PETROLOGICAL STUDIES OF YAMATO-74 METEORITES (1)

Hideo YABUKI,

The Institute of Physical and Chemical Research, Hirosawa, Wako-shi 351

Kenzo YAGI and Kosuke ONUMA

Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, Kita-ku, Sapporo 060

Abstract: Chemical and petrologic classification of seven Yamato-74 meteorites was investigated in terms of microscopic observations and X-ray powder method. Yamato-74013 meteorite belongs to calcium-poor achondrite, diogenite with a granoblastic texture. Other six meteorites are ordinary chondrites. Recrystallization is fairly advanced in chondrites, except in Yamato-74191 meteorite which contains glassy material and clinohypersthene. Composition of olivine and orthopyroxene and petrographic observation indicate that Yamato-74014, -74080, -74094, -74191, -74362, and -74459 meteorites belong to H5, L6, H6, L3, L6 and H6 types of chondrite according to the classification of VAN SCHUMUS and WOOD (1967).

1. Introduction

Following the discovery of 9 and 12 stony meteorites at the southeast end of the Yamato Mountains in 1969 and in 1973 respectively, a total of 663 pieces of meteorites were collected in nearly the same area by the traverse party of the 15th Japanese Antarctic Research Expedition (JARE-15) in November and December 1974 (YANAI, 1976). It is remarkable that such a large number of meteorites of various kinds are distributed in such a limited area. Classification of these meteorites was required before the detailed research. In this paper seven Yamato-74 meteorites (Yamato-74013, -74014, -74080, -74094, -74191 and -74459) are described. One of them, Yamato-74013, is assigned to a calcium-poor achondrite, namely diogenite whereas the others are all ordinary chondrites.

The composition of olivine was determined by optical properties and d_{130} spacing of X-ray powder pattern, using the empirical curves of DEER *et al.* (1962) and SHINNO (personal communication, 1976), and the composition of orthopyroxene and plagioclase by the determinative curves of KUNO (1958) and SMITH (1958), respectively.

2. Petrography and Mineralogy

2.1. *Yamato-74013*

This meteorite consists almost entirely of orthopyroxene, with only accessary amounts of opaque minerals and trace of plagioclase and tridymite (Table 1).

Table 1. Modal composition of Yamato meteorites (vol. %).

	Yamato-74013	Yamato-74014	Yamato-74080	Yamato-94094	Yamato-74191	Yamato-74362	Yamato-74459
Matrix							
Olivine		52.1	47.4	45.9	10.0	54.2	48.4
Orthopyroxen	96.5	29.8	31.5	31.4	1.2	24.6	33.3
Clinopyroxene		0.6	2.9	1.1	4.2	1.4	3.0
Plagioclase	0.1	1.6	5.5	5.2		6.2	1.7
Apatite		trace	0.9			0.1	
Tridymite	trace						
Glass					6.9		
Opaque minerals	3.4	15.9	11.8	16.4	58.1	13.5	13.5
Others*					19.6		
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Chondrules							
Olivine		55.7	70.3	11.3	42.8	58.4	46.8
Orthopyroxene		32.1	5.4	66.3	16.2	27.3	34.2
Clinopyroxene		8.5	10.8	15.7	30.2	6.5	16.5
Plagioclase		trace	8.1	2.2	trace	3.9	1.2
Glass					7.1		
Opaque minerals		3.7	5.4	4.5	2.7	3.9	1.3
Others*					1.0		
Total	0.0	100.0	100.0	100.0	100.0	100.0	100.0
Matrix	100.0	84.1	96.7	92.7	17.9	93.3	94.1
Chondrules	0.0	15.9	3.3	7.3	82.1	6.7	5.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Cryptocrystalline materials.

It has a granoblastic texture consisting of equigranular orthopyroxene, distributed homogeneously throughout the entire mass (Fig. 1) as seen in the Yamato-692(b) meteorite collected in nearly the same area in 1969 (OKADA, 1975). This structure is rather unusual for ordinary diogenites, which have generally brecciated structures (MASON, 1963). Orthopyroxene, 0.1 to 0.5 mm in size, is almost colorless in thin section and shows well-developed (210) cleavages and no pleochroism. From optical properties the molar composition of pyroxene is $En_{74} Fs_{26}$ (Table 2), which is within the usual compositional range of diogenites (MASON, 1963). Trace amounts of plagioclase and tridymite occur in xenomorphic forms, filling the interstices of orthopyroxene grains. Some grains of plagioclase show twinning on the albite law. Coarse chromite grains, a few millimeters in size, are dispersedly distributed in the olive-yellow meteorite mass. They are

Table 2. Optical properties, unit cell parameters and molar composition of olivine, orthopyroxene and plagioclase in Yamato meteorites.

	Yamato-74013	Yamato-74014	Yamato-74080	Yamato-74094	Yamato-74191	Yamato-74362	Yamato-74459
Olivine							
d_{130}		2.7782	2.7805	2.7776	2.7803	2.7805	2.772
Optic axial angle		−88°	−86°	−88°	−87°	−87°	−88°
Refractive indices α_D		1.667	1.675	1.669	1.656	1.676	1.666
γ_D		1.708	1.719	1.709	1.727	1.718	1.708
Unit cell parameters a		4.769±.003	4.773±.005	4.771±.003	4.768±.003	4.771±.004	4.764±.004
(Å) b		10.250±.005	10.266±.007	10.253±.003	10.263±.004	10.260±.004	10.258±.008
c		6.004±.004	6.006±.006	6.001±.003	6.009±.003	6.010±.003	6.004±.002
Molar composition		$Fo_{82}Fa_{18}$	$Fo_{77}Fa_{23}$	$Fo_{81}Fa_{19}$	Fo_{73}–Fo_{88}	$Fo_{77}Fa_{23}$	$Fo_{82}Fa_{18}$
Orthopyroxene							
Optic axial angle	−70°	−80°	−72°	−80°	−71°	−72•	−82°
Refractive indices α_D	1.682				1.663		
γ_D	1.694				1.701		
Unit cell parameters a	18.308±.005	18.261±.004	18.275±.007	18.265±.005		18°227±.013	18.267±.012
(Å) b	8.884±.004	8.855±.001	8.861±.007	8.852±.004		8.863±.011	8.850±.012
c	5.213±.003	5.203±.004	5.201±.006	5.192±.005		5.205±.014	5.194±.010
Molar composition	$En_{74}Fs_{26}$	$En_{81}Fs_{19}$	$En_{75}Fs_{25}$	$En_{81}Fs_{19}$	En_{69}–En_{92}	$En_{75}Fs_{25}$	$En_{82}Fs_{18}$
Plagioclase							
Optic axial angle		−61°	−59°	−60°		−59°	−59°
Refractive indices α_D		1.536	1.537	1.536		1.535	1.535
γ_D		1.546	1.545	1.545		1.544	1.543
Molar composition		An_{15}–An_{20}	An_{17}–An_{18}	An_{15}–An_{18}		An_{14}–An_{18}	An_{14}–Ab_{86}

weakly magnetic and show an X-ray powder pattern of the isometric system. It is slightly translucent in thin section, showing a reddish brown color. Very fine-grained opaque minerals, mostly troilite and kamacite, are uniformly distributed within the silicate mass and coarse chromite grains. They often show angular idiomorphic forms (Fig. 3).

2.2. *Yamato-74014*

Yamato-74014 meteorite is an olivine-bronzite chondrite. Various types of chondrules, 0.2–2.0 mm in size, are still readily distinguishable, although they have a more or less rugged outline. Most part of the well-recrystallized granular matrix is thinly covered with a brownish weathered product.

Olivine, which is the most predominant mineral, occurs usually as xenomorphic grains, but is idiomorphic within some chondrules. From optical properties, its composition is determined as $Fo_{82}Fa_{18}$ (mole percent) (Table 2).

Orthopyroxene occurs as xenomorphic crystals, colorless in thin section. The optical properties indicate a composition of $En_{80}Fs_{20}$ in mole percent. The grains are sometimes partly surrounded by clinopyroxene with much higher birefringence, probably augite. The extinction angle ($Z\wedge c$) of the rim clinopyroxene is about 45°.

A small amount of plagioclase is present interstitial to other silicates and opaque minerals in both matrix and chondrules. Some grains show albite- or carlsbad twinning between crossed nicols. Optical properties suggest the molar composition of $An_{15}Ab_{85}$–$An_{20}Ab_{80}$, belonging to a high-temperature oligoclase.

Among the opaque phases, kamacite is most predominant and usually occurs as irregular-shaped veins among silicates in the matrix. Taenite occurs in an intimate intergrowth with kamacite. Myrmekitic or plessitic intergrowth of both phases is not rare (Fig. 5). Troilite is also very common and occurs in a xenomorphic form. Chromite is less than other opaque minerals in amount. Aggregates of fine-grained chromite are occasionally found within some chondrules as the interspatial material between silicate minerals.

2.3. *Yamato-74080*

Yamato-74080 meteorite belongs to an olivine-hypersthene chondrite and consists for the most part of olivine, orthopyroxene, kamacite-taenite and troilite with accessary clinopyroxene, apatite, plagioclase and chromite (Table 1). Individual minerals are essentially xenomorphic and show an intensively fractured feature (Fig. 6). Most silicate grains show extensively distinct undulatory extinction, and kink bands are also observed in some olivine and orthopyroxene grains. Some grains of plagioclase show a thin lamellar structure. These features may be explained by fairly strong shock deformation due to pre-terrestrial collision. Few chondrules are identifiable in the thin section without the aid of crossed polarized light. Molar composition of olivine is $Fo_{77}Fa_{23}$ by optical properties and d_{130} spacing in X-ray powder pattern (Table 2). Orthopyroxene, $En_{75}Fs_{25}$, is sometimes locally concentrated in some parts of the entire mass. Clinopyroxene occurs as exsolved thin lamellae in orthopyroxene or as a thin

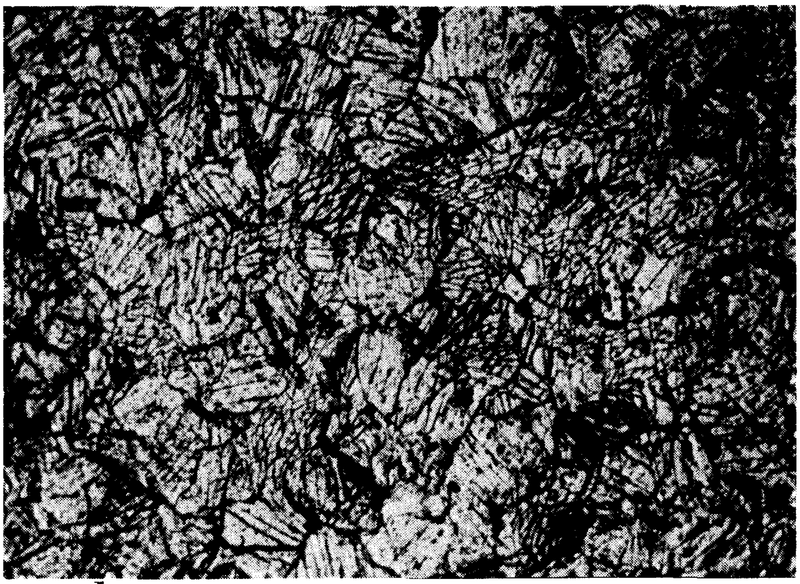

Fig. 1. Photomicrograph of the texture in Yamato-74013 meteorite. The entire mass is composed mostly of compact assemblage of orthopyroxene grains. Long dimension of photograph = 1.3 mm.

Fig. 2. Plagioclase (P_L) filling the interstices among orthopyroxene grains. Yamato-74013. Long dimension of photograph is 0.26 mm in length.

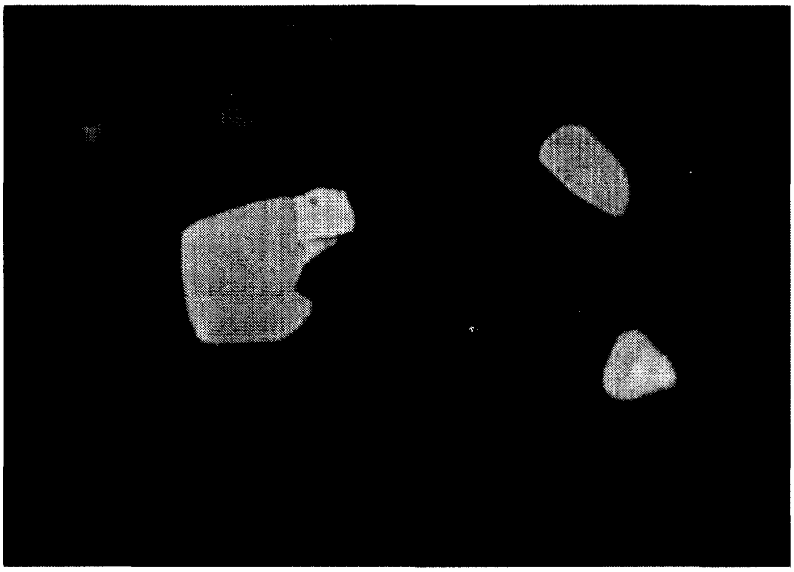

Fig. 3. Fine-grained troilite (grey) intergrown with kamacite (light grey) and chromite (dark grey) within orthopyroxene mass (black). They often show idiomorphic outlines. Yamato-74013. Reflected light. Long dimension of photograph is 0.043 mm in length.

Fig. 4. Photomicrograph of a thin section of Yamato-74014 meteorite. Although the textural integration is fairly advanced, several chondrules with various internal structure are still recognizable. Long dimension of photograph = 2.6 mm.

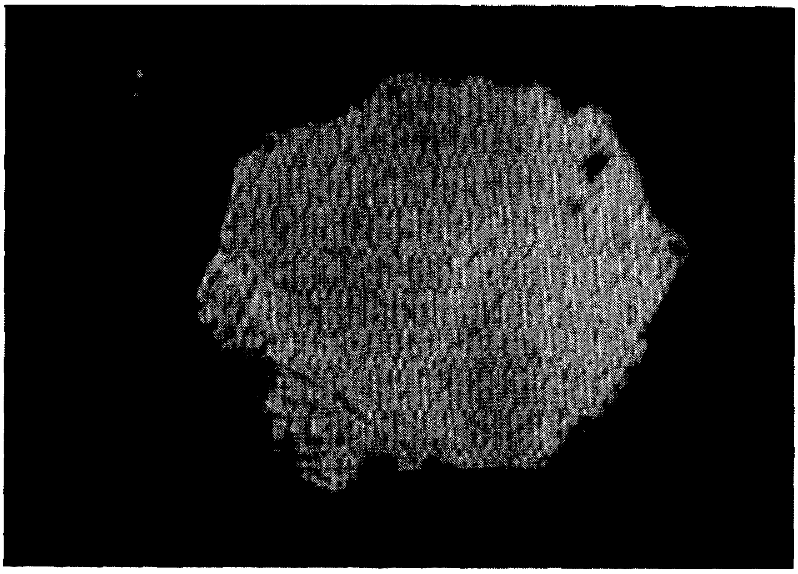

Fig. 5. Plessitic intergrowth of kamacite and taenite. Yamato-74014. Reflected light. Long dimension of photograph is 0.22 mm in length.

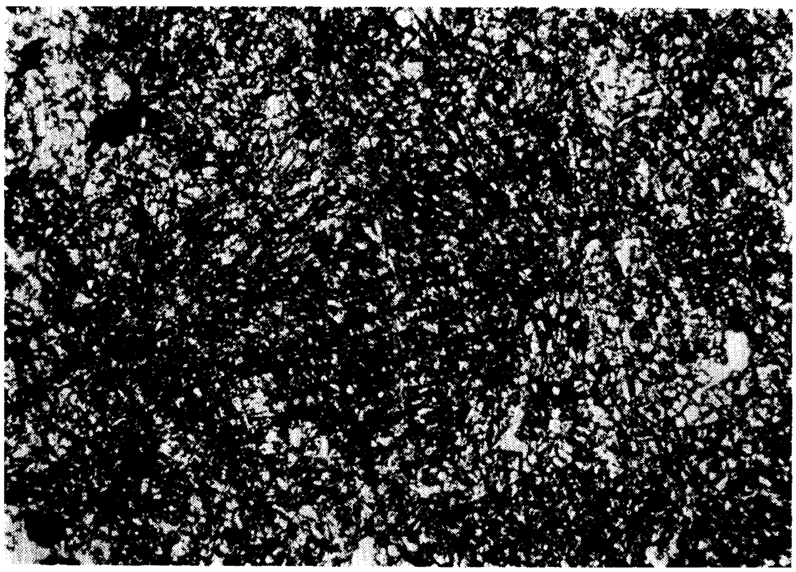

Fig. 6. Photomicrograph of a thin section of Yamato-74080 meteorite, showing advanced recrystallized and extremely fractured texture. Long dimension of photograph = 1.3 mm.

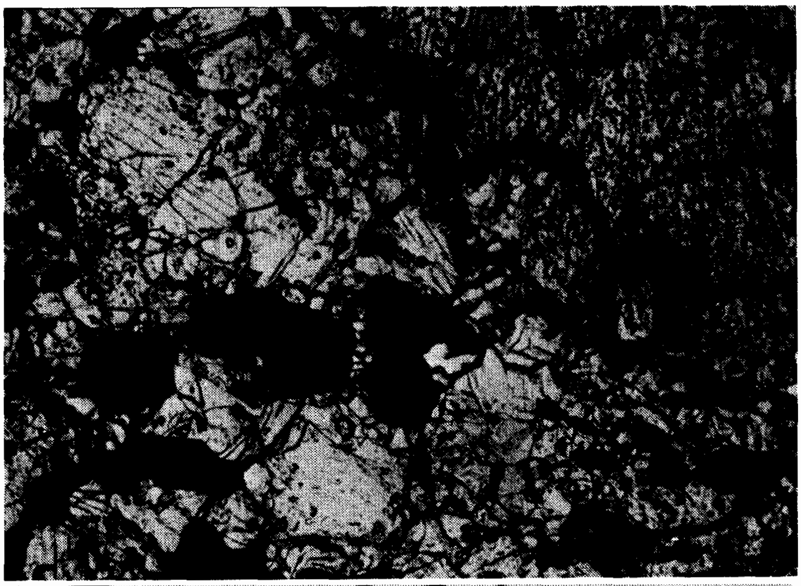

Fig. 7. Photomicrograph of a thin section of Yamato-74094 meteorite. The matrix is composed of well-recrystallized granular silicates and opaque minerals in irregular shape. Long dimension of photograph=1.3 mm.

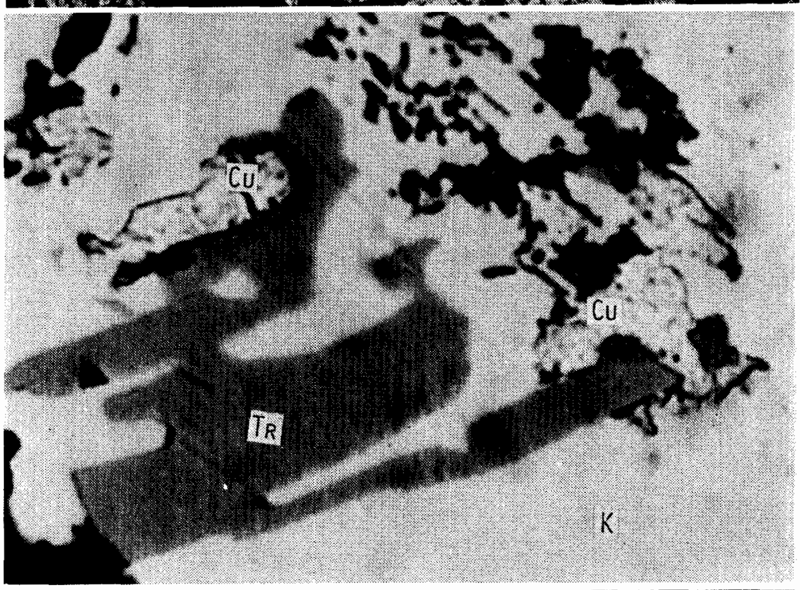

Fig. 8. Native copper (C_U) and troilite fragments (T_R) included in metallic nickel-iron (K). Yamato-74094. Reflected light. Long dimension of photograph=0.043 mm.

Fig. 9. Photomicrograph of a thin section of Yamato-74191 meteorite, showing a notable chondritic structure. Chondrules are various in texture and size. Interstices among chondrules are filled with opaque minerals or cryptocrystalline materials. Long dimension of photograph=2.6 mm.

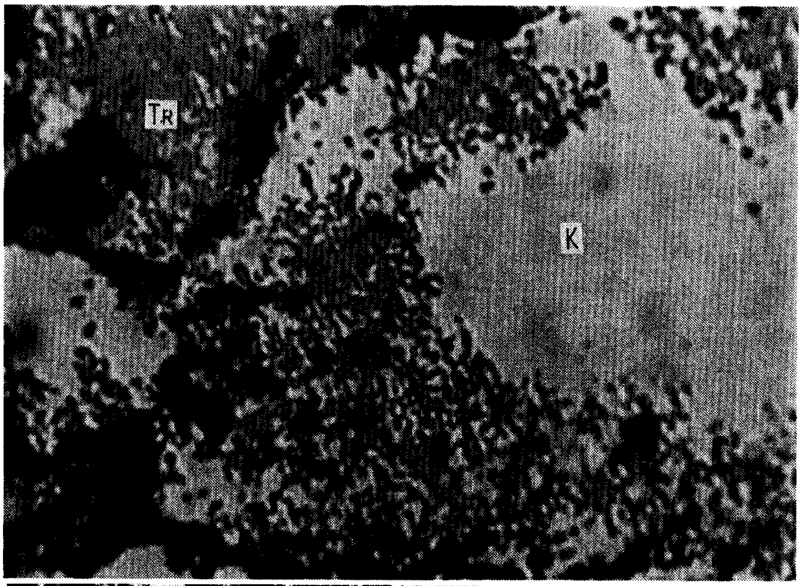

Fig. 10. *Network of troilite (T_R) invading kamacite (K) grains from the boundaries with silicates. Yamato-74191. Reflected light. Long dimension of photograph is 0.11 mm in length.*

Fig. 11. *A thin section of Yamato-74362 meteorite, showing well-recrystallized texture. Boundaries between chondrules and matrix are obliterated. Feldspar (white) is conspicuous in both matrix and chondrules. Long dimension of photograph = 1.3 mm.*

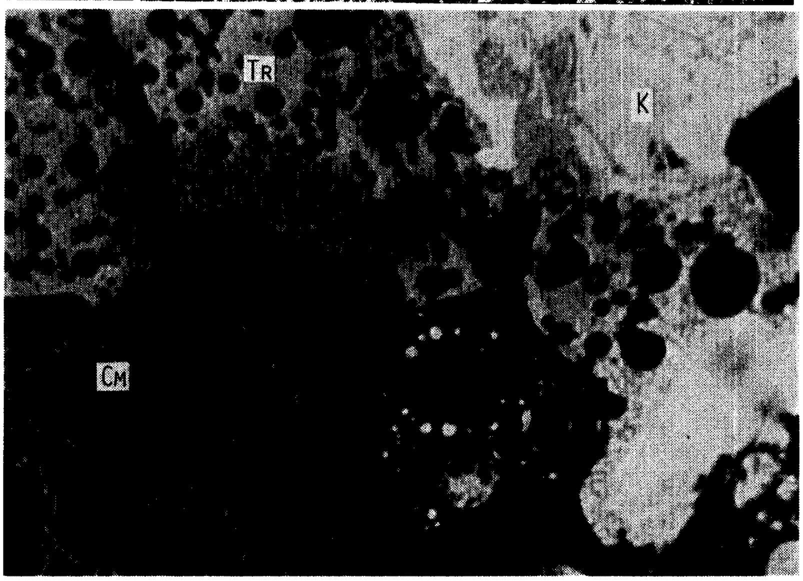

Fig. 12. *Fused texture is observable in troilite (T_R), kamacite (K) and silicates, but not in chromite (C_M). Fine network of troilite is partly invading kamacite grains. Yamato-74362. Reflective. Long dimension of photograph is 0.11 mm in length.*

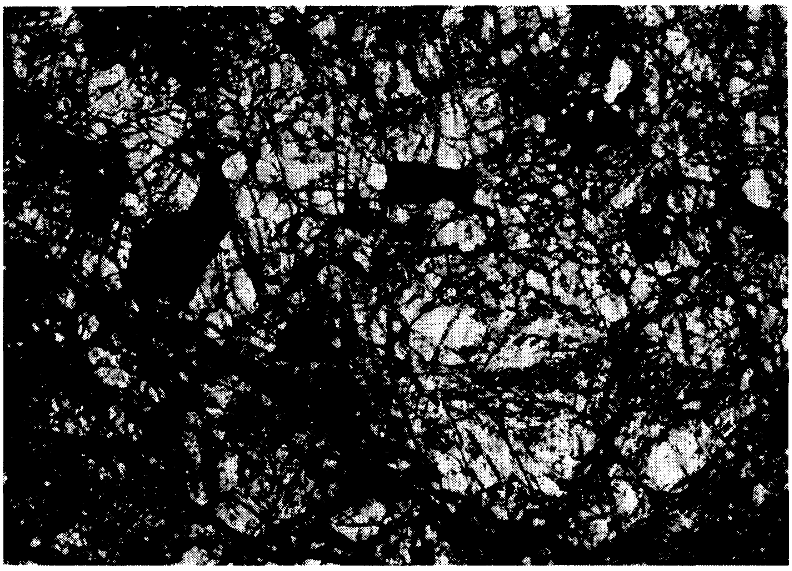

Fig. 13. Photomicrograph of a thin section of Yamato-74459 meteorite. Matrix is composed mainly of well-crystallized granular grains of silicates and opaque minerals. Most part of the thin section is covered with brownish oxidized material due to atmospheric weathering. Long dimension of photograph is 1.3 mm in length.

Fig. 14. Exsolution lamellae of clinopyroxene in clinopyroxene (probably augite) which is a reaction rim of orthopyroxene. Yamato-74459. Transmitted light. Nicols crossed. Long dimension of photograph = 0.13 mm.

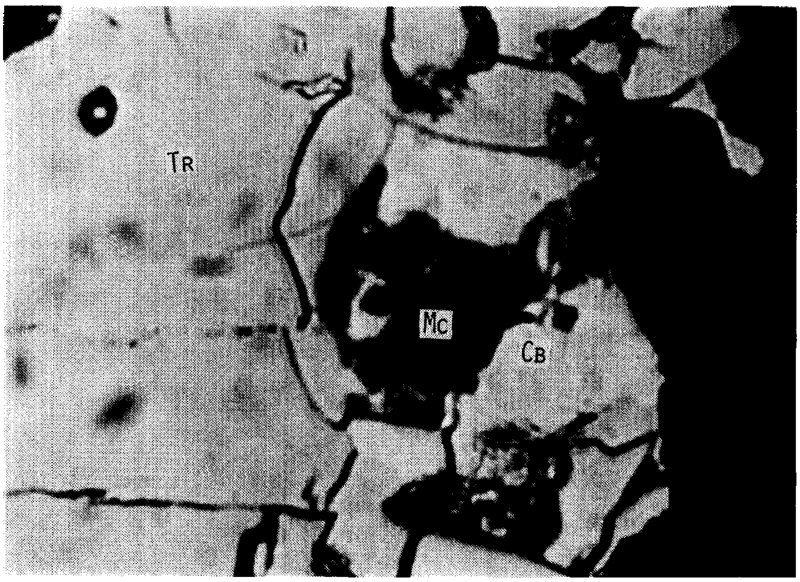

Fig. 15. Mackinawite (in dark position) (M_C) included in cubanite (?) (C_B), being enclosed by troilite (Tr). Yamato-74459. Reflected light. Long dimension of photograph is 0.043 mm in length.

reaction rim around orthopyroxene grains.

A small amount of apatite occurs in xenomorphic forms interstitial to silicates. It is characterized by very low birefringence and lower relief than mafic minerals. It occasionally shows weak cleavages and fractured appearance.

Plagioclase of accessary amount also occurs interstitial to other silicates. It often contains many minute grains of pyroxene and olivine in rounded shapes. In some chondrules plagioclase occurs as interspatial material separating bar-shaped olivine crystals.

Kamacite is the most predominant opaque mineral, frequently attaining to 1.0 mm. Taenite occurs mostly in an intimate intergrowth with kamacite, but it is occasionally seen as an isolated grain. Troilite is also dominant and often shows a somewhat fractured feature. Chromite occurs not only as massive crystals but also as aggregates of numerous minute grains in idiomorphic forms. Native copper is present only in a trace amount associated with troilite fragments within metallic nickel-iron grains. Copper shows a characteristic pink color and high reflectivity.

2.4. *Yamato-74094*

Yamato-74094 meteorite is composed of highly recrystallized clear matrix and some chondrules of various sizes (Fig. 7). Chondrules and matrix intergrow so strongly that the boundaries are obliterated in most cases. Silicate minerals are sometimes partly covered with brownish weathered products.

Olivine occurs usually as irregular grains, except in porphyritic chondrules, in which hypidiomorphic crystals are not rare. It often shows undulatory extinction between crossed nicols. The optical properties and d_{130} are indicating a composition of $Fo_{81}Fa_{19}$ in mole percent.

Orthopyroxene ($En_{81}Fs_{19}$) occurs also as xenomorphic grains, colorless in thin section. Clinopyroxene is present in irregular shapes showing exsolved thin lamellae within some chondrules.

Plagioclase occurs in a small amount as xenomorphic grains both in the matrix and in the chondrules. Optical properties indicate that it is high temperature oligoclase (Table 2).

Kamacite is the most predominant opaque mineral, which is occasionally intergrown with taenite or troilite. A fine plessitic intergrowth of kamacite and taenite is also common. Chromite occurs less in amount compared with metallic nickel-iron and troilite. The aggregates of fine chromite grains in irregular shape are frequently found among silicate minerals. Only a trace amount of native copper is present as inclusions within some kamacite grains associated with irregular troilite fragments (Fig. 8). A few grains of mackinawite are found within troilite grains, associated with cubanite(?) as seen in Yamato-74459 meteorite (Fig. 15).

2.5. *Yamato-74191*

Yamato-74191 meteorite is composed mainly of olivine, clinopyroxene, orthopyroxene and opaque minerals with small amounts of glassy materials. This meteorite shows a remarkably chondritic texture consisting of numerous chondrules, ranging from 0.1 to 3.0 mm in diameter, with the interstitial dark matrix (Fig. 9). Chondrules have varying internal structures and clear outlines. They sometimes contain pale brown glasses characteristic of the low recrystallization state. Some chondrules are composed entirely of devitrified and weakly birefringent glassy materials, in which radial aggregates of minute needle-like crystals are observable. The matrix of this chondrite consists mainly of troilite, metallic nickel-iron with very fine to cryptocrystalline dark material which includes many fine-grained olivine and pyroxene.

Most of olivine crystals in chondrules are idiomorphic. Some grains are surrounded by a thin reaction rim of pyroxene. Refractive indices of olivine indicate its wide compositional range (Table 2), whereas $2V$ (aver.) and d_{130} suggest the average composition of about $Fo_{79}Fa_{21}$ in mole percent.

Orthopyroxene occurs mostly as relatively coarse laths rimed by clinopyroxene in porphyritic chondrules. Orthopyroxene has also a wide range of composition from En_{92} to En_{69}, according to its α_D and γ_D. Rim clinopyroxene shows higher birefringence than core, extinction angle ($Z \wedge c$) of about 44° and optical axial angle of +45°. It is considered to be augite. Granular grains of clinopyroxene, which show excellent twinning lamellae and low birefringence, are also commonly seen in many chondrules. The refractive indices of the clinopyroxene are $\alpha_D = 1.659$ and $\gamma_D = 1.706$ and extinction angle ($Z \wedge c$) is about 38°. They are probably clinohypersthene.

Plagioclase is present in a trace amount filling the interstices among silicates grains in a few chondrules.

Troilite, the most predominant opaque phase, occurs usually as the aggregates of randomly oriented grains of various size and shape, which can be readily distinguished with crossed nicols. Kamacite is also dominant and often invaded by network of troilite, especially at the margins (Fig. 10). A lesser amount of taenite is also present in an intimate intergrowth with kamacite. Minute grains of chromite with an idiomorphic outline are occasionally noticed in the groundmass within some porphyritic chondrules.

2.6. *Yamato-74362*

Constituents of this meteorite are olivine, orthopyroxene and opaque minerals with minor amounts of feldspar, clinopyroxene and apatite. Chondrules are not abundant and similar to the matrix (Fig. 11).

Olivine is the most abundant silicate mineral in both chondrules and matrix. It occurs mostly as irregular grains, and show undulatory extinction. Hypidiomorphic crystals are noticed in some parts of the matrix where the relict internal structure of porphyritic chondrules is still recognizable. Some grains show distinct cleavage lines parallel to (010). Optical properties and d_{130} indicate the composition of $Fo_{77}Fa_{23}$ in mole percent.

Orthopyroxene occurs usually as xenomorphic grains, elongated to *c*-axis. Some grains have thin exsolution lamellae of clinopyroxene parallel to (001) plane of the host. Clinopyroxene occurs also as a reaction rim surrounding some grains of orthopyroxene. Granular grains of clinopyroxene are also noticed being included in the well-developed plagioclase.

Plagioclase is xenomorphic, interstial to mafic minerals in the matrix and also as thin irregular intergrowth with olivine in some chondrules. Most grains show distinct undulatory extinction between crossed nicols. Optical properties indicate a high-temperature oligoclase.

Apatite is present as xenomorphic crystals filling the interstices among silicate grains and opaque minerals in the matrix. Some grains show faint cleavage lines.

Opaque minerals of this meteorite are essentially troilite and kamacite-taenite associated with a minor amount of chromite and a trace amount of native copper. Intergrowth of these minerals is frequently observed. It is worthy of note that a fused texture is notably seen in troilite, metallic nickel-iron and silicate but not in chromite (Fig. 12). The aggregates of very fine-grained chromite of an idiomorphic form are often included within silicate minerals. Native copper is trace in amount occurring as minute irregular grains embedded in metallic nickel-iron.

2.7. *Yamato-74459*

This meteorite is classified as an olivine-bronzite chondrite. Microscopically, various types of chondrules are still discernible with the aid of polarized light, although the intergrowth between chondrules and matrix is fairly advanced (Fig. 13). Matrix of this chondrite shows a highly recrystallized feature, being made up of rather coarse-grained crystals. Most of the matrix minerals are covered with a brownish thin film composed probably of iron oxide due to atmospheric oxidation.

Olivine grains are mostly xenomorphic but either hypidiomorphic or idiomorphic within some chondrules. Molar composition of olivine is $Fo_{82}Fa_{18}$ (Table 2).

Orthopyroxene occurs usually as xenomorphic grains, colorless in thin section. Prismatic pyroxene crystals elongated to *c*-axis constitute some chondrules. Orthopyroxene grains often have exsolved thin lamellae of clinopyroxene, parallel to the (100) plane of the host. Some grains are rimmed by clinopyroxene with higher birefringence, probably augite ($Z \wedge c = 40°$). Rim clinopyroxene occasionally shows exsolution lamellae as seen in Fig. 14.

Plagioclase is present in an accessary amount, interstitial to mafic minerals.

Opaque phase of Yamato-74459 meteorite consists of kamacite-taenite, troilite, chromite and trace amounts of native copper, cubanite(?), and mackinawite. Predominant opaque minerals, troilite and kamacite, are usually present as irregular masses and veins which are interstitial to the silicate phase in the matrix. Taenite always occurs in an intimate intergrowth with kamacite. Chromite occurs as coarse irregular shaped grains and also as minute idiomorphic inclusions in silicate grains. Native copper, less than 0.002 mm in size, are noticed within kamacite and troilite grains. A few grains of mackinawite of irregular shape are recognized within cubanite (?) embedded in troilite grains (Fig. 15). Mackinawite shows distinct pleochroism, pinkish grey to grey. Cubanite(?) is isotropic and less reddish-brown than the lightest position of troilite.

3. Summary

Yamato-74013 meteorite belongs to diogenite, which has a granoblastic texture composed of relatively coarse-grained orthopyroxene (En_{74}) just as Yamato-692(b) meteorite collected in 1969 in the same area. Other six meteorites are ordinary chondrites. Yamato-74014, -74094 and -74459 meteorites belong to olivine-bronzite chondrites, while Yamato-74080, -74191 and -74362 meteorites are olivine-hypersthene chondrites. Among these, Yamato-74191 is composed of various types of chondrules with the clear outline and the dark matrix filling the interstices. Constituent minerals of the chondrules are mainly olivine, clinopyroxene and orthopyroxene associated with considerable amounts of devitrified glasses. Average composition of olivine and orthopyroxene is Fo_{79} and En_{74}, respectively. Yamato-74080 and -74362 meteorites show a well-recrystallized texture and are composed mainly of olivine (Fo_{77}), orthopyroxene (En_{75}), high-temperature plagioclase (An_{14}–An_{18}) and opaque minerals. Some evidences of shock effect are also observed. Yamato-74014, -74094 and -74459 meteorites consist mainly of olivine (Fo_{81}–Fo_{82}), orthopyroxene (En_{81}–En_{82}), high-temperature plagioclase (An_{14}–An_{20}) and opaque minerals. Brownish weathered products cover most part of the thin sections. Chondrules are not clear and fairly small in number except in Yamato-74014.

Metallic nickel-iron, troilite and chromite are always predominant opaque minerals in each chondrite. Trace amounts of native copper, mackinawite and cubanite(?) are also noticed in some chondrites. Petrographic observation indicates that Yamato-74014, -74080, -74094, -74191, -74362 and -74459 meteorites belong to H5, L6, H6, L3, L6 and H6 type chondrites of the classification of VAN SCHMUS and WOOD (1967). These chemical and petrologic classifications were based only on optical properties of main silicate constituents, X-ray powder data and petrographical studies. Bulk composition and microprobe analyses of constituent minerals will be needed for accurate classification. Detailed discussion about this will be given elsewhere.

References

DEER, W. A., HOWIE, R. A. and ZUSSMAN, J. (1962): Rock-Forming Minerals, Vol. 1. Longmans, 333 p.

KUNO, H. (1958): Study of orthopyroxenes from volcanic rocks. Am. Mineral., **39**, 30–46.

MASON, B. (1963): The hypersthene achondrites. Am. Mus. Novitates, **2155**, 1–13.

OKADA, A. (1975): Petrological studies of the Yamato meteorites–Mineralogy of the Yamato meteorites. Mem. Natl Inst. Polar Res., Spec. Issue, **5**, 14–66.

SMITH, J. R. (1958): The optical properties of heated plagioclase. Am. Mineral., **43**, 1179–1192.

VAN SCHMUS, W. R. and WOOD, J. A. (1967): A chemical-petrologic classification for the chondrites. Geochim. Cosmochim. Acta, **31**, 747–765.

YANAI, K. (1976): 1974-nen no nankyoku-san Yamato inseki no tansa to saishû (Search and collection of Yamato meteorites, Antarctica, in October and November 1974). Nankyoku Shiryo (Antarct. Rec.), **56**, 70–81.

(Received June 15, 1977)