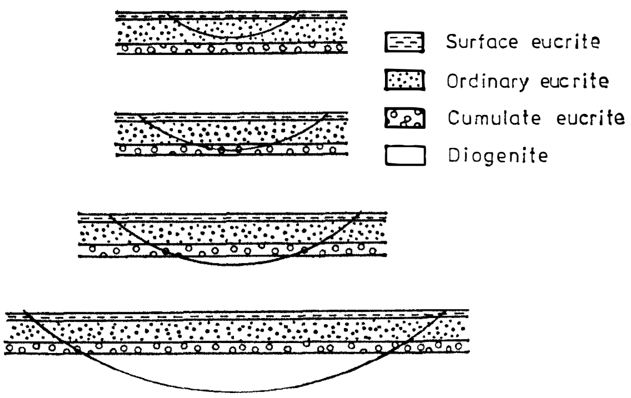


Fig. 18. Schematic models of four hypothetical impacts into the layered crust of the howardite parent body, producing various polymict eucrites and howardites.

(REID and BARNARD, 1979), but the degree of zoning depends on the crystallization and cooling conditions. There are three major chemical trends of pyroxene, as discussed by TAKEDA *et al.* (1982). The exsolution textures of pyroxenes in the ordinary eucrites or equilibrated eucrite types in polymict eucrites are more diverse than those of non-polymict eucrites. Y-790266 contains a large clast of medium-grained eucrite with a unique zoned pyroxene composition. The abundances of two types of eucrite differ from one polymict eucrite to another. Y-74450 is rich in surface eucrites with a variolitic texture and Mg-rich pigeonite phenocrysts. This group of polymict eucrites was interpreted as produced by impacts down to the bottom of the ordinary eucrite layer (Fig. 18). However, there may be lateral variations.

(2) Shallow (polymict eucrites with cumulate eucrites). In addition to the pyroxene mentioned in the above group, polymict eucrites of this group contain fragments of pyroxenes from cumulate eucrites such as Binda and Moama. Recent reinvestigation of Y-74159 and Y-74450 shows that they contain fragments of the Binda-like pyroxene. The components of cumulate eucrites have always been mineral fragments and no crystalline clast has been detected. The first occurrence of crystalline clasts exactly identical to Binda in their composition and texture has been noted in Y-790007 (Fig. 6a and 8c). Some pyroxenes of ordinary-eucrite type show exsolution lamellae coarser than those in ordinary eucrites. Inverted pigeonite of Moore County type has been detected in Y-790020. Round clasts of the surface-type eucrite are still abundant. The impact for this group may have excavated materials down to the cumulate eucrite layer.

(3) Intermediate depth (polymict eucrites with minor diogenites). This group is intermediate between polymict eucrite and howardite. Because the amount of diogenitic orthopyroxene is small, the group should be called polymict eucrites with minor diogenite. We thought at one time that Macibini, reported by REID (1974), is the first example of a polymict eucrite. However, a recent examination by MASON *et al.* (1979) mentioned the presence of orthopyroxene as Mg-rich as Fs_{19}. Macibini may belong to this group. Y-790007 and Y-790020 rich in cumulate eucrites may contain a very small amount of diogenite. The meteorite impact may excavate materials just to the very upper portion of the diogenitic mantle.

(4) Deep (Howardites). Many known howardites (LABOTKA and PAPIKE, 1980; PRINZ *et al.*, 1980) belong to this group. We identified a new howardite, Y-790727, in the Yamato-79 collection (TAKEDA and YANAI, 1981). Greenish or yellow-

ish pyroxene fragments are common in this breccia and have been identified as orthopyroxene by the single-crystal X-ray method. This type of polymict breccia is so abundant that it should be an abundant lithology on the parent body.

The deepest variety may be howardite rich in diogenite. Polymict breccias of this group are rich in the diogenite component, but still contain ordinary eucrite clasts and pyroxene fragments similar to Yamato-75032. It can be called 'polymict diogenite' if we exclude minor clasts. The most Mg-rich orthopyroxene is very poor in Ca content and approaches that in Steinbach. To excavate materials of the deepest portion of the diogenitic mantle, the impact must be very large scale. It may correspond to a large multi-ring basin on the howardite parent body, such as Mare Imbrium on the Moon.

It is to be noted that no Mg-rich olivine, residues of partial melting, nor rocks of source regions have been recovered in polymict breccias (DELANEY *et al.,* 1980). The evidence is in favor of the above layered crust model.

The preservation of moderate chemical zoning in pigeonites slightly more Mg-rich than those of the ordinary eucrites in a coarse-grained equigranular clast (E in Fig. 11c) in Y-790122 suggests that there are intermediate states between the Pasamonte-type pigeonite and that in ordinary eucrites. The terminology equilibrated and unequilibrated eucrites may be too simplified a model to describe the complex nature of the rock types on the parent body.

In summary, the variety of polymict eucrites and howardites can be explained in terms of impacts of meteorites into a primitive layered crust with pyroxene from rapidly cooled to very slowly cooled varieties (TAKEDA, 1979). The four different schematic models of impact are shown in Fig. 18. Of course, there may be local differences in the thickness and components of each layer. Three types of zoning trends of pyroxene found in clasts from Y-75011, ALH-77302 and Y-790266, respectively, may represent different types of lava units (TAKEDA *et al.,* 1982). Absence of the Moore County-type inverted pigeonite in Y-75015, and of the Binda-type in ALH-78006, suggests that there is only one type of cumulate eucrite in certain areas.

Different types of breccia might have been distributed on the surface of the parent body. The presence of large clasts of surface eucrite in polymict eucrites implies that original lava units may be left intact on the surface. A wide area of the surface before destruction might have been covered by the diogenite-rich howardites, because a large basin-forming impact is required to excavate the deep-seated rock type such as diogenite. Some portions of the parent body may have a exposure of Mg-rich cumulate pyroxenes. This expectation has been supported by observational rotational studies of 4 Vesta by GAFFEY (1981), who discovered orthopyroxene-rich areas on the surface. His observation may support our model.

4.2. *Some characteristics of Antarctic ureilites*

Recent work on the nature and origin of ureilites by BERKLEY *et al.* (1980) and on petrogenetic considerations for ureilites by RYDER (1981) have clarified important problems in ureilite genesis. Nevertheless, the restricted availability of ureilites has constrained investigations of these enigmatic bodies. As summarized by REID (priv. commun., 1981), six ureilites recovered from Antarctica and described by us extended the range of known variability within the group, as could be expected since there were only eight known ureilites prior to the Antarctic discoveries. Of particular interest is Yamato-74659, which is a low-Fe ureilite carrying the most magnesian pigeonite recorded from the group. At the other end of the spectrum Yamato-74130 carries augite together with pigeonite (Table 5) and has an unusually Fe-rich olivine (Fa_{22}). ALH-78019 and ALH-78262 also have Fe-rich olivine (Fa_{23}) and are less shocked than other groups. The new Yamato-79 ureilite is the largest among the Yamato ureilites but its mineral compositions are similar to Kenna. However, the first evidence of exsolution in a ureilite suggests that it may be large slowly-cooled broken mass.

4.3. Discussion on the Antarctic achondrites

The Yamato-79 polymict eucrites revealed many similarities to the previously described Antarctic polymict eucrites, but some are rich in clasts of different types, and a few breccias are rich in cumulate eucrites. There are monomict or shocked crystalline eucrites (*e. g.* Y-792510) in the last portion of the Yamato-79 collection (MASON, priv. commun., 1982). There are other group of polymict eucrites collected from a region marked as Eucrite (B) in Fig. 1 such as Y-792769 in Table 2a. The presence of only one howardite in a thousand meteorites (Y-790001–Y-790990) processed to date confirms the statement that polymict eucrites are predominant over howardites among Antarctic meteorites. Y-790727 (120.4 g), previously described as a polymict eucrite, turned out to be a howardite richer in eucritic components than Y-7308. It contains olivines and a diogenite fragment partly melted and recrystallized.

A number of achondrites similar to Y-75032 in hand specimen have been found in a region designated as Diogenite (B) in Fig. 1. Y-791199 is rich in a crystalline portion which is 4×3 cm and contains light yellowish-gray pyroxene crystals up to a few cm in diameter. Y-791200 contains a lithic clast 1.5×2.0×0.3 cm with inverted pigeonites and plagioclase up to 3 mm long. Pyroxenes in the clast are dark olive in color, and are similar to those in the cumulate eucrite Moama. An apparent interface is sharp. Y-791201 similar in shock texture to Y-75032 is a dimict cumulate eucrite breccia. The facts that diogenites and cumulate eucrites are present in a single meteorite give strong support for a close genetic link between diogenites and cumulate eucrites, or Y-75032 may be a plagioclase-less eucrite.

In summary, the varieties of clast type found in the Yamato-79 polymict eucrites can be still explained by impact processes on various scales into a layered crust of the parent body. Basaltic clasts derived from the near surface are more dominant in size. Because the total number of the Yamato-79 collection is comparable to that of the world meteorite collection, it was expected that frequencies of different meteorites types may be similar to the known collection. However, our statistics on the achondrites processed to date revealed that the Yamato meteorites may represent meteorite falls during a certain period on some restricted areas of the Antarctic Continent. Two falls of diogenites have been recognized. Polymict eucrite falls represented at Yamato Mountains (Fig. 1) might be interpreted as evidence of 2 distinct falls if details of the last half of the Y-79 polymict eucrites become available.

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