CHEMICAL AND PETROLOGIC RELATIONS OF THE CONSTITUENT UNITS IN ALH-77249 METEORITE (L3)

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Abstract: This paper describes all constituent units in ALH-77249 (L3), and states genetic relations of the units. This meteorite is identical with ALH-77015 and probably -77033. ALH-77249 consists of chondrules, mineral fragments, several types of inclusions, and matrix in order of amount. Some inclusions were derived from precursor materials which are depleted in plagioclase component. Some other inclusions were derived from chondrules through shock-metamorphism. Early-formed chondrules were frequently disaggregated to form a large amount of silicate mineral fragments. ALH-77249 includes some carbonaceous chondritic materials such as an amoeboid olivine inclusion and matrix.

1. Introduction

Unequilibrated ordinary chondrites, as well as carbonaceous chondrites, are the only samples reflecting the primitive solar nebula process. Unequilibrated ordinary chondrites comprise various constituent units such as chondrules, matrix, and so on. Thus, the studies of these constituent units clarify the evolution and reaction of chondritic materials in the primitive solar nebula, and the process of accretion to parent bodies.

The present study is focused on ALH-77249 meteorite which is an L3 chondrite (SCORE *et al.*, 1981). This paper reports the chemical and petrologic features of constituent units, especially mineral fragments and various inclusions, in this meteorite, and discusses the genetic relations between them and chondrules.

2. Results

2.1. Petrography of the constituent units

ALH-77249 meteorite shows the texture of common unequilibrated ordinary chondrites, being an aggregate of various constituent units (Fig. 1). As a whole, this meteorite has hardly undergone shock-metamorphism. This meteorite belongs to petrologic type 3.4 (SEARS *et al.*, 1982).

ALH-77249 consists of chondrules, inclusions, mineral fragments, and matrix (Table 1). Mineral fragments are single crystals or aggregates of a few crystals, larger than several microns in size. They are further divided into silicate and opaque mineral fragments. In this paper the definition of inclusions is wide, covering various materials besides chondrules, mineral fragments, and matrix. They are further classified into four types based on their texture and mineralogy. Dark-brownish matrix fills

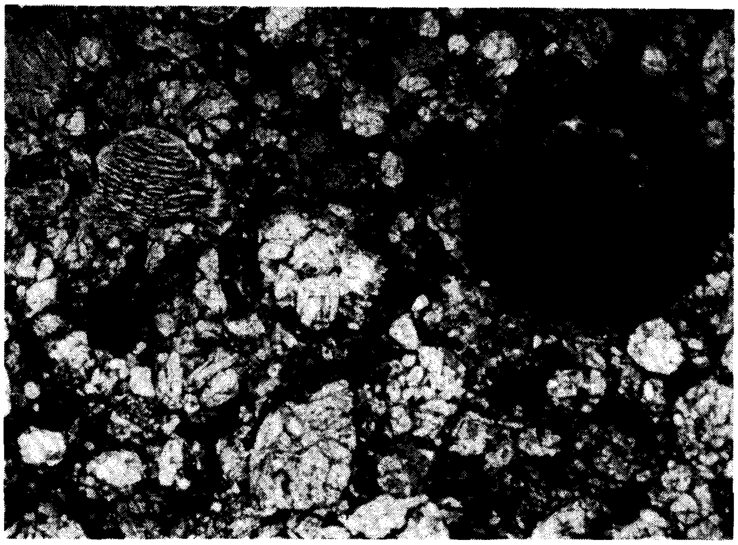

Fig. 1. Thin section of ALH-77249. Sharply defined chondrules are abundant. Long dimension of photograph, 4.5 mm.

Table 1. Constituent units of ALH-77249.

Condrules	
Inclusions	Fine-grained lithic fragments (FGF)
	Coarse-grained lithic fragments (CGF)
	Amoeboid olivine inclusion (AOI)
	Others
Mineral fragments	Silicate mineral fragments (SMF)
	Opaque mineral fragments (OMF)
Matrix	

( ): Abbreviations

the interstices among the others. This corresponds to opaque matrix of HUSS *et al.* (1981).

2.1.1. Chondrules

In this paper the term "chondrule" refers to all materials that have been derived directly from molten materials themselves.

About 80% of chondrules show porphyritic or granular textures. This figure agrees with those in other unequilibrated ordinary chondrites (KIMURA and YAGI, 1980; GOODING and KEIL, 1981). Such chondrules consist mainly of phenocrysts of olivine and/or pyroxene, and glassy groundmass. The abundance ratio of olivine to pyroxene is variable. Almost holocrystalline chondrule is rarely present. Some dark-zoned chondrules of DODD and VAN SCHMUS (1971) are observed. About 20% of chondrules show radial, barred, or glassy to cryptocrystalline textures.

2.1.2. Coarse-grained lithic fragments (CGF's hereafter)

These are nearly holocrystalline and comprise anhedral grains of olivine and pyroxene, up to 0.8 mm in size (Fig. 2). Poikilitic enclosure of olivine by pyroxene is often observed. The texture of CGF's is different from those of holocrystalline chondrules consisting of euhedral to subhedral crystals, and resembles that of terrestrial peridotite. Plagioclase and Ca-rich pyroxene are absent in ALH-77249 CGF's. Although the modal ratio of olivine to pyroxene in CGF's, as well as chondrules, changes contin-

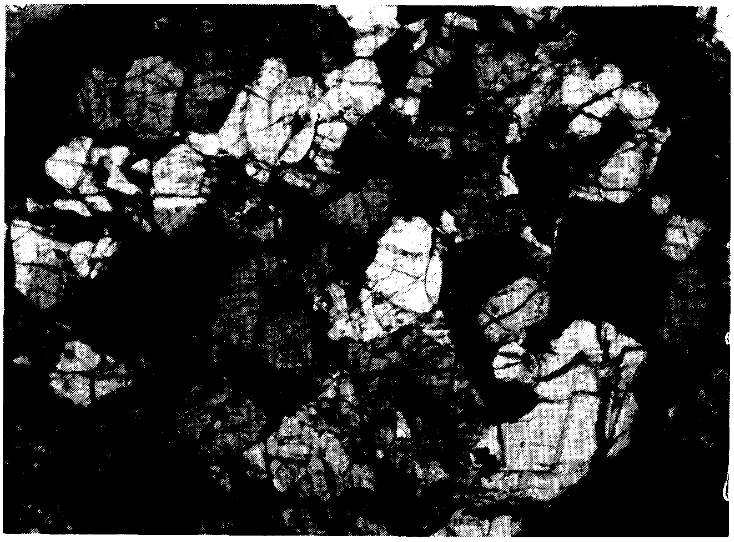

Fig. 2. A coarse-grained lithic fragment (No. 290) consisting of olivine and orthopyroxene. Nicols crossed. Long dimension of photograph, 1.2 mm.

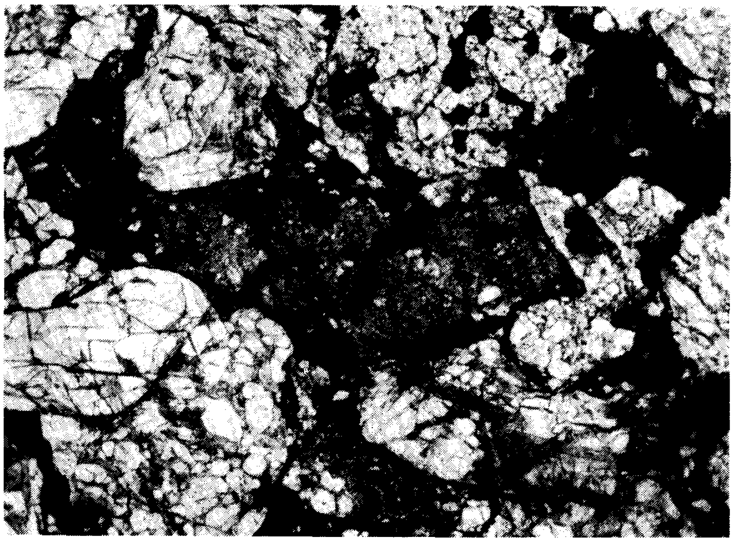

Fig. 3. A fine-grained lithic fragment (No. 37). Long dimension of photograph, 1.2 mm.

Fig. 4. An amoeboid olivine inclusion (No. 11). Long dimension of photograph, 0.45mm.

uously, olivine is always present in CGF's. All pyroxenes in CGF's are orthorhombic. Only one subhedral spinel, 0.08 mm in size, is surrounded by olivines in a CGF (No. 302). A few CGF's include trace amount of devitrified glass among the interstices or in grains.

2.1.3. Fine-grained lithic fragments (FGF's hereafter)

They consist largely of fine-grained crystals, about several microns in size (Fig. 3). They frequently contain small amounts of irregular-shaped olivine and pyroxene crystals, about several tens of microns in size. Various amounts of opaque minerals, especially troilite, are present in them. Glass and plagioclase are not observed. Most of the grains in FGF's are subhedral to anhedral in spite of their size. The fine-grained olivine crystals surround coarse-grained pyroxene and olivine. The features of FGF's are evidently different from those of microporphyritic chondrules which consist of euhedral to subhedral phenocrysts and glassy to microcystalline groundmass. However, they closely resemble fine-grained and transparent zone of dark-zoned chondrules of DODD and VAN SCHMUS (1971) and in ALH-77249, though opaque rim zone of such chondrules is rarely found in FGF's.

2.1.4. Amoeboid olivine inclusion (AOI hereafter)

Only one AOI (No. 11) is present in ALH-77249 (Fig. 4). This AOI consists of cryptocrystalline portion and fine string of crystals, which are olivine (Fo_{65-63}) and a small amount of Ca-rich pyroxene (Table 5). Thin crystalline rim surrounds it. Cryptocrystalline portion contains a large amount of very fine-grained spinel. This AOI occurs directly in matrix, and is not included in a carbonaceous chondritic clast.

2.1.5. Mineral fragments

Silicate mineral fragments (SMF's hereafter) are subhedral to anhedral olivine, pyroxene, and a smaller amount of glass. SMF's fill the interstices among chondrules and inclusions with matrix. Some of them, in spite of their grain size, show the same features as chondrule phenocrysts show: (1) polysynthetically twinned Ca-poor clinopyroxene inverted from protopyroxene, (2) glass in or around crystals, and (3) texture of minerals like chondrule phenocrysts. Figure 5 shows the apparent maximum grain size

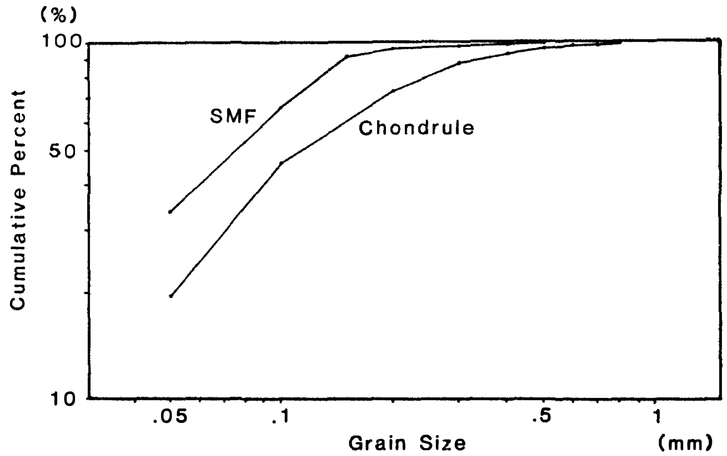

Fig. 5. Frequency distribution of apparent maximum grain size of SMF's and chondrule phenocrysts. Grain size is plotted with a cumulative percent ordinate.

distribution of SMF's in comparison with that of chondrule phenocrysts. Grain sizes of SMF's become smaller than those of chondrule phenocrysts.

Opaque mineral fragments (OMF's hereafter) are Fe-Ni metal (kamacite and taenite) and troilite. Troilite often rims metal. OMF's often include fine-grained olivine, pyroxene, and cryptocrystalline materials, up to several tens of microns in size.

2.1.6. Modal composition of ALH-77249

Chondrules occupy above fifty percent of ALH-77249 in volume (Fig. 6). Min-

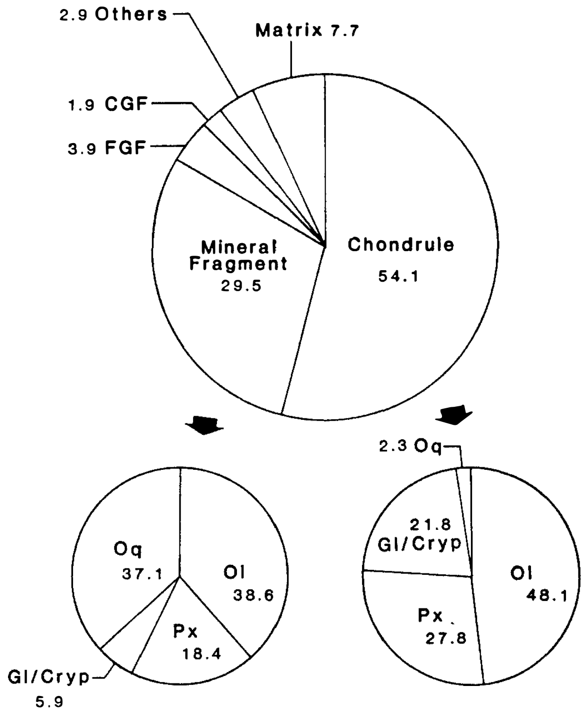

Fig. 6. Modal composition of ALH-77249 (vol %). Mineral compositions of chondrule and mineral fragment are shown below. Ol: olivine, Px: pyroxene, Gl: glass, Cryp: cryptocrystalline material, Oq: opaque minerals (Fe-Ni metal, troilite, and limonite).

eral fragments are also abundant, whereas inclusions and matrix are smaller in amount. Opaque minerals occur more abundantly as OMF's than in chondrules (Fig. 6). Especially Fe-Ni metal is depleted in chondrules. Modal percents of troilite and metal in chondrules or mineral fragments are 2.0 and 0.2, or 22.2 and 6.3, respectively. On the contrary, olivine occurs roughly twice as much as pyroxene in both chondrules and SMF's.

2.2. *Bulk compositions of the constituent units*

Bulk chemical compositions of silicate portions of chondrules and inclusions were obtained by broad-beam electron microprobe analysis, using the method of IKEDA (1980). Standard correction procedure of BENCE and ALBEE (1968) was employed, and further polyphase-correction was performed by the method of IKEDA (1980). The matrices were analyzed by electron microprobe analysis with a beam of about ten microns in diameter.

Total numbers of analyzed units are 187 for chondrules, 25 for FGF's, 6 for CGF's, and 1 for AOI. All CGF's and AOI in the thin section of this meteorite were analyzed. Ninety-two percent of FGF's and about seventy percent of chondrules were analyzed.

The bulk compositions of chondrules (Appendix) vary widely: SiO_2, 38–58% (average 47.2); Al_2O_3, 0.8–11% (2.5); FeO, 3–30% (15.1); MgO, 11–47% (30.8); CaO, 0.3–11% (2.0); Na_2O, 0.1–4% (1.0). Chemical compositions indicate that chondrules consist mainly of normative olivine and hypersthene with small amounts of diopside and plagioclase. The ratios of normative olivine to hypersthene change widely and continuously.

Although chemical compositions of inclusions vary widely (Tables 2 and 3), SiO_2,

Table 2. Chemical compositions of coarse-grained lithic fragments.

No.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
87	54.61	0.09	1.20	1.12	4.59	0.30	36.37	1.11	0.18	0.00	99.57
218	41.94	0.04	0.59	0.18	2.62	0.04	55.28	0.51	0.02	0.01	101.23
254	52.43	0.06	1.02	0.92	12.69	0.35	28.61	1.33	0.05	0.02	97.48
274	49.37	0.06	0.76	0.81	13.39	0.22	33.48	0.66	0.04	0.02	98.81
290	40.29	0.15	2.84	0.71	14.07	0.23	38.86	2.42	0.05	0.02	99.64
302	43.64	0.06	2.13	0.81	18.99	0.27	33.56	1.84	0.09	0.03	101.42

Table 3. Chemical compositions of fine-grained lithic fragments.

No.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
37	45.10	0.17	2.87	0.70	19.00	0.32	28.87	2.25	1.50	0.03	100.81
41	38.70	0.06	1.85	0.56	30.48	0.32	25.84	1.62	1.09	0.12	100.64
43	44.50	0.10	3.76	0.59	23.89	0.45	22.50	2.86	2.57	0.09	101.31
58	40.10	0.08	2.17	0.61	25.31	0.42	28.66	1.89	1.32	0.05	100.61
84	42.48	0.14	2.18	0.59	23.36	0.30	29.13	1.77	1.04	0.02	101.01
105	44.89	0.13	1.82	0.44	22.11	0.46	28.33	1.17	0.72	0.48	100.55
119	36.64	0.08	1.63	0.36	26.43	0.29	32.60	1.18	0.71	0.17	100.09
128	36.58	0.07	1.97	0.61	33.17	0.30	22.98	1.68	1.01	0.33	98.70
134	45.98	0.12	2.14	0.84	15.74	0.32	33.03	1.76	1.12	0.06	101.11
148	40.48	0.11	1.02	0.64	21.90	0.41	31.17	1.03	0.64	0.06	97.46
156	43.05	0.20	3.29	0.52	26.18	0.38	21.17	1.80	1.84	0.40	98.83
159	37.99	0.06	2.20	0.48	28.69	0.30	26.06	1.84	0.88	0.58	99.08
165	43.56	0.17	3.22	0.65	23.91	0.37	20.12	3.11	1.71	0.33	97.15
168	38.05	0.13	2.73	0.52	31.54	0.54	23.89	1.92	1.32	0.58	101.22
186	35.97	0.06	2.02	0.57	35.04	0.54	21.83	1.03	1.23	0.04	98.33
193	45.02	0.10	2.31	0.62	21.21	0.21	28.43	1.44	0.90	0.48	100.72
215	40.80	0.10	1.41	0.40	18.47	0.21	39.90	1.24	0.54	0.10	103.17
244	47.70	0.21	2.31	0.61	13.76	0.42	31.93	2.07	1.26	0.04	100.31
246	38.20	0.09	1.61	0.50	31.08	0.36	26.78	0.69	0.69	0.04	100.04
247	42.10	0.07	1.68	0.48	21.46	0.32	32.70	1.62	0.72	0.16	101.31
251	48.44	0.20	3.86	0.87	10.26	0.40	29.49	2.72	1.67	0.51	98.42
257	40.08	0.16	2.21	0.47	27.03	0.46	27.31	1.86	0.91	0.32	100.81
301	39.78	0.19	3.09	0.32	27.89	0.46	22.64	2.82	1.60	0.31	99.10
242	49.36	0.13	3.21	0.64	17.03	0.53	22.62	3.00	1.38	0.70	98.60
114	40.91	0.14	4.36	0.53	25.70	0.27	19.23	2.44	2.10	0.92	96.60

MgO, and FeO are dominant such as in chondrules.

Bulk compositions besides AOI are plotted in Figs. 7–9.

2.2.1. Al/Al+Na+K ratio

This ratio shows the composition of plagioclase component in the units. Figure 7 excludes some chondrules and inclusions in which the sum of Al_2O_3, Na_2O, and K_2O is low (less than 2%). The atomic Al/Al+Na+K ratio changes from 0.45 to 0.97. IKEDA (1980) classified chondrules into SP, IP, and N types, on the basis of the following criteria: (1) the atomic Ca/Ca+Al+Na+K ratio of N-chondrule is lower than 0.1, (2) the Al/Al+Na+K ratio of SP and N is lower than 0.65, whereas that of IP is higher than 0.65. SP-chondrules contain normative albitic plagioclase (Ab_{100-70}). About 77% of chondrules belong to SP type in ALH-77249, whereas about 20 and 3% to IP and N types, respectively. Atomic K/K+Na ratio is lower than 0.34 in all chondrules and inclusions. The Ca/Ca+Al+Na+K ratio of FGF's is higher than 0.1, and the Al/Al+Na+K ratio of them changes from 0.46 to 0.60 (Fig. 7). FGF's correspond to SP-chondrules in chemical composition.

2.2.2. (F+Ne)/(F+Ne+Ol+Px) ratio

Figure 8 is the histogram of ratio of normative feldspar and nepheline to olivine,

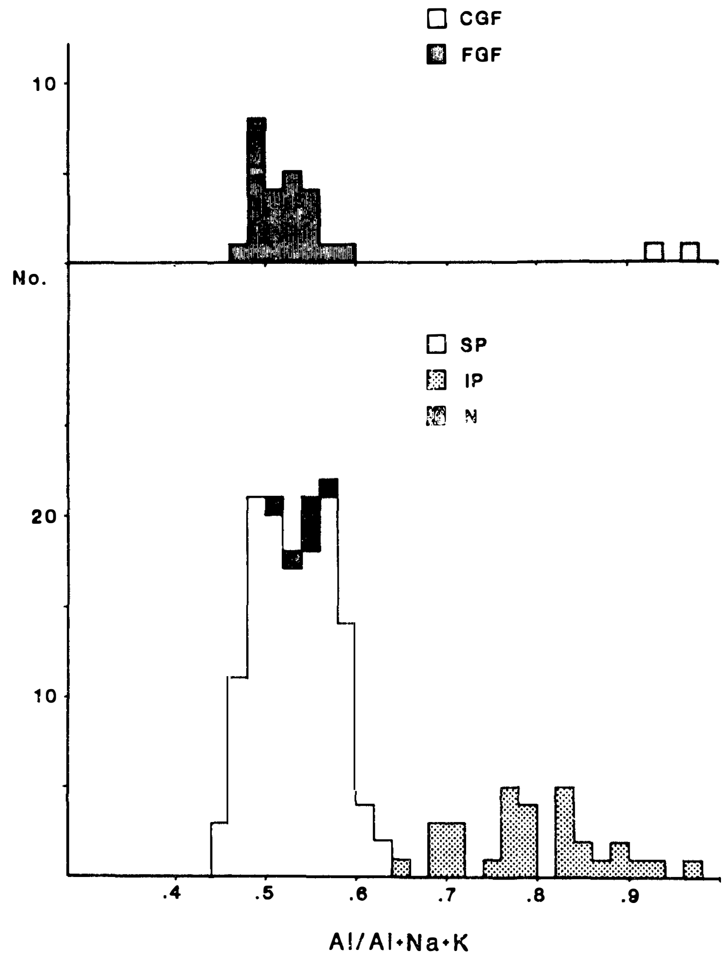

Fig. 7. Distribution of atomic Al/Al+Na+K ratios in chondrules and inclusions.

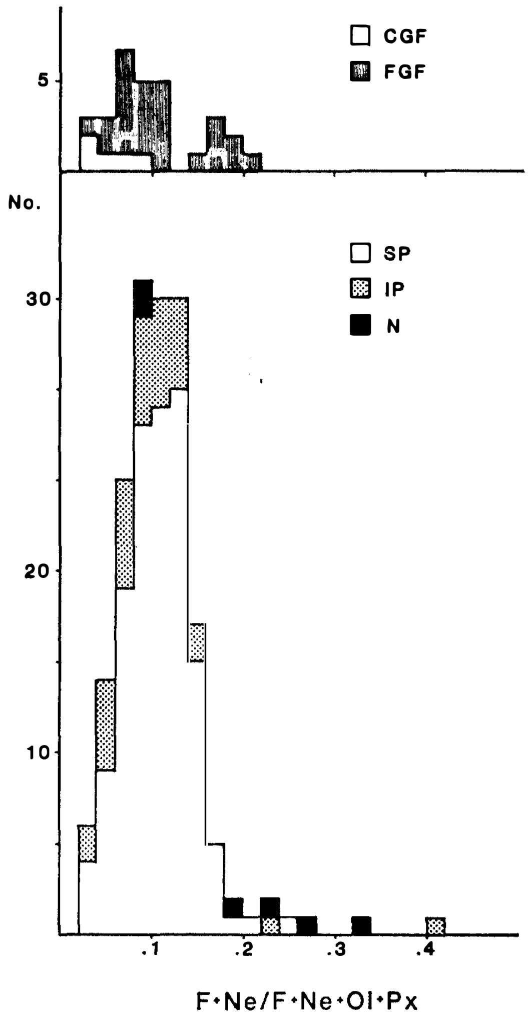

Fig. 8. Distribution of normative F+Ne/F+Ne+Ol+Px ratios in chondrules and inclusions. F:feldspar, Ne: nepheline, Ol: olivine, Px: pyroxene.

pyroxene, feldspar, and nepheline in chondrules and inclusions. N-chondrules always contain a small amount of normative nepheline (4–9 wt %), whereas the others rarely do. The F+Ne ratios are fairly uniform, about 0.1, in chondrules. This indicates that the precursors of them had uniform content of plagioclase, in spite of variable olivine to pyroxene ratio and chemical type of chondrules. DODD (1978) also noticed such a feature in chondrules.

The F+Ne ratios of CGF's are lower than those of the others, which agrees with observation that glass and plagioclase are hardly present in CGF's. Thus, plagioclase component should have been depleted from CGF's.

2.2.3. Si-Fe-Mg plot

In the atomic plotting of Si-Fe-Mg (Fig. 9a), most of chondrules are continuously distributed from the neighborhood of forsterite to that of enstatite. Although Fe-rich IP- and N-chondrules are not common, SP are distributed in a wider region rather than IP and N in the diagram. The ranges of atomic Mg/Mg+Fe ratios of SP-, IP-, and N-chondrules are 0.94–0.52 (average 0.76), 0.94–0.68 (0.82), and 0.90–0.76 (0.85), respectively.

The distribution of CGF's is included in that of Mg-rich chondrules (Fig. 9b).

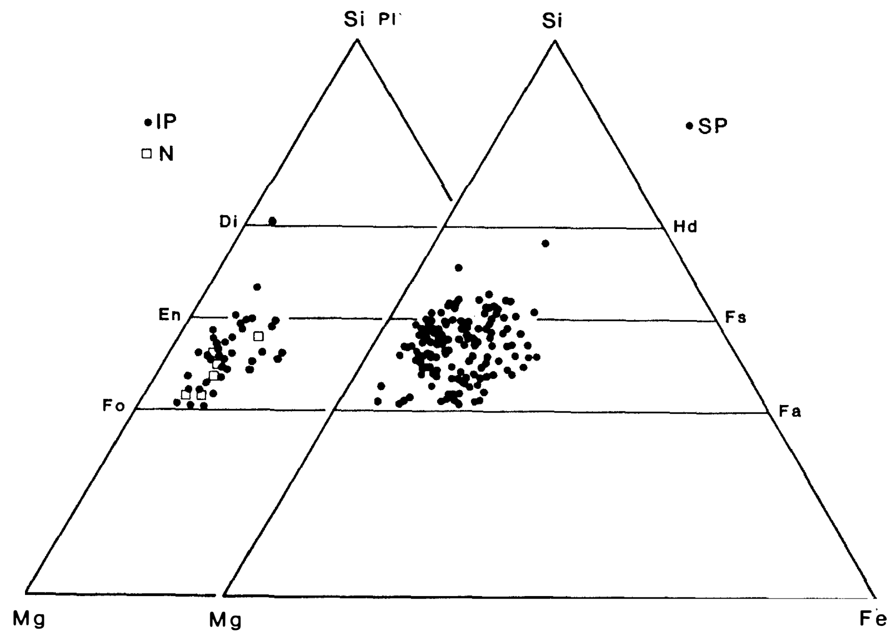

Fig. 9a. Atomic plotting of Si-Fe-Mg for chondrules. Fo: forsterite, Fa: fayalite, En: enstatite, Fs: ferrosilite, Di: diopside, Hd: hedenbergite.

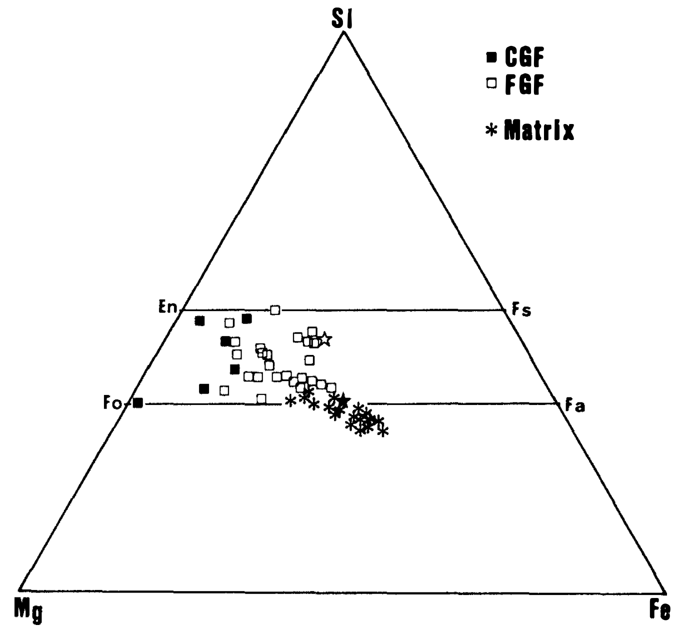

Fig. 9b. Atomic plotting of Si-Fe-Mg for inclusions and matrix. Open and solid sta are the average compositions of opaque matrices in L and LL chondrites (HUSS et al., 1981), and matrices in C2 and C3 chondrites (MCSWEEN and RICHARDSON, 1978), respectively.

Although Mg-rich FGF's are not abundant, the distribution of FGF's is included in that of SP-chondrules. The ranges of Mg/Mg+Fe ratios of CGF's and FGF's are 0.98–0.75 and 0.84–0.52, respectively.

2.2.4. Matrix

IKEDA *et al.* (1981) already reported the composition of matrix in ALH-77249. Table 4 shows some additional data of it. The composition of the matrix is similar not to those of matrices in ordinary chondrites by HUSS *et al.* (1981), but to those of C2 and C3 matrices by MCSWEEN and RICHARDSON (1978) (Fig. 9b).

Table 4. Chemical compositions of amoeboid olivine inclusion and matrix.

	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
AOI	32.60	0.43	11.49	0.16	24.53	0.32	21.99	3.56	2.78	0.06	97.92
Matrix	30.93	0.14	0.77	0.41	34.98	0.30	24.10	1.16	0.33	0.00	93.12
Matrix	33.41	0.08	0.66	0.14	34.20	0.39	26.25	0.32	0.05	0.02	95.52
Matrix	33.24	0.08	1.29	0.55	31.27	0.42	24.18	0.58	0.29	0.03	91.93

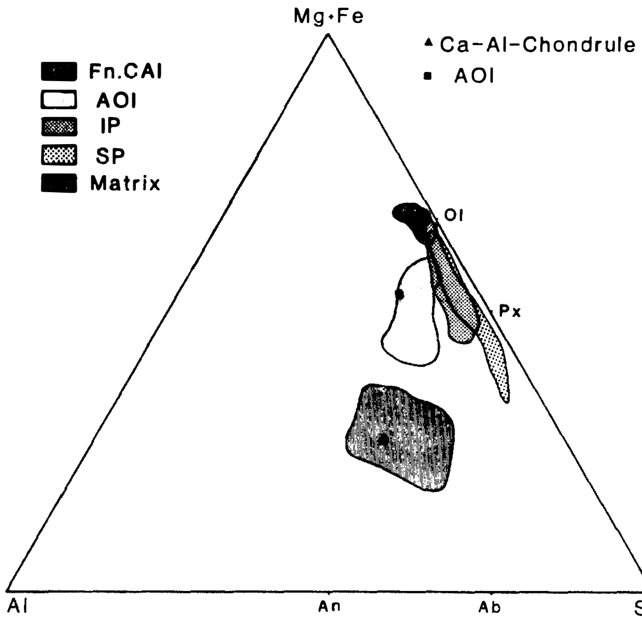

Fig. 10. Atomic plotting of Si-Al-(Mg+Fe) for Ca-Al-rich chondrule in ALH-77015 (NAGAHARA and KUSHIRO, 1982), and AOI in ALH-77249, in comparison with the compositional ranges of fine-grained (Fn) CAI and AOI in Allende (IKEDA, 1983), and SP, IP, and matrix in ALH-77249. Ol: olivine, Px: pyroxene, An: anorthite, Ab: albite.

2.2.5. AOI

Table 4 shows the bulk chemical composition of an AOI. Figure 10 shows that the AOI in ALH-77249 is included in the Allende AOI compositional region by IKEDA (1983).

2.3. *Mineralogy of Inclusions and SMF's*

Olivine and pyroxene in each CGF are homogeneous (Fig. 11). Pyroxene always contains wollastonite molecule lower than 1%. Chemical zoning is not observed in them. The chemical composition of a spinel in No. 302 CGF is presented in Table

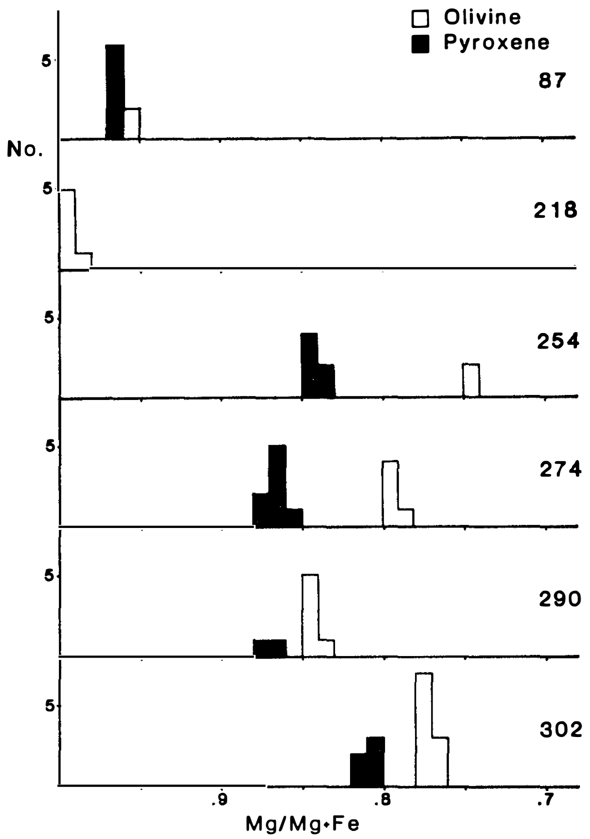

Fig. 11. Distribution of atomic Mg/Mg+Fe ratios of olivine and pyroxene in CGF's. Each number of CGF is shown in righthand corner.

Table 5. Chemical compositions of minerals in AOI, CGF, and SMF's.

	AOI	CGF (No.302)			SMF's						
	Px	Px	Px	Sp	Gl	Gl	Gl	Gl	Gl	Gl	Gl
SiO_2	45.54	46.59	46.01	0.09	70.30	51.93	60.50	62.13	62.77	65.86	58.31
TiO_2	0.50	1.79	1.31	0.54	0.45	0.47	0.50	0.38	0.41	0.42	0.32
Al_2O_3	1.91	5.64	5.63	23.57	13.40	17.38	12.35	9.85	9.57	14.06	10.03
Cr_2O_3	0.00	0.00	0.00	42.68	0.00	0.08	0.46	0.35	0.35	0.00	0.13
FeO	11.94	5.63	7.32	27.45	3.35	8.39	4.56	7.04	5.92	3.70	10.43
MnO	0.16	0.01	0.03	0.33	0.00	0.36	0.60	0.17	0.14	0.24	0.18
MgO	20.17	17.50	18.95	5.56	2.72	4.18	6.59	8.01	6.90	2.71	4.76
CaO	19.75	19.91	17.62	0.06	1.51	8.31	9.68	6.82	7.10	6.22	10.16
Na_2O	0.06	0.03	0.04	0.00	9.98	4.67	5.81	5.21	5.29	8.42	3.43
K_2O	0.01	0.01	0.00	0.00	0.05	0.19	0.09	0.08	0.06	0.08	2.23
Total	100.86	98.17	97.71	100.28	101.75	96.58	101.19	100.02	98.51	101.71	100.11

Px: pyroxene, Sp: spinel, Gl: glass.

5. Equilibrium temperature between spinel and coexsisting olivine is calculated to be about 600° C, using the method of ROEDER *et al.* (1979).

Pyroxenes in FGF's, in spite of their grain size, are always rich in Mg (Fig. 12). Some FGF's include coarse-grained olivines which are always poorer in Fe than fine-grained ones. Fine-grained olivines have fairly uniform composition in each FGF.

Olivine and pyroxene of SMF's were randomly analyzed. The atomic Mg/Mg+

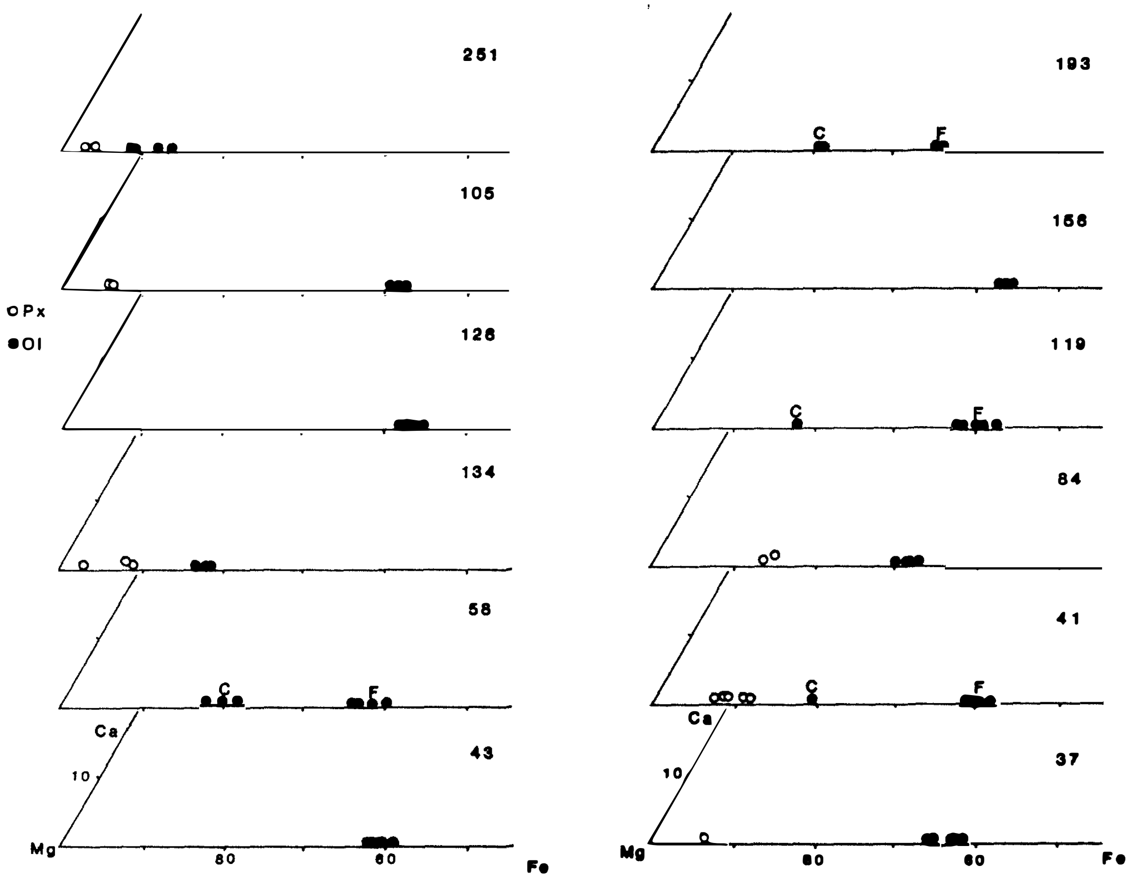

Fig. 12. Atomic plotting of Ca-Mg-Fe for olivine and pyroxene in each FGF. Some FGF's contain both coarse (C) and fine (F)-grained olivines. Olivines in the other FGF's are always fine-grained.

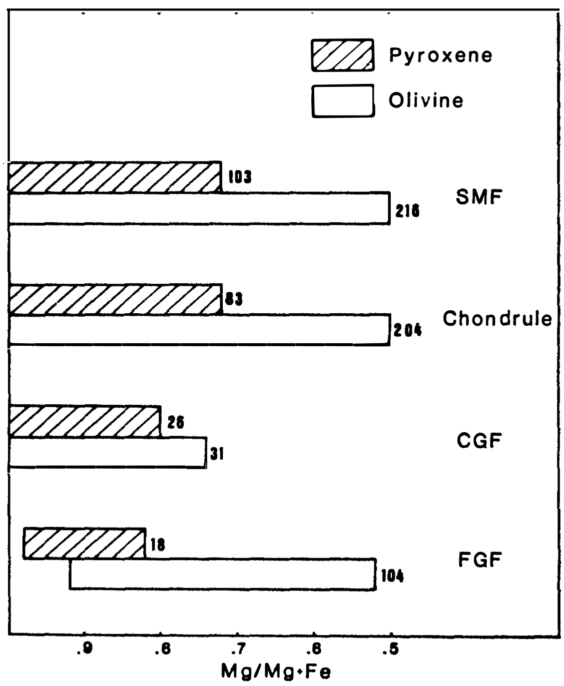

Fig. 13. Distribution of atomic Mg/Mg+Fe ratios in olivines and pyroxenes in SMF's chondrules, CGF's, and FGF's. Total of analyses in each unit is shown in the diagram.

Fe ratios of olivine and pyroxene of SMF's change continuously, and the distributions of ratios of them resemble those of chondrule phenocrysts (Fig. 13). Some Ca-rich pyroxenes (Wo_{30-40}) are present in SMF's as well as chondrules. Chemical compositions of glasses accompanying olivine and pyroxene of SMF's are rich in Si, Al, and Na (Table 5), and resemble those of chondrule glasses in ordinary chondrites (*e.g.*, KIMURA and YAGI, 1980).

3. Discussion

3.1. Carbonaceous chondritic materials in ALH-77249

ALH-77249 has the same features as carbonaceous chondrites have: (1) the presence of AOI, and (2) matrix composition.

Ordinary chondrite matrix (Type I of IKEDA *et al.*, 1981) is evidently different from carbonaceous chondrite matrix in composition. However, IKEDA *et al.* noticed some carbonaceous chondritic matrix (Type II) in ALH-77015 (L3) and -77033 (L3), as well as -77249. NAGAHARA and KUSHIRO (1982) found a Ca-Al-rich chondrule in ALH-77015, which is also not a clast. Chemical composition of this chondrule is similar to those of Ca-Al-rich inclusions in Allende (Fig. 10). ALH-77015 also contains carbonaceous chondritic materials. However, the textures of ALH-77249, -77015, and -77033 are very similar to each other. MCKINLEY *et al.* (1981) have suggested from microscopic observation that these and some ALH-77 chondrites (L3) are paired. On the other hand, the distribution of chondrule compositions in ALH-77015 agrees with that in ALH-77249 in the atomic Si-Fe-Mg plotting (Fig. 14). From the compositions of chondrules and matrices, and texture, we conclude that ALH-77249 and -77015

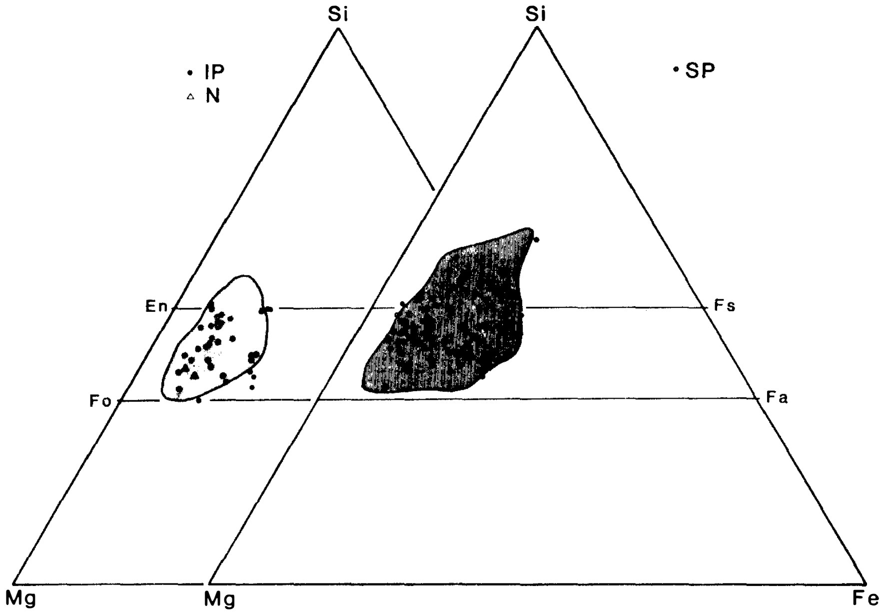

Fig. 14. Atomic plotting of Si-Fe-Mg for chondrules in ALH-77015 reported by NAGAHARA (1981) and FUJIMAKI et al. (1981). Symbols are the same as in Fig. 9. Shaded areas show the compositional ranges of IP and N, and SP-chondrules in ALH-77249, respectively.

were derived from a common larger meteorite. ALH-77033 may be identical with these meteorites.

The mode of occurrence of carbonaceous chondritic materials such as in ALH-77249 has been often reported. For example, NOONAN (1975) and NAGAHARA and KUSHIRO (1982) found Ca-Al-rich chondrules in Clovis (H3) and ALH-77278 (LL3). Carbonaceous chondritic materials, especially matrix, in ALH-77249 and so on occur uniformly over these meteorites. If such materials are mixed with ordinary chondrites after the formation of parent bodies, they should occur as clasts which are often found in ordinary chondrites, *e.g.*, Mezö-Madaras (VAN SCHMUS, 1967). Therefore, they should have been mixed with the other constituent units before accretion of all units to parent body. Carbonaceous chondritic materials may have entered into the region in which some ordinary chondritic materials formed, and were mixed mechanically with the other units.

3.2. The origin of the constituent units

3.2.1. The origin of CGF's

Mg-rich olivine and pyroxene are dominant in modal composition of CGF's and Mg-rich chondrules. Modal olivine to pyroxene ratios vary widely in both units. The distribution of bulk compositions of CGF's agrees with that of Mg-rich chondrules in the Si-Fe-Mg plotting (Fig. 9). Thus, the CGF's are related to Mg-rich chondrules in major constituent minerals and bulk compositions.

However, CGF's have the following features different from those of chondrules: (1) homogeneous olivine and orthopyroxene, (2) allotriomorphic-granular texture, and (3) depletion of plagioclase component. It seems that CGF's are equivalent to chondrules depleted in plagioclase in chemical composition, and that they underwent different thermal history from common chondrules which are regarded as rapidly cooled molten materials. Although the texture of CGF's resembles that of equilibrated chondrites at first sight, it is evident that CGF's are not fragments of equilibrated chondrites, because plagioclase component is fairly depleted in CGF's.

Plagioclase component should have been fractionated from the precursors of CGF's during or after condensation. It may be difficult to fractionate plagioclase from precursor materials during condensation, because forsterite, enstatite, and anorthite condense under the similar temperature range (GROSSMAN and LARIMER, 1974). Alternatively, we suppose that plagioclase was fractionated after condensation, due to melting, from the precursor materials of CGF's which had mainly consisted of Mg-rich olivine and pyroxene with plagioclase. The precursor materials were probably heated above 1200–1300° C, on the basis of the partial melting temperature of CGF's in the forsterite-anorthite-silica system.

Orthopyroxenes in CGF's are Mg-rich and Ca-poor as mentioned before. Such orthopyroxenes are stable at about 600–1000° C (HUEBNER, 1980). Pyroxenes in CGF's should have been heated under such a temperature range for a long time. Olivine-spinel thermometer shows that CGF's had been heated above about 600° C. In addition, homogeneous composition of constituent minerals and texture of CGF's also show that CGF's were heated at high temperature for a long time, in comparison with chondrules. All these features suggest that the precursor materials of CGF's may have cooled slowly after the fractionation of plagioclase. Later they broke into fragments (CGF's). Such a process had occurred until various units were finally consolidated in the parent body, because mineralogy and texture of ALH-77249 suggest that this meteorite was not so heated in the parent body.

3.2.2. The origin of FGF's

Although FGF's resemble SP-chondrules in bulk composition, texture and mineralogical features of FGF's closely resemble those of some portions of dark-zoned chondrules which reflect secondary modification of orthodox condrules by heat and shock (DODD and VAN SCHMUS, 1971). It is, therefore, probable that FGF's also were derived from SP-chondrules through such a modification.

Fine-grained olivines in FGF's are richer in Fe than coarser ones and pyroxenes (Fig. 12). Olivines in dark-zoned chondrules also became rich in Fe (DODD and VAN SCHMUS, 1971). Some reaction should have caused olivines to be rich in Fe, probably at shock-metamorphism. Then, the bulk compositions of FGF's are richer in Fe than those of orthodox SP-chondrules. FGF's and SP-chondrules whose atomic Mg/Mg+Fe ratios are lower than 0.7, are 59 and 26% of them, respectively in ALH-77249.

In general, the bulk compositions of FGF's become rich in Fe with increasing normative olivine (Fig. 15). The line in Fig. 15 shows a reaction trend of enstatite+

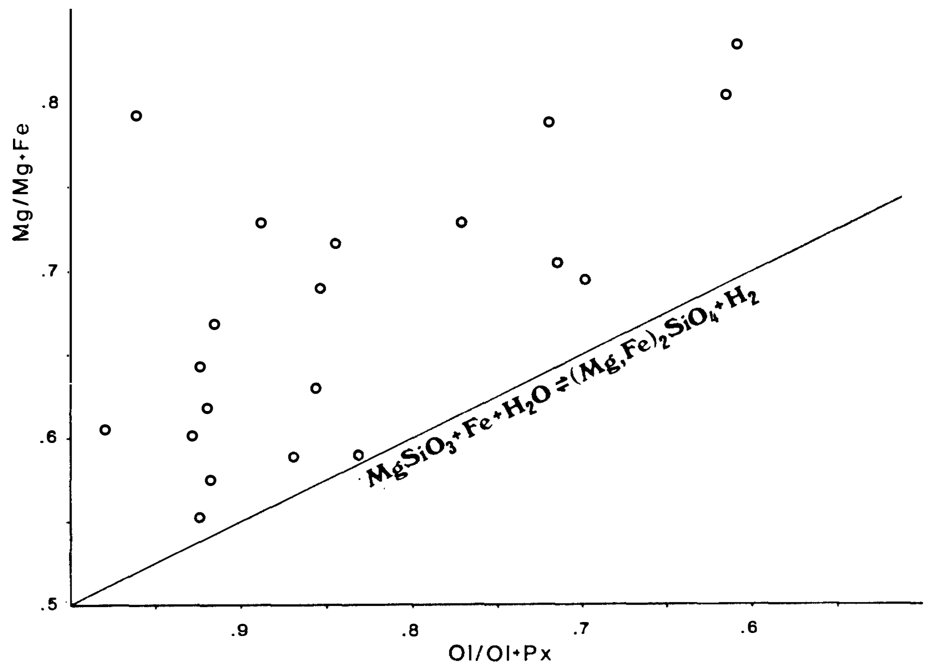

Fig. 15. Distribution of the bulk compositions of FGF's in the diagram of normative Ol/Ol+Px vs. atomic Mg/Mg+Fe ratio.

iron to form fayalite component. FGF's are distributed in a normative olivine-rich portion with respect to this line. Such a reaction is assumed to form fayalite component in low-temperature primitive solar nebula (GROSSMAN and LARIMER, 1974). FGF's may have become rich in olivine component and Fe-content due to such a reaction.

3.2.3. The origin of SMF's

Some SMF's and chondrules have the same mineralogical features and compositions of glasses as mentioned before. Such SMF's were evidently derived from chondrules.

The compositional range of SMF's is much wider than those of CGF's and FGF's (Fig. 13), and the modal percent of CGF's and FGF's is very low, in comparison with SMF's (Fig. 6). On the other hand, the compositional ranges of olivine and pyroxene of SMF's agree with those of chondrule phenocrysts. Therefore, most of SMF's should have been derived from chondrules. A large volume of SMF's in this meteorite can be explained from that they were derived from chondrules.

SMF's are generally fine-grained in comparison with chondrule phenocrysts (Fig. 5). When chondrules were disaggregated, probably due to collision, phenocrysts in them frequently broke into fine-grained crystals.

3.3. Genetic relations of the ALH-77249 units

At first, forsterite, enstatite, diopside, and anorthite are assumed to have condensed from high-temperature nebular gas, according to GROSSMAN and LARIMER (1974). Such a mineral assemblage agrees with normative compositions of chondrules and inclusions free from Fe and Na. Fe-Ni metal also condensed at high temperature. Since metal is poor in chondrules and mostly occurs as OMF's, most of metal was probably separated from silicate condensates before chondrule formation. Separated metal may have formed the core of preexisting planetesimal, which became fragmented to form OMF's during collision (IKEDA, 1982).

We suppose that silicate condensates successively reacted and changed into various chondritic units as follows. IP-chondrules are poorer in Fe and especially Na than SP-chondrules. The precursor of IP may have separated early from nebular gas during the reaction of Fe and Na under intermediate temperature nebula. The residual silicate condensates became rich in sodic-plagioclase components. These condensates melted to form SP-chondrules. Some SP later underwent shock-metamorphism and became rich in Fe. They are FGF's. Some materials had been heated and melted to lose plagioclase component. Later, they cooled slowly and became fragmented to form CGF's.

Some chondrules were later disaggregated, probably due to collision, and SMF's formed. A large amount of SMF's in unequilibrated chondrites suggests that early-formed chondrules frequently broke.

Later, all constituent units including carbonaceous chondritic materials mixed thoroughly until all the materials in ALH-77249, -77015, -77033, and others were finally consolidated in the parent body, because various units are distributed uniformly over ALH-77249 and others. The constituent units in unequilibrated chondrites had undergone complicated processes different from each other before consolidation in the parent body.

4. Conclusions

(1) This meteorite is identical with ALH-77015 and probably -77033. It contains carbonaceous chondritic materials such as AOI, and matrix. These materials mixed mechanically with the other units before accretion to the parent body.

(2) Chondrules are classified mainly into SP and IP types. SP-chondrules often underwent shock-metamorphism, and they (FGF's) became rich in Fe and olivine component through the reaction of enstatite and iron.

(3) Although CGF's were primarily derived from the similar precursor materials to chondrules, they fairly lost plagioclase component due to melting. Later they cooled slowly and broke into CGF's.

(4) Some chondrules were later disaggregated to form SMF's, probably due to collision. A large amount of SMF's indicates that early-formed chondrules frequently broke.

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Appendix 1. Chemical compositions of SP-chondrules.

No.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
1	47.50	0.14	2.93	0.60	10.82	0.38	34.79	2.24	0.97	0.48	100.85
2	46.85	0.14	2.65	0.60	10.97	0.43	36.23	1.84	1.47	0.05	101.23
3	49.01	0.10	1.82	0.40	11.05	0.42	35.79	1.98	0.70	0.32	101.59
4	41.67	0.10	2.37	0.55	7.64	0.14	46.83	0.81	1.16	0.24	101.51
6	46.67	0.13	2.23	0.56	14.56	0.37	30.26	1.92	0.91	0.05	97.66
8	39.18	0.07	2.10	0.51	25.17	0.38	30.02	1.56	1.31	0.15	100.45
12	54.00	0.14	1.95	0.69	8.25	0.18	32.04	1.73	0.95	0.07	100.00
16	40.04	0.03	1.37	0.42	21.48	0.30	32.62	1.09	0.81	0.08	98.24
18	53.73	0.07	1.27	0.63	17.88	0.92	23.95	1.06	0.83	0.00	100.34
19	45.00	0.10	2.26	0.60	6.25	0.00	44.68	0.81	1.12	0.08	100.90
20	43.30	0.03	1.65	0.56	19.58	0.32	31.34	1.49	0.89	0.06	99.22
21	49.15	0.04	2.58	0.51	24.16	0.39	17.31	3.39	1.55	0.51	99.59
23	52.98	0.11	2.07	0.84	10.89	0.58	31.74	1.50	0.91	0.01	101.63
26	48.42	0.11	1.52	0.48	20.95	0.48	24.97	3.06	0.81	0.36	101.16
28	49.02	0.20	3.86	0.50	5.93	0.08	36.75	1.80	1.42	0.06	99.62
32	48.26	0.16	3.02	0.83	11.77	0.49	29.44	3.00	1.57	0.09	98.63
34	43.76	0.11	1.78	0.77	14.65	0.59	35.41	1.39	0.79	0.07	99.32
35	48.81	0.17	2.72	0.84	11.66	0.47	30.53	2.28	1.48	0.13	99.09
36	46.72	0.11	2.70	0.88	14.13	0.38	30.85	2.16	1.30	0.24	99.47
47	55.00	0.15	2.58	0.67	10.32	0.66	27.12	2.18	1.30	0.05	100.03
48	53.63	0.21	3.87	0.45	16.68	0.55	10.89	8.13	1.57	1.08	97.06
50	51.23	0.15	1.88	0.65	19.05	0.65	24.18	2.10	1.00	0.06	100.95
53	54.03	0.10	1.75	0.56	16.80	0.53	25.20	1.44	0.84	0.00	101.25
55	56.07	0.12	1.82	0.63	10.19	0.53	28.14	2.07	0.90	0.05	100.52
60	48.56	0.04	1.75	0.50	19.16	0.42	27.91	1.26	0.90	0.02	100.52
61	49.44	0.15	2.04	0.70	13.00	0.53	30.50	1.45	0.97	0.06	98.84
63	51.50	0.08	1.89	0.60	21.00	0.73	22.57	1.80	0.90	0.01	101.08
64	43.60	0.14	2.80	1.03	27.24	0.35	23.16	1.31	1.80	0.18	101.61
66	52.53	0.13	2.41	0.84	8.52	0.42	31.95	2.07	1.34	0.04	100.25
67	47.32	0.10	1.00	0.42	25.23	0.41	20.98	2.06	0.50	0.07	98.09
69	40.30	0.10	2.56	0.44	13.65	0.18	39.90	1.22	0.99	0.11	99.45
71	53.27	0.08	1.64	0.55	7.32	0.34	31.79	2.48	0.81	0.09	98.37
72	42.12	0.12	2.35	0.50	24.62	0.30	27.33	1.94	1.29	0.24	100.81
73	46.70	0.04	0.98	0.44	12.30	0.23	37.78	0.86	0.38	0.04	99.75
77	45.13	0.11	3.62	0.64	21.15	0.39	24.39	2.11	1.75	0.16	99.45
79	40.01	0.09	1.40	0.36	23.00	0.30	31.00	1.44	0.90	0.24	98.74
83	41.37	0.10	3.09	0.15	16.37	0.21	35.66	1.56	1.35	0.53	100.39
85	45.05	0.10	2.03	0.56	14.80	0.32	35.38	2.20	0.98	0.07	101.49
88	48.65	0.09	2.10	0.56	20.04	0.65	24.11	3.08	1.30	0.30	100.88
89	53.48	0.04	1.84	0.56	18.21	0.67	22.54	1.34	1.30	0.05	100.03
90	50.09	0.08	1.51	0.61	9.30	0.42	36.80	1.17	0.63	0.06	100.67
91	42.63	0.00	1.96	0.50	22.51	0.44	27.99	1.88	1.25	0.14	99.30
93	46.90	0.16	2.45	0.60	17.04	0.42	28.73	2.07	1.50	0.07	99.94
97	42.30	0.12	1.81	0.43	28.98	0.40	21.26	2.10	1.01	0.17	98.58
99	53.57	0.16	1.65	1.06	7.60	0.42	33.49	1.31	0.77	0.06	100.09
106	44.99	0.13	2.51	0.52	24.14	0.36	23.25	1.95	1.27	0.21	99.33
107	52.27	0.08	1.54	0.43	9.32	0.36	36.41	0.97	0.55	0.02	101.95
108	47.02	0.20	3.01	0.68	9.56	0.37	35.91	3.24	1.05	0.48	101.52
111	44.16	0.16	2.09	0.85	24.07	0.44	22.13	2.82	1.02	0.42	98.16

Appendix 1. Continued.

No.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
116	47.73	0.18	2.94	0.84	15.88	0.42	27.29	3.01	1.80	0.06	100.15
117	37.80	0.08	1.40	0.44	20.00	0.29	35.40	1.40	0.64	0.10	97.55
118	47.58	0.30	4.90	0.41	6.60	0.00	34.10	2.52	2.59	0.24	99.24
120	47.80	0.17	2.77	0.67	12.89	0.53	29.24	2.15	1.19	0.07	97.48
121	46.91	0.21	3.49	0.47	16.43	0.32	23.99	3.42	1.74	0.10	97.08
122	43.06	0.13	1.89	0.56	22.13	0.20	31.92	1.53	0.72	0.24	102.38
125	49.83	0.16	2.81	0.84	14.50	0.51	27.70	2.01	1.34	0.22	99.92
126	46.46	0.14	2.60	0.70	13.11	0.38	33.41	2.16	1.17	0.08	100.21
127	43.01	0.05	1.61	0.70	18.83	0.41	33.23	1.28	0.72	0.14	99.98
131	50.30	0.18	2.34	0.90	9.22	0.60	34.48	2.15	0.91	0.10	101.18
133	48.88	0.12	2.33	0.76	10.74	0.54	32.54	2.06	0.89	0.10	98.96
135	40.54	0.06	1.53	0.56	23.25	0.30	33.76	1.15	0.76	0.16	102.07
136	48.83	0.14	2.34	0.94	22.81	0.63	23.58	2.15	1.52	0.11	103.05
138	47.32	0.17	3.42	0.99	16.72	0.33	26.54	2.29	1.51	0.05	99.34
139	50.91	0.03	0.95	0.95	22.42	0.54	20.67	0.77	0.45	0.03	97.72
141	48.37	0.17	3.26	0.84	11.67	0.44	30.34	2.59	1.47	0.03	99.18
146	46.46	0.07	1.10	0.87	12.51	0.48	33.49	0.94	0.52	0.00	96.44
149	52.12	0.11	2.10	0.67	10.67	0.42	29.42	1.88	0.91	0.05	98.35
150	52.77	0.20	2.30	0.63	14.33	0.62	21.09	5.97	1.39	0.04	99.34
152	50.80	0.16	2.91	1.12	17.32	0.53	21.32	2.66	1.87	0.06	98.75
162	53.26	0.14	2.24	0.98	7.98	0.32	32.34	1.62	0.98	0.05	99.91
163	47.04	0.09	2.01	0.99	9.94	0.18	37.02	2.28	0.84	0.46	100.85
166	57.04	0.00	1.28	1.06	7.05	0.10	32.69	1.01	0.56	0.10	100.89
170	52.84	0.13	2.61	0.95	6.86	0.47	33.99	1.70	1.32	0.02	100.89
172	43.99	0.15	2.30	0.71	17.27	0.39	32.57	1.76	1.24	0.03	100.41
174	52.30	0.12	1.98	0.61	12.16	0.76	28.33	1.91	0.80	0.13	99.10
175	41.65	0.09	1.68	0.23	13.64	0.19	42.33	1.13	0.65	0.08	101.67
176	48.53	0.18	2.88	0.78	16.47	0.39	22.36	2.69	1.76	0.14	96.18
180	43.04	0.06	1.42	0.40	24.66	0.46	29.96	1.06	0.73	0.06	101.85
183	55.93	0.11	1.94	0.62	9.40	0.29	28.16	1.88	0.76	0.05	99.14
184	57.66	0.19	3.64	0.90	6.86	0.82	22.70	3.69	2.45	0.14	99.05
185	49.32	0.07	1.94	0.48	22.78	0.57	22.60	1.57	1.24	0.10	100.67
187	50.25	0.16	2.88	0.99	13.88	0.43	27.16	2.35	1.14	0.02	99.26
189	38.15	0.07	1.12	0.28	26.20	0.30	31.04	1.17	0.48	0.24	99.05
191	48.56	0.12	2.40	0.80	18.60	0.54	24.62	2.19	1.54	0.14	99.51
192	54.04	0.05	1.63	0.55	8.31	0.43	34.23	1.88	0.58	0.16	101.86
195	53.34	0.13	2.62	0.97	10.24	0.49	25.22	2.48	1.33	0.05	96.87
197	42.45	0.09	2.02	0.63	22.77	0.38	26.18	1.87	1.18	0.15	97.72
200	41.63	0.16	2.10	0.55	21.35	0.36	31.39	1.79	1.12	0.11	100.56
203	55.28	0.02	2.45	0.60	11.02	0.63	25.73	3.10	1.17	0.55	100.55
208	43.34	0.07	1.55	0.70	19.87	0.44	32.97	1.51	0.94	0.07	101.46
209	38.50	0.10	1.09	0.36	20.50	0.35	34.99	0.88	0.47	0.07	97.31
211	39.83	0.08	1.23	0.57	12.89	0.11	42.72	0.65	0.61	0.05	98.74
219	49.70	0.15	2.64	0.50	16.80	0.53	27.83	1.98	1.14	0.06	101.33
220	53.27	0.08	1.78	0.50	18.78	0.61	22.74	1.59	1.16	0.01	100.52
221	54.47	0.13	2.45	0.67	9.33	0.46	29.79	2.25	1.27	0.02	100.84
222	38.08	0.01	1.19	0.51	23.75	0.36	34.27	0.92	0.68	0.07	99.84
225	48.07	0.13	2.30	0.62	12.59	0.41	31.38	2.14	1.01	0.44	99.09
226	43.90	0.11	2.70	0.44	22.79	0.32	25.88	2.16	1.50	0.08	99.88

Appendix 1. Continued.

No.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
227	51.83	0.09	2.20	0.63	15.25	0.75	26.38	1.92	1.01	0.03	100.09
229	50.11	0.12	1.88	0.94	15.04	0.51	26.69	1.93	1.04	0.18	98.44
232	43.52	0.10	3.08	0.44	19.76	0.32	31.20	1.80	1.38	0.08	101.68
235	41.01	0.09	1.64	0.21	25.20	0.42	30.56	1.53	0.84	0.16	101.66
236	48.03	0.10	2.10	0.77	10.82	0.42	35.54	1.80	0.98	0.02	100.58
237	55.80	0.10	1.68	0.78	14.54	0.84	23.78	1.44	1.02	0.08	100.06
238	51.99	0.15	2.31	0.61	7.72	0.32	34.69	1.71	0.98	0.02	100.50
253	50.94	0.12	2.23	0.66	18.42	0.61	23.68	2.34	1.34	0.09	100.43
256	46.12	0.19	2.93	0.58	18.32	0.38	25.22	3.07	1.59	0.10	98.50
258	51.01	0.17	3.10	0.99	9.00	0.39	30.92	2.58	1.74	0.04	99.94
260	40.78	0.21	2.73	0.60	26.22	0.36	24.03	2.21	1.45	0.06	98.65
261	53.52	0.14	2.45	0.68	10.23	0.50	26.89	1.73	1.38	0.03	97.55
266	42.20	0.19	2.31	0.54	29.51	0.42	22.57	2.07	1.41	0.12	101.34
267	43.81	0.10	2.21	0.80	17.03	0.36	32.57	2.06	1.41	0.11	100.46
270	49.40	0.14	2.96	1.16	8.82	0.43	32.48	1.88	1.27	0.06	98.60
273	49.67	0.19	3.46	0.99	11.07	0.54	30.02	2.27	1.55	0.04	99.80
277	49.55	0.13	2.23	0.66	10.28	0.44	33.23	2.20	1.08	0.01	99.81
283	40.12	0.19	2.96	0.41	28.71	0.43	18.87	2.75	1.49	0.30	96.23
284	52.84	0.15	2.05	1.06	8.03	0.48	34.17	1.38	0.82	0.04	101.02
285	53.75	0.18	1.98	0.94	6.04	0.27	33.89	1.47	0.80	0.05	99.37
286	42.30	0.14	2.86	0.76	23.87	0.35	24.58	2.30	1.22	0.20	98.58
291	44.65	0.11	2.80	0.51	19.48	0.40	27.98	2.25	1.68	0.11	99.97
293	54.20	0.02	1.12	0.55	20.00	0.50	20.05	2.70	0.54	0.16	99.84
304	48.47	0.07	1.99	0.87	15.21	0.50	28.68	2.14	1.11	0.07	99.11
309	48.89	0.09	1.90	0.33	6.00	0.03	38.95	0.90	1.03	0.30	98.42
310	51.83	0.08	1.37	0.76	19.05	0.59	19.70	1.40	0.76	0.02	95.56
75	49.89	0.08	3.21	0.59	11.05	0.44	27.78	2.78	1.25	0.04	97.12
113	53.77	0.16	1.48	0.60	16.57	0.48	23.37	2.26	0.56	0.42	99.67
182	49.64	0.16	2.12	0.71	12.43	0.42	32.40	2.02	0.94	0.02	100.86
206	39.65	0.10	1.32	0.45	20.12	0.28	34.14	0.88	0.55	0.05	97.54
207	41.52	0.16	2.04	0.62	21.47	0.35	28.65	2.48	0.92	0.34	98.55
216	47.14	0.13	2.15	0.66	13.68	0.54	33.37	1.84	0.98	0.05	100.54
223	38.15	0.09	2.83	0.49	22.23	0.27	33.88	1.03	1.08	0.02	100.07
243	37.87	0.10	1.44	0.48	26.97	0.37	31.49	1.33	0.58	0.07	100.70
248	50.02	0.12	2.56	0.48	13.91	0.32	30.49	1.83	1.20	0.20	101.13
263	45.71	0.13	2.11	0.50	12.51	0.35	36.02	1.35	1.03	0.09	99.80
268	43.30	0.16	2.73	0.56	23.07	0.24	26.70	2.28	1.49	0.13	100.66
280	43.80	0.12	3.64	0.40	12.65	0.07	36.23	0.99	1.74	0.18	99.82
300	46.36	0.13	2.94	0.52	14.48	0.27	31.41	2.42	1.19	0.05	99.77
307	54.54	0.10	1.14	0.64	7.65	0.44	32.98	1.16	0.37	0.02	99.04
314	45.40	0.10	1.32	0.35	19.40	0.47	30.20	1.44	0.63	0.02	99.33
317	42.41	0.16	1.90	0.54	22.83	0.28	32.49	1.10	0.72	0.10	102.53
319	41.55	0.12	2.49	0.54	24.71	0.38	26.11	2.39	1.54	0.20	100.03
299	39.84	0.18	2.93	0.37	27.58	0.40	23.13	2.19	1.44	0.45	98.51
14	42.98	0.12	3.04	0.46	15.60	0.25	34.52	1.39	1.05	0.07	99.48
269	43.67	0.19	2.65	0.54	26.54	0.39	20.53	2.20	1.41	0.34	98.46

Appendix 2. Chemical compositions of IP-chondrules.

No.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
5	39.05	0.06	0.77	0.40	14.06	0.16	43.01	0.90	0.12	0.01	98.54
15	49.06	0.10	2.31	0.84	9.45	0.32	36.43	1.62	0.56	0.02	100.71
24	49.72	0.19	2.94	0.71	9.93	0.38	33.86	2.46	0.76	0.02	100.97
39	48.62	0.09	1.18	0.84	8.15	0.17	38.80	1.17	0.32	0.01	99.35
52	47.37	0.25	4.07	1.06	11.16	0.23	30.71	3.86	0.46	0.05	99.22
68	40.98	0.16	2.49	0.56	21.84	0.59	30.09	1.85	0.63	0.10	99.29
81	40.30	0.10	3.50	0.22	8.40	0.00	46.83	2.25	0.31	0.05	101.96
94	53.02	0.06	1.68	0.67	7.35	0.32	36.75	1.62	0.42	0.02	101.91
103	41.71	0.13	2.93	0.38	8.54	0.15	43.21	2.03	0.46	0.06	99.60
124	51.55	0.08	2.02	0.93	16.39	0.93	26.29	1.59	0.54	0.03	100.35
130	52.31	0.74	10.72	0.32	3.52	0.21	15.09	11.25	2.07	0.12	96.35
143	51.06	0.15	2.41	0.67	10.50	0.38	33.71	2.07	0.42	0.01	101.38
144	44.14	0.15	1.40	1.01	13.67	0.27	35.38	1.12	0.30	0.04	97.48
145	49.70	0.11	2.73	0.68	9.13	0.20	35.28	2.39	0.29	0.05	100.56
147	46.46	0.08	2.04	0.78	12.13	0.17	35.87	1.84	0.34	0.04	99.75
157	45.11	0.13	2.99	0.90	6.64	0.15	42.17	2.64	0.55	0.02	101.30
173	40.10	0.13	3.91	0.35	13.24	0.19	39.55	2.04	0.49	0.20	100.20
177	49.17	0.12	1.74	0.74	12.95	0.39	34.69	0.95	0.26	0.02	101.03
201	46.89	0.20	4.94	0.45	9.94	0.06	36.03	3.87	0.35	0.01	102.74
214	44.99	0.10	2.18	0.65	14.33	0.35	35.97	1.52	0.38	0.04	100.51
239	54.03	0.10	1.56	0.80	6.33	0.42	35.73	1.71	0.21	0.03	100.92
250	52.16	0.17	2.31	0.78	11.24	0.44	29.59	2.25	0.54	0.03	99.51
262	43.48	0.21	4.24	0.77	21.67	0.36	26.68	2.99	0.30	0.02	100.72
272	41.80	0.27	5.51	0.27	13.04	0.11	36.56	3.91	0.56	0.09	102.12
275	50.67	0.05	0.82	0.69	6.20	0.26	39.94	0.54	0.18	0.02	99.37
276	42.10	0.10	4.21	0.81	17.71	0.33	32.23	3.72	0.20	0.00	101.41
297	53.80	0.07	1.12	0.70	10.50	0.50	31.90	1.53	0.19	0.02	100.33
321	46.98	0.07	1.86	0.74	18.95	0.20	30.06	1.96	0.08	0.02	100.92
323	42.96	0.23	3.61	0.73	16.08	0.19	30.68	2.92	0.20	0.01	97.61
324	40.02	0.01	1.17	0.42	11.40	0.05	45.72	0.50	0.27	0.02	99.58
316	44.31	0.22	3.66	0.73	20.63	0.34	26.12	2.71	0.55	0.02	99.29
129	48.39	0.38	5.59	0.76	11.01	0.36	26.38	3.08	1.72	0.10	97.77
160	41.69	0.12	2.95	0.37	10.69	0.18	41.32	2.42	0.34	0.02	100.10
240	51.02	0.14	2.93	0.68	11.52	0.55	30.66	2.21	0.51	0.07	100.29
245	50.78	0.18	2.27	0.49	16.78	0.42	26.52	2.88	0.04	0.01	100.37
305	48.25	0.38	7.93	0.17	7.87	0.05	27.62	7.05	0.76	0.10	100.18
311	42.66	0.13	3.84	0.32	11.41	0.09	39.23	2.46	0.48	0.04	100.66
315	49.21	0.12	2.41	0.66	7.98	0.07	38.89	1.89	0.28	0.02	101.53

Appendix 3. Chemical compositions of N-chondrules.

No.	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
33	42.34	0.20	5.46	0.40	11.95	0.11	36.08	0.63	2.40	0.12	99.69
74	42.88	0.28	6.36	0.19	10.68	0.10	34.50	0.77	2.86	0.08	98.70
100	40.38	0.14	2.98	0.42	8.81	0.06	43.13	0.66	1.13	0.25	97.96
132	44.65	0.35	6.30	0.12	8.80	0.11	34.09	0.90	2.94	0.08	98.34
154	41.20	0.18	3.27	0.42	11.29	0.11	42.03	0.64	1.86	0.10	101.10
161	43.66	0.41	8.04	0.36	13.87	0.17	26.04	0.36	3.65	1.12	97.68