A REVIEW OF THE YAMATO-74 METEORITE COLLECTION

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Abstract: Examination of the specimens and petrological investigation of thin sections of many of them, and review of the literature, has enabled the classification of 543 out of a total of 663 meteorites in the 1974 Yamato collection, including all those weighing more than 100 g. The classified meteorites include 1 pallasite, 3 ureilites, 22 diogenites (all paired), 3 eucrites, 3 C2 chondrites, 1 E3-4 chondrite, 10 H3 chondrites, 4 L3 chondrites, 1 LL3 chondrite, 32 H4 chondrites, 3 L4 chondrites, 2 LL4 chondrites, 212 H5 chondrites (of which 149 are probably pieces of a single meteorite), 5 L5 chondrites, 193 H6 chondrites (of which 143 are probably pieces of a single meteorite), 42 L6 chondrites, 5 LL6 chondrites and 1 H4 or L4 chondrite. There are 120 unclassified specimens in the Yamato-74 meteorite collection.

1. Introduction

After the incidental discovery of 9 meteorites in 1969 and 12 in 1973 in bare ice areas near the Yamato Mountains (71–72°S, 35–36°E), a systematic search was carried out in November and December 1974 by a four-man party led by one of us (K.Y.). This resulted in the collection of 663 specimens. An account of the field work, with locality maps and many photographs of the meteorites, has been published (YANAI, 1978). A catalog of the meteorites, giving weights, brief descriptions, classifications where available, and some chemical analyses was published in 1979 (YANAI, 1979). HONDA (1981) has discussed the terrestrial history of these meteorites, as recorded in the cosmogenic nuclides.

The meteorite descriptions which follow are arranged by class and type.

2. Pallasite

Y-74044 is a small (51.8 g) weathered fragment of a pallasite meteorite. YANAI (1981, photo 12) has published a photograph of the specimen, which shows rounded yellow olivine crystals up to 1 cm across enclosed in brown weathered nickel-iron. A brief description has been provided by TAKEDA *et al.* (1978c), who give microprobe analyses of the olivine ($Fa_{12.3}$, the common value for pallasites), chromite, and troilite. The metal phase shows Widmanstatten texture; it has 10.6% Ni and 0.75% Co, and the thermomagnetic curve shows that the major constituent is kamacite with 6.6% Ni

Table 1. Data on classified Yamato-74 meteorites.

Name	Weight (g)	Class and type	% Fa in olivine (range)	% Fs in low-Ca pyroxene (range)	*	Comment
Yamato-74001	246.1	H5	18.3(17.2–19.5)	16.1(15.5–16.6)	C	With H4 Clast
74002	69.7	LL4	27.9(26.7–28.4)	22.9(22.5–23.4)	A	
74005	3.6	Dio	—	24	A	
74007	162.3	L6	25.5	21	B	
74010	298.5	Dio	—	24	A	
74011	206.0	Dio	—	24	A	
74012	75.4	H5	19.6	17.6	B	
74013	2059.5	Dio	—	24	A	
74014	2367.9	H6	19.6	16	B	
74015	88.0	L6	26.7	22.1	B	
74021	39.3	H5	19.9	18.1	C	
74022	34.7	L5	26.7(25.7–29.0)	22.1(21.7–22.6)	A	
74024	50.0	L3	22.8(0.8–26.0)	10.5(2.4–18.7)	A	
74028	90.2	L6	25.4	22.1	B	$En_{45}Fs_9Wo_{46}$, Pl(An_{11})
74031	6.1	Dio	—	24	A	
74035	115.7	L6	24.5	21	B	
74036	201.4	L6	25.2	21	B	
74037	591.9	Dio	—	24	A	
74038	208.9	H5	18.9	17	B	
74039	47.6	L6	25.8	22.5	A	
74044	51.8	Pal	12.3	—	B	
74048	67.1	LL6	30.3	25.6	B	
74049–064	493.3	H4	18.7(18.0–21.3)	16.5(15.8–17.0)	B	
74065–066	24.5	L6	24.4(23.3–24.8)	20.2(19.6–21.1)	A	With L4 Clast
74070–075	194.4	H5	18.7(17.9–19.6)	16.6(15.9–17.2)	B	
74077	5575.1	L6	21.8(20.9–23.2)	18.4(17.5–19.1)	A	
74079	620.8	H5			A/B	
74080	536.9	LL6-L6	24.8(23.8–26.8)	20.6(20.3–21.0)	A	
74081	102.5	H4	18.3(17.3–19.6)	15.9(15.4–16.4)	C	$En_{48.3}Fs_{6.0}Wo_{44.7}$
74082	179.8	H4	19.0(18.0–20.1)	16.9(15.8–18.4)	B	
74085	30.5	H4	18.2(16.9–19.3)	15.9(14.9–16.9)	B/C	$En_{72.4}Fs_{13.4}Wo_{14.2}$, $En_{78.4}Fs_{6.4}Wo_{14.5}$
74094	867.2	H6	19.0(17.5–19.8)	16.6(15.9–17.2)	C	
74096	16.1	Dio	—	24	A	
74097	2193.9	Dio	—	24	A	
74104–108	447.3	H5	18.9	16.8	A/B	
74109	43.6	Dio	—	24	A	
74110	90.1	L6	21.4	19.2	C	
74111	58.0	H4	19.4	18.3	B/C	
74115	1045.1	H5	18.1	16.0	B	
74116	68.9	L5	24.6(23.1–25.5)	20.5(19.9–21.1)	C	Pl ($An_{9.9}$)
74117	80.2	L6	25.5	22.1	A	
74118	845.1	L6	24.5(23.4–25.2)	20.8(19.7–21.6)	A	
74120	90.5	L6	25.6	22.2	B	
74123	69.9	Ure	21.6(13–23)	18.2	B	
74124	62.4	H4	18.5(16.9–19.2)	15.8(14.9–16.7)	B	
74125	107.0	Dio	—	24	A	
74126	14.5	Dio	—	24	A	
74130	17.9	Ure	22	17.9	C	
74136	725.0	Dio	—	24	A	

Table 1. Continued.

Name	Weight (g)	Class and type	% Fa in olivine (range)	% Fs in low-Ca pyroxene (range)	*	Comment
Yamato-74138–141	41.8	H3	17.1(0.3–36.9)	14.5(3.0–25.9)	A/B	Tridymite, $En_{48.7}Fs_{5.7}Wo_{45.5}$
74142	29.5	H3	16.9(10.9–27.9)	13.4(1.0–16.9)	A	
74144	141.4	L6	24.8	21.9	B	
74150	33.5	Dio	—	24	A	
74151	49.4	Dio	—	24	A	
74155–156	3788.1	H4	18.5(17.6–19.2)	16.0(14.5–17.9)	A	
74157–158	135.8	L6	24.8(23.6–25.7)	20.5(19.7–21.8)	B	Pl ($An_{10.4}$)
74159	98.2	Euc	—	35–65	A	
74160	31.4	LL6(or 7)	29.4(28.2–30.6)	23.1(22.0–24.1)	A	Pl (An_{7-17})
74162	3.8	Dio	—	24	A	
74163	134.2	H5	17.7(16.7–18.6)	15.8(15.0–16.5)	C	
74164	284.8	L6	25.1	21	A	
74165	203.4	L4	25.2(24–27)	(19–25)	C	
74166–170	6.7	H3	18.1(17.6–19.4)	15.5(13.8–16.4)	B	
74173–181	89.9	L6	24.0(23.1–24.9)	20.3(19.7–22.5)	B	Pl (An_{11})
74182–185	16.6	L6	24.5	20.5	A	Pl (An_{10})
74187–188	13.3	H5	18.0(16–22)	17.1(16–18)	C	Pl, Cpx
74190	3235.7	L6	24.6	21.1	A	
74191	1091.6	L3	18.8(12–25)	(4–25)	A	
74192	420.3	H5 (or 6)	18.2	15.8	C	
74193	1818.5	H5 (or 4)	19.1	17.3	B	
74194–342	728.9	H5	19.1	17.7	C	
74344	1.4	Dio	—	24	A	
74347	7.8	Dio	—	24	A	
74348–353	43.6	H4	18.0	16.6	C	
74354	2721.1	L6	24.2	20.8	A	
74355	82.9	L4	24.9	21.4	B	
74356	10.0	Euc	—	62	A	
74362	4175.0	L6	25.1	20.9	A	
74364	757.8	H4	17.7	16.0	B	
74367	165.6	L6	26.0	22.0	A	
74368	4.1	Dio	—	24	A	
74370	42.1	E3-4	0.1	0.9(0–5.1)	B/C	
74371	5067.9	H5	18.6	17	A	
74372	84.6	L6	25.2	21.8	B	
74374	205.2	H6	18.4	16	B	
74375	92.7	H4	18.1(17.3–19.3)	15.6(14.7–18.3)	C	
74376	120.0	L5	24.7	21.3	B	
74379–416	66.0	H5	18.0	16.6	C	
74417	44.5	L3	13.7(0.2–31.8)	10.9(3.1–27.0)	A	
74418–436	719.5	H6	18.7(17.8–19.8)	16.3(15.1–17.8)	C	
74441	27.4	L3	15.1(1.5–31.3)	11.6(2.0–29.4)	B	
74442	173.3	LL4	29.0(27–31)	(21–25)	A	
74445	2293.2	L6	24.8(23.7–25.8)	20.8(20.2–22.0)	C	
74447	14.3	H6	18.0(17.1–18.7)	15.6(14.8–16.2)	B	
74448	17.7	Dio	—	24	A	
74450	235.6	Euc	—	30–65	A	
74452	33.9	L6 (or 5)	24.0(23.1–24.7)	20.1(19.5–20.7)	A	
74454	578.8	L6	23.6	20.8	A	

Table 1. Continued.

Name	Weight (g)	Class and type	% Fa in olivine (range)	% Fs in low-Ca pyroxene (range)	*	Comment
Yamato-74455	114.1	L6	24.7(24.0–25.4)	20.8(20.0–24.4)	A	Pl ($An_{9.8-10.8}$)
74457	120.8	L5	25.3	22	B	
74546	7.3	Dio	—	24	A	
74459–602	5156.3	H6	18.8	17.4	C	
74603	188.7	L4	21.8(20.2–25.0)	20.4(18.8–22.7)	C	
74605	580.8	L6	23.8(22.8–24.9)	20.2(19.4–21.1)	B	
74606	2.9	Dio	—	24	A	
74609	257.2	H5	18.4(17.2–19.2)	16.0(14.4–17.4)	C	
74610	46.8	H4	17.9(17.1–19.1)	15.8(15.1–16.9)	B	
74613–638	145.1	H6	18.0(17.0–18.7)	15.9(15.6–16.1)	C	
74639	89.5	L5	24.1(23.2–25.2)	20.4(18.9–22.5)	A	
74640	1065.9	H6	19.0	17	C	
74641–642	15.1	C2	10.1(0.3–55.0)	3.1(0.5–20.3)	A	
74645	35.6	H4-L4	21.1(20.0–22.1)	17.9(17.2–18.4)	C	
74646	554.7	LL6	29.1(27.6–29.8)	24.8	A	$En_{45.5}Fs_{8.6}Wo_{45.9}$
74647	2323.8	H5	18.3(17.3–19.3)	15.9(15.4–16.7)	A	
74648	185.5	Dio	—	24	A	
74650	163.2	L6				
74652	7.9	L6	24.4(23.9–25.1)	20.6(19.7–21.4)	A	
74659	18.9	Ure	8	8	B	
74660	27.2	LL3	10.5(0.4–49.5)	8.9(0.4–34.5)	B	
74662	150.9	C2	10.9(0.4–52.8)	5.0(0.5–45.3)	A	
74663	213.9	LL6	28.1(26.8–28.8)	23.0(21.8–23.8)	B	

Pal: Pallasite, Dio: Diogenite, Ure: Ureilite, Euc: Eucrite.
* Degree of weathering

(NAGATA, 1978). MATSUI *et al.* (1980) have described dislocation structures in olivine from this meteorite.

3. Ureilites

Three ureilite specimens were collected in 1974, Y-74123 (69.9 g) Y-74130 (17.9 g), and Y-74659 (18.9 g). They have been described by TAKEDA *et al.* (1978b, 1979), and are especially significant in that they provide us with the extremes of chemical variation in the ureilites: Y-74130 has the lowest MgO/(MgO+FeO) ratio and Y-74659 the highest (bulk chemical analyses in TAKEDA *et al.*, 1979, p. 61). This is reflected in their mineralogy. Y-74130 has augite ($Ca_{33}Mg_{53}Fe_{13}$) in addition to pigeonite as in other ureilites, and olivine (Fa_{23}) more iron-rich than in previously known ureilites. Y-74123 contains olivine with composition (Fa_{22}) together with minor pigeonite (mean $Ca_{6.6}Mg_{75}Fe_{18.4}$). Y-74659 has approximately equal amounts of Mg-rich olivine ($Fa_{7.9-8.6}$) and Mg-rich pigeonite ($Ca_7Mg_{85}Fe_8$). The textures of these ureilites are similar to those of non-antarctic ones. Photographs of these ureilites have been published by YANAI (1981).

TAKEDA (1982) has published the following account of Y-74130:

"Yamato-74130 is a very samll stone (17.9 g). Three thin sections made from a chip (1.151 g) of Y-74130,65 have been studied by an optical microscope and electron microprobe. Three pyroxenes have been investigated by the single crystal X-ray diffraction method. Possible orthopyroxene-pigeonite-augite assemblage has been found in Yamato-74130. In contrast to other ureilites, Y-74130 contains olivines (Fa_{22}), augites up to 2 mm in size and small pigeonites in augites (Fig. 1). The augites are rich in Cr_2O_3 (1.8 wt %) and Na_2O (0.8 wt %). In contact with these minerals with curved boundaries rich in carbon, there is a low-Ca pyroxene $Ca_{4.4}Mg_{77.7}Fe_{17.9}$, 8×4 mm in size, which includes round small inclusions of olivine and rare augite and patches of carbonaceous (C) materials. Their X-ray photographs show weak reflections of orthopyroxenes and twinned clinobronzites with (100) in common. This pyroxene may have been originally an orthopyroxene and converted into clinobronzites by a shock or reheating events. The pigeonite-augite geothermometer of ISHII *et al.* (1979) indicates that the last equilibration temperature is higher than that estimated from the pigeonite eutectoid reaction line, 1170° C of ISHII *et al.* The high temperature is in agreement with the phase relations and the high CaO contents in the olivines."

HINTENBERGER *et al.* (1978) have determined the rare gases and 13 major and minor elements in Y-74123, and NAGATA (1980) has measured the magnetic parameters of Y-74123, Y-74130 and Y-74659. GIBSON and YANAI (1979a,b) have determined carbon and sulfur abundances in Y-74659. TAKEDA *et al.* (1980) have published pyroxene analyses for all three ureilites.

4. Diogenites

Twenty-two pieces of diogenite were collected in 1974, ranging in weight from 2193.9 g (Y-74097) down to 1.4 g (Y-74344); the total weight is 6389.8 g. They are all pieces of single meteorite, a unique granoblastic diogenite. Detailed petrographic descriptions have been published by TAKEDA *et al.* (1979, 1981a), who list additional specimens from the 1969 and 1975 collections. They showed that the three largest specimens can be joined together as a single stone. They report that this diogenite consists almost entirely of orthopyroxene ($Ca_2Mg_{74}Fe_{24}$) with a little chromite, plagioclase, a silica mineral, troilite, and nickel-iron. The pyroxene has a granoblastic texture, with grain size 0.1–0.2 mm in finer-grained areas, 0.4–3.0 mm in coarser-grained areas. Finer-grained portions have a haze of tiny inclusinos, with even smaller metal blebs in some troilite grains. In coarser-grained areas, the troilite also is coarser and the pyroxene clear. In a very coarse-grained area, plagioclase (An_{91}) and a silica mineral coexist with a coarse opaque mineral. Chromite occurs as clots up to 5 mm across and in veinlets. Analyses of three of these diogenites are published in YANAI (1979). Y-74097 shows parallel linear structures made by tiny opaque inclusions.

Photographs of several of these diogenites are published in YANAI (1981). ONUMA *et al.* (1978) have measured oxygen isotopes in Y-74013, WÄNKE *et al.* (1977) have measured many minor and trace elements, and BRECHER (1980) has made magnetic measurements of this specimen. JOCHUM *et al.* (1980) have determined Na, Mg, Al, Si, S, K, Ca, Cr, Mn, Fe, Co, and Ni in 7, and NAGATA (1980) has determined magnetic parameters in 5 of these diogenites. NAKAMURA (1979) has reported on the Sm-Nd and Rb-Sr systematics of these meteorites.

5. Eucrites

Three eucrites were collected during the 1974 expedition: Y-74159 (98.2 g), Y-74356 (10.0 g), and Y-74450 (235.6 g). Photographs of them have been published by YANAI (1981). Y-74159 and Y-74450 are almost complete partly crusted stones, and Y-74356 is a fragment with remnants of fusion crust. These meteorites have been described by TAKEDA *et al.* (1978a, c, 1979) and MIYAMOTO *et al.* (1978). Y-74356 is unique among the Yamato eucrites in being monomict; all others are polymict. Analyses of Y-74159 and Y-74450 are published in YANAI (1979).

TAKEDA *et al.* (1978a) have described Y-74159 as follows:

"This meteorite is a complex mixture of basaltic rock fragments and mineral grains (MIYAMOTO *et al.*, 1978). Basaltic fragments have textures including ophitic, subophitic, variolitic and vitric types, with grain sizes generally less than 1–2 mm. The meteorite clearly is polymict in terms of lithic variability but carries no magnesian orthopyroxene of the type found in howardites. As all the clasts are basaltic, and its bulk composition is similar to other eucrites, it is tentatively classed as a eucrite.

The pyroxene variations for several rock fragments are similar to those of Pasamonte, showing distinct iron-enrichment and calcium-enrichment trends (Figs. 2c, d). Pigeonites in some rock fragments show distinct exsolution lamellae of augite." This meteorite also contains fragments of the Binda-like cumulate eucrites (TAKEDA *et al.*, 1978a). NAGATA (1980) has determined the magnetic parameters of this meteorite; NISHIIZUMI and ARNOLD (1981) have measured ^{53}Mn.

TAKEDA *et al.* (1981b) have described Y-74356 as follows:

"Yamato-74356 is a small monomict eucrite (10.0 g) partly covered by a shiny black fusion crust. Lithic clasts are abundant but some of the pyroxene crystals have become aggregates of small polygonal crystals showing a granoblastic texture. Augite in Yamato-74356 occurs as discrete grains with uniform chemical compositions of the host and exsolved phases, coexisting with major pigeonite. The pigeonite grains resemble those in Juvinas in that small opaque inclusions or clouding (HARLOW and KLIMENTIDIS, 1980) are aligned along slightly curved lines. The width of pigeonite lamellae in augite is 1.5 μm on the average and is up to 2.1 μm. The pyroxene compositions are given in Fig. 1 (b) and Table 2. The closure temperature or that of apparent equilibration for the exsolved pair is estimated as 880°C by the pigeonite-augite geothermometer (ISHII *et al.*, 1979). The temperature of crystallization obtained by the bulk chemical composition of a coexisting pigeonite-augite grain (TAKEDA, 1979) is 1000°C."

TAKEDA *et al.* (1978a) described a clast-rich portion of Y-74450 as follows:

"This meteorite is a breccia containing basalt fragments with subophitic to variolitic textures similar to Pasamonte (TAKEDA *et al.*, 1978c). In the single thin section available the principal basalt type contains pigeonite phenocrysts which have served as nucleation centers for laths and needles of feldspar and interstitial granular to radiating clinopyroxene (Figs. 4a, b). In rare fragments in this section, coarser-grained subophitic material is present, suggesting that a larger sample might show a larger diversity of basalt types. As in Pasamonte, pyroxenes in the rock fragments studied do not show microscopic exsolution lamellae; however, some pyroxene fragments in the matrix exhibit well-defined augite exsolution lamellae (triangles in Fig. 2e), similar to those found in Juvinas (see below). The cores of phenocrysts are pigeonite slightly richer in Mg than pigeonite cores in Pasamonte. Electron microprobe traverses show a combined calcium-enrichment and iron-enrichment zonation that is continuous from the core outward, but which is stronger near grain rims. Fractionation trends and analyses are shown in Fig. 2e and Table 1. The separate calcium-enrichment and iron-enrichment trends shown in Pasamonte are not observed." Other portion of this meteorite is matrix-rich and show characteristic features of polymict eucrite (pers. commun. H. TAKEDA). This meteorite also contains fragments of the Binda-like cumulate eucrite pyroxene. A chemical analysis of Y-74450 has been published by WÄNKE *et al.* (1977); JOCHUM *et al.* (1980) have determined Na, Mg, Al, Si, S, K, Ca, Cr, Mn, Fe, Co, and Ni in this meteorite, and NAGATA (1980) has determined its magnetic parameters.

6. Carbonaceous Chondrites

Three carbonaceous chondrites, all classified as C2, were collected by the 1974 expedition: Y-74641 (4.5 g), Y-74642 (10.6 g), and Y-74662 (150.9 g). Photographs of them are published in YANAI (1981). Y-74641 is a partly crusted fragment and Y-74642 is an abraded fragment without fusion crust. Y-74662 is a fairly complete stone with some fissured black fusion crust typical of C2 chondrites; Y-74641 and Y-74642 were collected together and are believed to be pieces of the same meteorite, whereas Y-74662 is probably a different meteorite.

Y-74662 was described, with bulk chemical analysis, by YANAI and HARAMURA (1978); carbon and sulfur determinations have been published by GIBSON and YANAI (1979a, b); KNAB and HINTENBERGER (1978) determined 20 trace elements, and JOCHUM *et al.* (1980) 12 major and minor elements; NAGATA (1980) has determined its magnetic parameters. It is a friable stone, dark gray to black in color, and is made up largely (90% by volume) of fine-grained matrix, with relatively few chondrules; traces of metallic iron are present. AKAI (1982) has made a high-resolution electron microscopic investigation of the matrix. He finds that it is made up largely of phyllosilicates, with micron-sized grains of olivine, enstatite, diopside, calcite, and Fe, Ni sulfides. He distinguishes five types of phyllosilicate: 7 Å platy, 7 Å poorly organized tubular, 17 Å platy, poorly characterized 7 Å layer structure with 5 Å inter layers, and 11 Å platy. There is a close similarity in structure, morphology, and composition of the phyllosilicates between Y-74662 and Murchison (C2) chondrite.

SHIMOYAMA *et al.* (1979a, b) have reported on the amino acids in Y-74662; the amount found was of the same order of magnitude as in the Murchison and Murray C2 chondrites. BRECHER (1980) has made magnetic measurements on this meteorite.

TAKEDA *et al.* (1979) have published a bulk chemical analysis of Y-74642; it is comparable in composition to Y-74662, but YANAI (1979) noted that its appearance is different.

7. E3-4 Chondrite

Only one E3-4 chondrite has been identified in the 1974 Yamato collection, as follow: Yamato-74370 (42.1 g).

Y-74370 is an almost complete stone and covered with brownish-black fusion crust. A chipped surface shows a well-developed chondritic structure in a dark gray interior. Rusty brown weathering is concentrated below the fusion crust. A thin section shows a close-spaced aggregate of chondrules and chondrule fragments, set in a minor amount of dark-gray matrix. The matrix consists of fine-grained pyroxene with some coarser-grained nickel-iron and troilite. A variety of chondrule types is present, the commonest being granular, porphyritic, and radiating pyroxene. Most of pyroxene is polysynthetically twinned. Turbid devitrified glass is present within some chondrules. Minor amounts of nickel-iron and troilite are present, the metal being fairly weathered. Microprobe analyses show olivine, $Fa_{0.1}$, pyroxene, $Fs_{0-5.1}$, mean $Fs_{0.9}$.

8. H3 Chondrites

Several meteorites from the 1974 collection have been identified as H3 chondrites: Y-74142 (29.5 g) and Y-74166–170 (total weight 6.7 g); Y-74138–141 (total weight 41.8 g) are probably paired with Y-74142.

Y-74138 and Y-74142 are partly crusted fragments from a larger stone; surface weathering has revealed a highly chondritic structure. A thin section shows an aggregate of chondrules and chondrule fragments, in a moderate amount of fine-grained matrix partly stained with brown limonite. Chondrule types include granular and porphyritic olivine and olivine-pyroxene, barred olivine, and fine-grained radiating pyroxene. Interstitial glass in chondrules is sometimes transparent and pale brown in color, sometimes turbid and partly devitrified. Most of the pyroxene is polysynthetically twinned clinobronzite. Minor amounts of nickel-iron and troilite are present. KOJIMA (unpublished) has determined the following mineral compositions: olivine, $Fa_{10.9-27.9}$, mean $Fa_{16.9}$; pyroxene $Fs_{1.0-16.9}$, mean $Fs_{13.4}$.

Y-74166–170 are five small weathered fragments partially coated with fusion crust, which were identified in the field as pieces of a single meteorite. A small section of Y-74167 shows a close-packed aggregate of chondrules and chondrule fragments in a minor amount of fine-grained matrix heavily infiltrated with red-brown limonite. The chondrules are mainly granular and porphyritic olivine and olivine-pyroxene; most of the pyroxene is polysynthetically twinned clinobronzite. Minor amounts of nickel-iron and troilite are present, the metal extensively corroded by weathering. MATSUEDA *et al.* (1979) showed that olivine and pyroxene in Y-74166 are variable in composition; the mean composition of olivine is $Fa_{19.0}$ with a % M. D. of 17.7, and the mean composition of pyroxene is $Fs_{20.8}$ with a % M.D. of 10.3 (M.D. = mean deviation). They classified this specimen as H3.

9. L3 Chondrites

The following specimens from the 1974 Yamato collection have been classified as

L3 chondrites: Y-74024 (50.0 g), Y-74191 (1091.6 g), Y-74417 (44.5 g) and Y-74441 (27.4 g).

Y-74024 is about one-half of a complete stone, and is partly covered with brownish-black fusion crust; the interior is highly chondritic, medium gray in color, with rusty halos around metal grains. A thin section shows a close-packed aggregate of chondrules and chondrule fragments in a small amount of fine-grained matrix which contains some larger grains of nickel-iron and troilite. Chondrule types include granular and porphyritic olivine and olivine-pyroxene, barred olivine, and fine-grained radiating pyroxene. Some chondrules have intergranular glass which can be either transparent brown or turbid and partly devitrified. Most of the pyroxene is polysynthetically twinned. KOJIMA (unpublished) has determined the following mineral compositions: olivine, $Fa_{0.8-26.0}$, mean $Fa_{22.8}$; pyroxene, $Fs_{2.4-18.7}$, mean $Fs_{10.5}$.

The largest of these, Y-74191, is illustrated in YANAI (1981). It is about two-thirds of a complete stone, covered with brownish-black fusion crust; exposed surfaces show numerous chondrules in a medium gray matrix. Weathering is limited to brown limonitic staining around metal grains. The meteorite has been well described in several papers. YANAI *et al.* (1978) identified it as an L3 or L3-4 chondrite on the basis of microprobe analyses of olivine and pyroxene; olivine composition ranged from Fa_{12} to Fa_{25}, with a mean of $Fa_{18.8}$, and pyroxene composition ranged from Fs_4 to Fs_{25}. IKEDA and TAKEDA (1979a) described the petrology, and published chemical analyses of the bulk, the matrix, the chondrules, and some silicate fragments; they distinguished seven groups of chondrules by their SiO_2 contents and textures. Additional data have been contributed by YABUKI *et al.* (1978) on petrology, ONUMA *et al.* (1978) on oxygen isotopes, KIMURA *et al.* (1980) on opaque minerals, KIMURA and YAGI (1980) on chondrule types and composition, HIRANO *et al.* (1980) on major and trace elements, IKEDA and TAKEDA (1979a) on matrix composition, NAGATA (1980) on magnetic properties, KIMURA (1982) on the petrology of lithic fragments, YOMOGIDA and MATSUI (1982) on physical properties, and MORIMOTO *et al.* (1982) on fine textures of pyroxenes.

Y-74417 is about three-fourths of a complete stone, partly coated with dull black fusion crust; the interior shows numerous white to pale gray chondrules in a dark gray matrix. Weathering is limited to minor brown limonitic staining on exposed surfaces. A thin section shows a close-packed aggregate of chondrules and chondrule fragments, set in a minimum amount of matrix. The matrix consists of fine-grained olivine and pyroxene with some coarser-grained nickel-iron and troilite. A variety of chondrule types is present, the commonest being granular and porphyritic olivine and olivine-pyroxene, and radiating pyroxene. The pyroxene is polysynthetically twinned. Some of the chondrules have clear pale brown glass between the olivine and pyroxene grains, but usually the glass is turbid and partly devitrified. KOJIMA (unpublished) has determined the following mineral compositions: olivine, $Fa_{0.2-31.8}$, mean $Fa_{13.7}$; pyroxene, $Fs_{3.1-27.0}$, mean $Fs_{10.9}$.

Y-74441 is a pyramidal fragment partly coated with dull black fusion crust; fracture surfaces are stained dark brown with limonite and show well-developed chondritic structure, with chondrules up to 3 mm in diameter. A thin section shows a close-packed aggregate of chondrules and chondrule fragments in a dark fine-grained matrix which has minor amounts of coarser-grained nickel-iron and troilite. Chondrule types are like those in Y-74024, and similar glass is present in some chondrules. Pyroxene is polysynthetically twinned clinobronzite. KOJIMA (unpublished) has determined the following mineral compositions: olivine, $Fa_{1.5-31.3}$, mean $Fa_{15.1}$; pyroxene, $Fs_{2.0-29.4}$, mean $Fs_{11.6}$. This meteorite is tentatively identified as an L3 chondrite but may be C3.

10. LL3 Chondrite

One LL3 chondrite have been identified in the 1974 Yamato collection: Y-74660 (27.2 g). Y-74660 is an angular, an almost complete stone and entirely covered with brownish-black fusion crust. A chipped surface shows a light gray interior with well developed chondritic structure and is essentially unweathered. A thin section shows a close-packed coarser aggregate of chondrules and chondrule fragments, in a minor amount of fine-grained matrix infiltrated with brown to dark gray limonite. Chondrule types include granular and porphyritic olivine and olivine-pyroxene, barred olivine, and radiating pyroxene. Most of pyroxene is polysynthetically twinned clinobronzite. Some chondrules have intergranular glass which can be either transparent brown or turbid and partly devitrified. The meteorite has a little nickel-iron and troilite. Microprobe analysis shows olivine, $Fa_{0.4-49.5}$ and pyroxene, $Fs_{0.4-34.5}$.

11. H4 Chondrites

Several H4 chondrites have been identified in the 1974 Yamato collection as follows: Y-74049–064 (total weight 493.3 g),Y -74081 (102.5 g), Y-74082 (179.8 g), Y-74085 (30.5 g), Y-74111 (58.0 g), Y-74124 (62.4 g), Y-74155–156 (total weight 3788.1 g), Y-74348–353 (total weight 43.6 g), Y-74364 (757.8 g), Y-74375 (92.7 g), and Y-74610 (46.8 g).

Y-74054 is the largest of the Y-74049–064 group, wieghing 134.9 g. It is a weathered fragment with a partial coating of brownish-black fusion crust; brown limonitic staining obscures the internal structure but some chondrules can be seen. YANAI *et al.* (1978) report that microprobe analyses show olivine ranging in composition from $Fa_{18.0}$ to $Fa_{21.3}$ with a mean of $Fa_{18.7}$ (2.5% M. D.); pyroxene composition ranged from $Fs_{15.8}$ to $Fs_{17.0}$.

Y-74081 is a cone-shaped fragment partly covered with fusion crust; the interior is somewhat obscured by brown limonitic weathering, but some areas are medium gray and show chondritic structure. MATSUEDA *et al.* (1981) have published microprobe analyses of olivine and pyroxene, and NISHIIZUMI *et al.* (1980) have measured ^{53}Mn in this meteorite.

Y-74082 is a fragment about three-fourths of a complete stone, with a brownish-black fusion crust, and a brown (oxidized) and gray (unoxidized) interior. YANAI *et al.* (1978) report mean olivine composition $Fa_{19.3}$ (5.1% M. D.) and pyroxene composition ranging from Fs_{15} to Fs_{18}.

Y-74085 is 30.5 g and shows well-developed chondritic structure.

Y-74111 is about one-half of a complete stone, with brownish-black fusion crust; it is extremely weathered, the interior being pervaded with brown limonite.

Y-74124 is about one-half of a crusted stone; weathering on a fracture surface has etched out the matrix and revealed abundant chondrules (see illustrations in YANAI, 1981).

Y-74155–156 are two pieces found approximately 30 m apart which fit together (see illustration in YANAI, 1981). The matching pieces form a roughly cuboidal stone, partly covered with dull black fusion crust. Chondritic structure is prominent on weathered surfaces, and internal fractures with black slickensides are visible. The interior is medium gray in color and essentially unweathered (Photo 28). JOCHUM *et al.* (1980) have determined 12 major and minor elements in these meteorites; YOMOGIDA and MATSUI (1982) have determined the physical properties of Y-74156.

Y-74348–353 are highly weathered fragments, some with fusion crust, Y-74348 is the largest, weighing 24.0 g. In the field they were noted as probably all from one stone. NISHIDA *et al.* (1979) report the following mineral compositions: Y-74348, olivine, $Fa_{18.5}$ (5.2% M. D.) and pyroxene, $Fs_{16.6}$ (4.6% M. D.); Y-74349, olivine, $Fa_{18.0}$ (3.4% M. D.) and pyroxene, $Fs_{16.6}$ (4.4% M. D.).

Y-74364 is a complete oriented stone in the form of a flattened cone, almost entirely covered with brownish-black fusion crust (see illustrations in YANAI, 1981). Where the fusion crust has broken away, the surface is stained brown with limonite and shows numerous chondrules. MATSUEDA *et al.* (1979) report the following mineral compositions: olivine, $Fa_{17.7}$ (4.8% M. D.); pyroxene, $Fs_{16.0}$ (4.1% M. D.).

Y-74375 is an irregular mass partly coated with dull brownish-black fusion crust, and with several deep fractures. Brown limonitic staining pervades the stone and obscures the internal structure. YANAI *et al.* (1978) report that olivine ranges in composition from Fa_{17} to Fa_{23} with a mean of $Fa_{18.6}$ (4.6% M. D.); pyroxene composition ranges from Fs_{16} to Fs_{21}. NISHIIZUMI and ARNOLD (1981) have measured ^{53}Mn in Y-74364 and Y-74375.

Y-74610 is an almost complete conical stone, largely covered with dull brownish-black fusion crust; a fracture surface shows numerous chondrules up to 3 mm in diameter. Brown limonitic staining pervades the specimen. A thin section shows well-developed chondritic structure.

Thin sections of these H4 chondrites resemble each other closely, and a single description will suffice. They all show well-developed chondritic structure, chondrules averaging 0.5–1.0 mm in diameter (Y-74610 has some unusually large chondrules, ranging up to 3 mm in diameter). A variety of chondrule types is present, the commonest being porphyritic or granular olivine, barred olivine, fine-grained radiating pyroxene, and granular olivine-pyroxene. Turbid partly devitrified glass is present within some chondrules. Much of the pyroxene is polysynthetically twinned clinobronzite. The chondrules are set in a fine-grained granular matrix consisting largely of olivine and pyroxene with minor amounts of coarser-grained nickel-iron and troilite (nickel-iron in a greater amount than troilite).

12. L4 Chondrites

Three L4 chondrites have been identified in the 1974 Yamato collection: Y-74165 (203.4 g), Y-74355 (82.9 g), and Y-74603 (188.7 g).

Y-74165 is the fragment partly coated with dull black fusion crust; the specimen has one large flat fracture surface showing slickensides. The stone is pervaded with brown limonite which obscures the internal structure. YANAI *et al.* (1978) report olivine composition ranging from Fa_{24} to Fa_{27}, with a mean of $Fa_{25.2}$ (3.6% M. D.); pyroxene composition ranges from Fs_{19} to Fs_{25}.

Y-74355 is a complete stone with dark brown fusion crust; the interior is pale gray and shows chondritic structure. Brown limonitic staining is present around metal grains. MATSUEDA *et al.* (1981) report the following mineral compositions: olivine, $Fa_{24.9}$ (2.3% M. D.); pyroxene, $Fs_{21.4}$ (1.3% M. D.).

Y-74603 is a well-rounded lens-shaped stone almost completely covered with dull brownish-black fusion crust; where the fusion crust is missing the surface is weathered, and brown limonitic staining obscures the internal structure, but chondrules can be seen. NISHIDA *et al.* (1979) report olivine compositions ranging from $Fa_{20.0}$ to $Fa_{25.0}$, with a mean of $Fa_{21.8}$; pyroxene compositions range from $Fs_{18.8}$ to $Fs_{22.7}$, with a mean of $Fs_{20.4}$.

The thin sections of these L4 chondrites are quite similar. They show well-developed chondritic structure, with a variety of chondrule types, the commonest being granular or porphyritic olivine and olivine-pyroxene. Most of the pyroxene is polysynthetically twinned. The groundmass consists of fine-grained olivine and pyroxene, with minor subequal amounts of nickel-iron and troilite. In the section of Y-74165 the chondrules have been deformed and fragmented, probably by shock, since the olivine grains show undulose extinction, and the section is traversed by numerous thin black veinlets.

13. LL4 Chondrites

Two LL4 chondrites have been identified in the 1974 Yamato collection: Y-74002 (69.7 g) and Y-74442 (173.3 g).

Y-74002 is a partly crusted fragment; interior surfaces are pale gray and essentially unweathered. Chondritic structure is prominent and well developed. Nickel-iron content is very low; a large (3 mm) sulfide grain was noted. A thin section shows numerous chondrules with relatively little matrix. A variety of chondrule types is present, the commonest being granular or porphyritic olivine with interstitial glass (usually turbid, sometimes transparent and pale brown in color). The matrix consists of finely granular olivine and pyroxene, with a little nickel-iron and troilite. JOCHUM *et al.* (1980) have analyzed this meteorite for 12 major and minor elements; MATSUEDA *et al.* (1981) report the following mineral compositions: olivine, $Fa_{29.8}$ (1.9% M.D.); pyroxene, $Fs_{25.4}$ (1.7 %M.D.).

Y-74442 is illustrated in YANAI (1981) and has been described, with bulk chemical analysis and many analyses of individual components, by IKEDA and TAKEDA (1979b). The meteorite is a fragment with a very irregular surface, partly coated with dull black fusion crust. Fracture surfaces show dark gray clasts in a lighter gray matrix: chondrules are present in the matrix. Weathering is limited to brown limonitic halos around metal grains. A thin section shows the cataclastic structure typical of many LL chondrites. Chondrules are abundant, but many are fragmented and partly comminuted. Porphyritic olivine chondrules have intercrystal glass which is partly devitrified. The matrix is finely granular olivine and pyroxene with a little nickel-iron and troilite. Some of the pyroxene is polysynthetically twinned. YANAI *et al.* (1978)

report olivine composition ranging from Fa_{27} to Fa_{31}, with a mean of $Fa_{29.0}$ (2.4% M.D.); pyroxene composition ranges from Fs_{21} to Fs_{25}. NAGATA (1980) has reported magnetic parameters for this meteorite.

14. H5 Chondrites

A large number of H5 chondrites have been identified in the 1974 Yamato collection; the following weigh more than 100 g each: Y-74001 (246.1 g), Y-74038 (208.9 g), Y-74079 (620.8 g), Y-74106 (146.6 g), Y-74107 (114.0 g), Y-74108 (139.3 g), Y-74115 (1045.1 g), Y-74163 (134.2 g), Y-74192 (420.3 g), Y-74193 (1818.5 g), Y-74371 (5067.9 g), Y-74609 (257.2 g), and Y-74647 (2323.8 g). Of these, Y-74038, Y-74193, Y-74371, and Y-74647 are illustrated in the photographic catalog of YANAI (1981). The H5 chondrites also include two groups of small fragments, Y-74194–342 and Y-74379–416; each group probably represents a single individual broken into many pieces. Y-74012 (75.4 g) was also examinated.

Y-74001 is a fragment with about one-third of the surface covered with brownish-black fusion crust; the interior shows brown weathering throughout. The stone appears to be finely granular, and no chondrules are visible. It has been petrographically described by KIMURA *et al.* (1979a); HIRANO *et al.* (1980) have published a chemical analysis for major and some trace elements; and JOCHUM *et al.* (1980) have determined 12 major and minor elements.

Y-74012 is a well-rounded complete stone; chondrules are developed in the groundmass.

Y-74038 is a complete stone with brownish-black fusion crust, and a gray interior showing small chondrules. Y-74079 is a large fragment partly covered with brownish-black fusion crust; the interior is somewhat weathered, with brown limonitic staining. KIMURA *et al.* (1978) have published a petrographic description.

Y-74106 is an almost complete stone with brownish-black fusion crust; the interior is medium gray, granular, with traces of chondritic structure. Weathering is minor, being limited to brown halos around metal grains. JOCHUM *et al.* (1980) have measured 12 major and minor elements, and olivine and orthopyroxene compositions have been determined by MATSUEDA *et al.* (1981). Y-74107 and Y-74108 are almost complete stones similar to Y-74106.

Y-74115 is an almost complete stone, with the shape of a flattened cone; it is covered with brownish-black fusion crust with differing texture on the front and near sides. The interior is pale gray and moderately chondritic, with rusty halos around metal grains. NAGAHARA (1979a, b, 1980) has reported on the petrology and mineral compositions; TAKAOKA *et al.* (1981) have measured the rare gases; and NAGATA and FUNAKI (1981) have studied the magnetic properties of this meteorite.

Y-74163 is about four-fifths of a complete stone, covered with fusion crust except for one fracture surface, on which chondrules are visible; brown limonitic staining coats the fracture surface and is present as halos around metal grains. Y-74192 is about one-half of a complete stone, with dull brownish-black fusion crust on all sides except for one fracture surface; the interior shows chondritic structure, and is pervaded by brown limonitic staining. Y-74193 is a complete pyramidal stone with dark brown weathered fusion crust and many deep fractures, a few well-developed chondrules are present. The composition of its olivine and pyroxene has been reported by NISHIDA *et al.* (1979), and TAKAOKA *et al.* (1981) have measured its rare gases.

Y-74371 is an almost complete approximately cuboidal stone, covered with dull brownish-black fusion crust; much of the fusion crust is coated with a white powdery efflorescence. The interior is pale gray, with some limonitic staining around metal grains and shows chondritic structure. KIMURA *et al.* (1978, 1979a, b) have described its petrology, YAMAJI and MATSUMOTO (1980) have made X-ray single-crystal studies on its olivine, and TAKAOKA *et al.* (1981) have measured the rare gases.

Y-74609 is an almost complete rounded stone, covered with dull brownish-black fusion crust; a sawn surface shows numerous metal grains and white to gray chondrules in a dark gray matrix. Y-74647 is an almost complete cuboidal stone, covered with dull black fusion crust; a small fracture surface has black slickensides. A sawn surface shows numerous metal particles and occasional metal veinlets in a pale gray finely granular matrix, with few chondrules. KIMURA *et al.* (1978, 1979a, b) have described its petrology, NAGATA (1980) its magnetic properties, and YOMOGIDA and MATSUI (1982) its physical properties.

In thin sections the H5 chondrites show well-developed chondritic structure, but the chondrules tend to merge with the granular groundmass, which consists largely of olivine and pyroxene with about 15% of nickel-iron and 5% troilite. A variety of chondrule types is usually present, the commonest being granular and porphyritic olivine and olivine-pyroxene, barred olivine, and fine-grained pyroxene.

NISHIIZUMI and ARNOLD (1981) have measured ^{53}Mn in the following H5 chondrites: Y-74192, Y-74193, and Y-74371.

15. L5 Chondrites

Five L5 chondrites have been identified in the 1974 Yamato collection: Y-74022 (34.7 g), Y-74116 (68.9 g), Y-74376 (120.0 g), Y-74457 (120.8 g), and Y-74639 (89.5 g).

Y-74022 is a pyramidal, almost completely crusted stone; a chipped surface is pale gray except for some brown halos around metal grains, and chondritic structure is not prominent. The composition of olivine and orthopyroxene has been reported by MATSUEDA *et al.* (1981). Y-74116 is a complete crusted stone; in a thin section chondritic structure is observed, but it is obscured in places by a network of black troilite-rich veinlets, probably a shock effect. NITOH *et al.* (1980) have reported on cosmogenic ^{40}K in this meteorite, and TAKAOKA *et al.* (1981) have measured the rare gases. Y-74376 is a wedge-shaped fragment, partly covered with dull black fusion crust; fracture surfaces are stained brown with limonite and show occasional chondrules. The interior is pale gray with a little limonitic staining around metal grains. MATSUEDA *et al.* (1981) have determined olivine and orthopyroxene compositions. Y-74457 is about one-half of a hemispherical stone, with frothy black fusion crust thickened around the flat rear surface (see photograph in YANAI, 1981). The interior is pale gray, granular, showing traces of chondritic structure. Y-74639 is a complete pyramidal stone with brownish-black fusion crust. The interior is pale gray and chondritic.

Thin sections of these L5 chondrites show that chondrules are moderately abundant but poorly defined, tending to merge with the granular groundmass, which consists largely of olivine and pyroxene with minor amounts of nickel-iron and troilite. Pyroxene is untwinned orthopyroxene, although rare grains of polysynthetically twinned clinobronzite are sometimes seen; plagioclase may be present as very small grains that are difficult to recognize.

NISHIIZUMI and ARNOLD (1981) have measured ^{53}Mn in Y-74116.

16. H6 Chondrites

Many H6 chondrites have been identified in the 1974 Yamato collection; those weighing more than 100 g are: Y-74014 (2367.9 g), Y-74094 (867.2 g), Y-74374 (205.2 g), Y-74418 (567.2 g), Y-74459 (1719.7 g), Y-74462 (205.0 g), Y-74491 (134.5 g), Y-74492 (112.1 g), Y-74495 (220.2 g), Y-74497 (301.2 g), Y-74498 (124.0 g), Y-74507 (116.1 g), Y-74640 (1065.9 g). Y-74418–436, Y-74459–602 (except Y-74546), and Y-74613–638 were grouped in the field as pieces of an individual stone or from a single shower. Y-74094 and Y-74640 resemble each other closely and can probably be paired.

Y-74014 is a complete crusted stone of pyramidal form (see photograph in YANAI, 1981). A chipped surface shows pale gray granular material with traces of chondritic structure: brown limonitic weathering is concentrated immediately below the crust and around metal grains. YABUKI *et al.* (1978) have described the petrology of this meteorite. Y-74094 is a wedge-shaped fragment with remnants of fusion crust on three surfaces; the other surfaces are fractures and are weathered reddish-brown (see photograph in YANAI, 1981). YABUKI *et al.* (1978) have described its petrology.

Y-74374 is approximately one-half of a complete stone with dark brown fusion crust and a brown strongly weathered interior. Y-74418 is about one-half of an individual stone with dull brownish-black fusion crust showing flow lines indicating oriented flight; the interior is pervaded with brown limonitic staining which obscures the structure. KIMURA *et al.* (1978) have described the petrology of this stone.

Y-74459, Y-74462, Y-74491, Y-74492, Y-74495, Y-74497, Y-74498, and Y-74507 are strongly weathered fragments, some with fusion crust, which belong to the Y-74459–602 group of paired specimens; Y-74459 is figured in YANAI (1981). The olivine and orthopyroxene compositions of several specimens in this group have been reported by MATSUEDA *et al.* (1981); YABUKI *et al.* (1978) have described the petrology of Y-74492, and NISHIDA *et al.* (1979) the compositions of olivines and orthopyroxenes in Y-74498 and Y-74507.

Y-74640 is about one-half of a complete stone, with partly abraded fusion crust on three faces; the other faces are fracture surfaces showing a greenish-gray granular interior with rare chondrules (illustration in YANAI, 1981).

Thin sections of the H6 chondrites are all very similar. Chondrules are sparse and poorly defined, tending to merge with the granular groundmass, which consists largely of olivine and orthopyroxene with minor amounts of nickel-iron, sodic plagioclase, and troilite, and accessory chromite.

NISHIIZUMI and ARNOLD (1981) have measured ^{53}Mn in the following H6 chondrites: Y-74418, Y-74462, Y-74471, and Y-74497.

17. L6 Chondrites

A considerable number of L6 chondrites have been identified in the 1974 Yamato collections; those weighing more than 100 g are: Y-74007 (162.3 g), Y-74035 (115.7 g), Y-74036 (201.4 g), Y-74077 (5575.1 g), Y-74118 (845.1 g), Y-74144 (141.4 g), Y-74164 (284.8 g), Y-74190 (3235.7 g), Y-74354 (2721. 1g), Y-74362 (4175.0 g), Y-74367 (165.6 g), Y-74445 (2293.2g), Y-74454 (578.8g), Y-74455 (114.1g), Y-74605 (580.8g) and Y-74650 (163.2 g).

Y-74007 is a large fragment partly coated with fusion crust. It has been described by NAGAHARA (1980). Y-74035 is a partly crusted fragment; fracture surfaces are weathered brown, and the interior appears to be finely granular with few traces of chondritic structure. HIRANO *et al.* (1980) have determined major and some trace elements in this meteorite. Y-74036 is an almost complete pyramidal stone with brownish-black fusion crust; broken surfaces show a pale gray poorly chondritic interior with brown limonitic weathering concentrated below the fusion crust.

Y-74077 is the largest stone of the 1974 collection; it is a complete cone-shaped specimen with well-developed regmaglypts (photograph in YANAI, 1981). Exposed surfaces are weathered brown, but the interior is pale gray and almost unweathered. NISHIIZUMI *et al.* (1980) have reported on cosmogenic ^{53}Mn in this meteorite and TAKAOKA *et al.* (1981) have measured its content of rare gases.

Y-74118 is a complete roughly cuboidal stone, covered with black fusion crust differing in texture on different surfaces. The interior is pale gray and shows chondritic structure. Weathering is limited to rusty halos around metal grains. Y-74144 is a cuboidal stone with dull brownish-black fusion crust on five faces; the sixth face is a fracture surface. Weathering has developed brown limonitic staining below the fusion crust and around metal grains. JOCHUM *et al.* (1980) have determined 12 major and minor elements, and MATSUEDA *et al.* (1979) have measured olivine and orthopyroxene compositions in this meteorite. Y-74164 is an irregular fragment partly coated with dull black fusion crust; chondrules are visible on weathered fracture surfaces. These surfaces have brown limonitic staining, but the interior is pale gray and essentially unweathered.

Y-74190 is a complete angular stone largely covered with dull black fusion crust (photograph in YANAI, 1981); some brown limonitic staining is present on exposed surfaces, but the interior is pale gray and essentially unweathered except for minor limonitic staining around metal grains. This meteorite has been described petrographically by KIMURA *et al.* (1978), and NAGAHARA (1979a, b, 1980); ONUMA *et al.* (1978) have measured oxygen isotopes; ITO *et al.* (1980) have examined the effects of shock and weathering on the Rb-Sr system; and NAGATA and FUNAKI (1981) have reported on its magnetic properties.

Y-74354 is an angular fragment partly coated with dull black fusion crust (photograph in YANAI, 1981); the interior is pale gray, except for brown limonitic halos around metal grains. NAGAHARA (1979a, b, 1980) has described its petrology, NAGATA and FUNAKI (1981) have studied its magnetic properties, and YAMAJI and MATSUMOTO (1980) have made X-ray single-crystal studies on olivine.

Y-74362 is an almost complete angular stone, covered with black fusion crust (YANAI, 1981, Photo 38); traces of a white efflorescence have developed along polygonal fractures in the fusion crust. The interior is pale gray, granular, with poorly defined chondritic structure. It has been studied petrographically by YABUKI *et al.* (1978) and NAGAHARA (1979a, b, 1980); SHIMIZU *et al.* (1979) have determined rare earths, Ba, and Sr; and NAGATA (1980) and NAGATA and FUNAKI (1981) have studied its magnetic properties.

Y-74367 is a fairly complete stone partly covered with fusion crust; where fusion crust is absent, the surface is stained with brown limonite, and occasional chondrules can be seen. The interior is pale gray, granular, and relatively unweathered. NISHIDA *et al.* (1979) have published an extensive series of analyses of olivine and orthopyroxene in this meteorite.

Y-74445 is an almost complete rounded stone, largely covered with dull black fusion crust; several deep fractures penetrate the stone (photograph in YANAI, 1981). The interior is granular and shows little trace of chondritic structure (Photo 45). It has been described petrographically by KIMURA *et al.* (1979a) and NAGAHARA (1980); IMAMURA *et al.* (1979) have measured cosmogenic ^{53}Mn.

Y-74454 is an almost complete trapezoidal stone covered with black fusion crust (photograph in YANAI, 1981); the interior is pale gray with occasional darker gray chondrules. NISHIDA *et al.* (1979) have published an extensive series of analyses of olivine and orthopyroxene in this meteorite; NITOH *et al.* (1980) have measured cosmogenic ^{40}K, and NISHIIZUMI *et al.* (1980) have measured cosmogenic ^{53}Mn.

Y-74455 is a nearly complete rounded stone; fusion crust is less well-developed on one face than the others, suggesting a late breakup in the atmosphere. The interior is pale gray except for brown limonitic staining around metal grains, granular, with little trace of chondritic structure.

Y-74605 is a rounded fragment covered with dull black fusion crust except on two fracture surfaces; these surfaces are stained brown with limonite, and occasional chondrules can be seen. Y-74650 is an almost complete pyramidal stone, covered with dull black fusion crust; a chipped surface shows a light gray granular interior, with little evidence of chondritic structure. KIMURA *et al.* (1979b) have described its petrology.

Thin sections of these L6 chondrites are all very similar, showing sparse poorly defined chondrules which tend to merge with the granular groundmass. Principal minerals are olivine and orthopyroxene in subequal amounts, together with minor amounts of sodic plagioclase, nickel-iron, troilite, and diopside, and accessory chromite and phosphate (merrillite and/or chlorapatite). Y-74445 is brecciated, and parts of the section show a network of black veinlets.

NISHIIZUMI and ARNOLD (1981) have measured ^{53}Mn in the following L6 chondrites: Y-74028, Y-74035, Y-74362, and Y-74454.

18. LL6 Chondrites

Five LL6 chondrites have been identified in the 1974 Yamato collections: Y-74048 (67.1 g), Y-74080 (536.9 g), Y-74160 (31.4 g), Y-74646 (554.7 g), and Y-74663 (213.9 g).

Y-74048 is a fairly complete partly crusted stone, the crust showing two different fusion stages. The interior is medium gray in color, finely granular, and without visible chondrules. Metal grains are rare. In a thin section chondrules are few and poorly defined, the meteorite consisting largely of granular olivine and pyroxene with a cataclastic and brecciated texture. Nickel-iron and troilite are present in a small amount (less than 5%). Minor brown limonitic staining is present. MATSUEDA *et al.* (1981) report the following mineral compositions: olivine, $Fa_{30.3}$, (1.44% M.D.); orthopyroxene, $Fs_{25.6}$ (1.55% M.D.).

Y-74080 is a complete stone, well-rounded, with black fusion crust (YANAI, 1981); chipping revealed a light gray interior showing slight weathering immediately below the fusion crust. YABUKI *et al.* (1978) have described it petrographically.

Y-74646 is illustrated by YANAI (1981). It is a nearly complete stone partly covered by frothy black fusion crust, thickened on the periphery and back surface. The interior shows mostly pale gray finely granular clasts bounded by dark gray veinlets, giving a highly brecciated appearance. Weathering is limited to near-surface limonitic staining. The brecciation is prominent in a thin section. Most of the clasts have only traces of chondritic structure and can be classified as LL6, but one has more pronounced chondritic structure and may be LL5. Numerous black veinlets are seen in the thin section. The meteorite consists largely of olivine and pyroxene with small amounts of plagioclase, nickel-iron, and troilite. YANAI *et al.* (1978) reported olivine composition $Fa_{30.6}$ (1.9% M.D.). YANAI (1979) published a chemical analysis. NAGAHARA (1979a, 1980) has given much information on mineral compositions and petrology of this meteorite; she found olivine compositions ranging from $Fa_{27.6}$ to $Fa_{29.8}$, with a mean of $Fa_{29.1}$; orthopyroxene ranging from $En_{75.4}Fs_{23.5}Wo_{1.1}$ to $En_{71.6}Fs_{25.9}Wo_{2.5}$, with a mean of $En_{73.7}Fs_{24.8}Wo_{1.5}$; augite with a mean composition of $En_{45.5}Fs_{8.6}Wo_{45.9}$. NAGATA (1980) and NAGATA and FUNAKI (1981) have studied magnetic properties of this meteorite.

Y-74663 is an almost complete rounded stone, largely covered with dull black fusion crust; the interior is pale gray, granular, with traces of chondritic structure. Weathering is minor, being limited to brown limonitic staining below the fusion crust and around metal grains. KIMURA *et al.* (1979b) have described its petrology. The specimen was classified as an LL chondrite.

Y-74160 has been described by TAKEDA *et al.* (1979) as follows: "This is a 31.4 g individual with a black fusion crust and olive yellow to pale gray interior. The meteorite is brecciated and a thin section examined is composed of subangular recrystallized clasts, which consist of olivine (~49%), low-Ca pyroxene (orthopyroxene) (~29%), augite (~9%), plagioclase (~8%), chromite (~3%), troilite (~2%) and Ca phosphate (~0.5%). Metal ($Fe_{50.0}$, $Co_{2.3}$, $Ni_{46.7}$ wt %) has been detected with chromite and troilite in a very small amount. Microprobe analyses show olivine (Fa_{30}), orthopyroxene ($Ca_4Mg_{72}Fe_{24}$), augite ($Ca_{43}Mg_{46}Fe_{11}$) of uniform composition. The percent mean deviation of Fa content in olivine is about 1%, and Fs content of pyroxene is about 2.5 %. The plagioclase shows a small range of compositions from An_7 to An_{25}. The silicate minerals in the clasts exhibiting a granoblastic texture have rounded grain boundaries. The brecciated matrix itself appears to have been recrystallized and became transparent." TAKEDA *et al.* estimated the bulk chemical composition of Y-74160 from the weight percentages of the minerals and their compositions from microprobe analyses. They commented that the compositions and texture are suggestive of an extensively recrystallized LL chondrite, and estimated the temperature of the last equilibration of the Opx-Aug pair at 1090°C, considerably higher than 970°C of ordinary chondrites. TAKEDA and YANAI (1980) suggested it might be classified as LL7. Additional data on a coarse-grained clast of this meteorite, including a bulk chemical analysis by H. HARAMURA, are given by MCFADDEN *et al.* (1982). Data on nickel-iron are given by OHTA *et al.* (1982).

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