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TEXTURE AND CHEMICAL COMPOSITION OF PYROXENES IN CHONDRULES IN CARBONACEOUS AND UNEQUILIBRATED ORDINARY CHONDRITES

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Abstract: The texture and composition of pyroxenes in chondrules in unequilibrated ordinary chondrites (UOCs) (petrologic subtype less than 3.5) and carbonaceous chondrites (CCs) were studied with SEM and EPMA. Four kinds of pyroxene can be recognized on the basis of the mode of occurrence and chemical composition; they are protopyroxene (now inverted to twinned low-Ca clinopyroxene) (Wo<2), orthopyroxene (Wo 2-5), pigeonite (Wo 5-15), and augite (Wo<25). Subcalcic augite is rare. Pyroxene compositions in CCs differ from those in UOCs. Most of pyroxenes in CCs are classified into three groups by Fs content: less than Fs 2, Fs 3-10 and Fs >10 (typically more than 20). In contrast, the Fs content of pyroxene in UOCs ranges from 0 to 50 continuously. A TiO_2 *vs.* Al_2O_3 plot for augite in CCs shows two trends with different TiO_2/Al_2O_3 ratios. Augites with a high TiO_2/Al_2O_3 ratio coexist with pigeonite in CCs except for Y-790112. Y-790112 and UOCs rarely have augites with a high TiO_2/Al_2O_3 ratio, though some augites coexist with pigeonite. Minor elements in augite in chondrules show that considerable amounts of Na^+ and Fe^{2+} were probably introduced into chondrules after crystallization of pyroxenes. The oxygen fugacity at which pyroxene in CC chondrules crystallized was lower than that for UOCs. During cooling the oxygen fugacity around CC chondrules became higher than that around UOC chondrules.

1. Introduction

Chondrules are the most prominent feature of chondritic meteorites. There is controversy about the conditions and mechanism of formation of chondrules, and there is no agreement about the latter at present. Nonetheless, it can be said that chondrules were formed by partial to total melting of precursor materials because of the discovery of relict olivine crystals in chondrules (NAGAHARA, 1981; RAMBALDI, 1981). There have been many studies on chondrules (*i.e.*, GOODING, 1983; GROSSMAN and WASSON, 1983a, b; RUBIN, 1986; GROSSMAN *et al.*, 1988). These studies have shown systematic differences among chondrites in each chemical group; differences in size distribution, ratio of chondrules to matrix, bulk composition of chondrules, and chemical composition of constituent minerals such as olivine and orthopyroxene. Though it is difficult to estimate what kind(s) of condition is reflected in the various properties, RUBIN and WASSON (1988) stated that siderophile/lithophile and refractory lithophile/common lithophile fractionation in chondrite whole rock was established before chondrule formation by comparing chondrule bulk compositions (GROSSMAN and WASSON, 1982, 1983a, b; RUBIN and WASSON, 1986, 1987).

There are several ways of classification of chondrules. The textural classification of chondrules in UOCs by GOODING and KEIL (1981) has been widely used, and those in CCs are classified on the basis of texture and bulk chemical composition (MCSWEEN, 1977a, b, c; MCSWEEN *et al.*, 1983). Many porphyritic olivine pyroxene (POP) chondrules in CCs have shells of low-Ca pyroxene crystals, but on the contrary, POP chondrules in ordinary chondrites (OCs) rarely have such texture. It is important to know the textural and chemical differences of minerals in similar type of chondrules in order to estimate the difference in formation conditions of chondrules in each chemical group of chondrites.

Mineralogical study on chondrules can give some clues on physical and chemical conditions for chondrules formation and subsequent thermal history. Pyroxenes in OC and CC chondrules have been studied by transmission electronmicroscopy (*e.g.*, ASHWORTH and BARBER, 1977; ASHWORTH, 1980, 1981; ASHWORTH *et al.*, 1984; KITAMURA *et al.*, 1984a, b; TOPEL-SCHADT and MULLER, 1985). ASHWORTH and BARBER (1977) stated that chondrules had not been cooled suddenly from high temperature in terms of size of antiphase domain of pigeonite. KITAMURA *et al.* (1984a, b) said that cooling rate of chondrule through 1000°C had been a few tens or several °C/h in terms of spinodal decomposition structure of pigeonite.

In this work, I concentrate on the texture and chemical composition of pyroxenes in chondrules in H-L-LL, CV, CO, CM and CR chondrites, because pyroxenes are abundant in every type of chondrite and because they are sensitive to thermal history at temperatures above 800°C.

2. Samples and Techniques

Polished thin sections of the following chondrites were studied: Allende (CV3), ALH-77003 (C3), ALH-77307 (CO3), Y-790112 (CR) and Y-74662 (CM2). OCs which belong to a subtype lower than 3.5 (SEARS *et al.*, 1980) were also studied for comparison; they are Semarkona (LL3.0), Krymka (LL3.0), Chainpur (LL3.4) and Sharps (H3.4).

All thin sections were observed under an optical microscope and a scanning electron microscope (SEM) (JEOL JSM-840), and then analyzed with an electron microprobe analyzer (JEOL JXA-733) operated at 15 kV accerelating voltage and 12 nA beam absorption on PCD. All analyzed points were selected on back-scattered electron image (BEI) photographs to avoid fluorescence effects from adjacent minerals. Using a focused beam in the SEM, augites and pigeonites, most of which occur as rims on low-Ca clinopyroxenes (about 10 μm) were analyzed with least contamination. Pyroxene analyses totaling 98 to 102 total wt% and with total cation 3.980 to 4.020 (oxygen 6 bases) were used. Correction by the Bence and Albee method using correcting factors of NAKAMURA and KUSHIRO (1970) was applied.

3. Nomenclature of Pyroxenes

Pyroxenes have complicated structural and compositional nomenclature, and the following names were used for simplification.

(1) Low-Ca clinopyroxene is used for inverted protopyroxene, which is most common in the unequilibrated chondrites. Pyroxenes with Wo content less than 2 belong to this category except for those that are optically identified as orthopyroxene.

(2) Orthopyroxene is used for pyroxenes which have Wo content 2 to 5. Pigeonite is used for pyroxenes which have Wo content 5 to 15. Their small grain sizes make it difficult to determine whether they are orthopyroxene or pigeonite under an optical microscope. Then, discrimination between orthopyroxene and pigeonite is mainly based on chemical composition and contrast in back-scattered electron images (BEIs). BEIs show sharp boundaries among low-Ca clinopyroxene, orthopyroxene and pigeonite.

(3) Subcalcic augite is used for pyroxenes with Wo content 15 to 25, which is classified only on chemistry. This type of pyroxene is rare.

(4) Augite is used for pyroxenes having a Wo content over 25.

4. Petrography of Chondrules Based on Pyroxene

The textural classification of GOODING and KEIL (1981) is used in this work in order to compare chondrules of UOCs and CCs. Pyroxene-bearing porphyritic chondrules, which are the most abundant type in both UOCs and CCs, were mainly investigated.

4.1. Carbonaceous chondrites

The most prominent difference between chondrules in UOCs and CCs is that POP chondrules in CCs have shells of low-Ca clinopyroxene crystals and core of olivine crystals. The texture of the shell varies from the one consisting of tabular low-Ca clinopyroxene crystals almost without glass, to one consisting of euhedral low-Ca clinopyroxene crystals rimmed by Ca-bearing pyroxenes with abundant glass (Fig. 1).

The texture of the interstitial materials between porphyritic crystals in many CC chondrules are also different from those in OC chondrules. The amount of glass (including devitrified glass) in most CC chondrules is smaller than in OC chondrules except for ALH-77003. The primary igneous texture in the CC chondrules, that is, igneous glass and embedded crystals, was modified by the growth of interstitial ferrous olivine laths and platelets in many Allende and some ALH-77307 chondrules and by the alteration of glass in CCs other than Allende. A conspicuous feature of many chondrules in Allende is that the interstices between phenocrysts are filled with small crystals, mostly ferrous olivine, which may correspond to the "ferrous olivine laths and platelets" noted by PECK and WOOD (1987). In the following sections, the petrography of chondrules and the texture and occurrence of pyroxenes in chondrules are described.

4.1.1. Allende (CV3)

Orthopyroxene and pigeonite are observed much more often in pyroxene-bearing porphyritic chondrules in Allende than in those of the other CCs investigated; orthopyroxene and/or pigeonite occur in nine chondrules of twenty studied with the SEM.

Anhedral plagioclase (An >80) was observed (Fig. 1) in some orthopyroxene and/or pigeonite-bearing porphyritic chondrules. Three out of fourteen chondrules in ALH-77307 have pigeonite, which is the second abundant type of pyroxene assemblage.

Pyroxene crystallization sequences in chondrules with interstitial glass are low-Ca clinopyroxene to augite or (low-Ca clinopyroxene to) pigeonite to augite. These sequences are also recognized in other CCs and UOCs. Many chondrules, especially in Allende, do not show a simple overgrowth texture of pyroxenes and show complex zoning from pigeonite to augite (Fig. 1).

Another type of texture in pyroxene that is specific to Allende chondrules is a reaction texture between low-Ca clinopyroxene and metal-iron oxide-sulfide spherules which has been described by HOUSLEY and CIRLIN (1983). At the contact between low-Ca clinopyroxene and spherule and also along cleavages in pyroxene, ferrous olivine about 10 μm thick is observed. This texture is prominent in chondrules that include large poikilitic pyroxene, olivine oikocrysts and spherules (Fig. 2). As already mentioned by PECK and WOOD (1987) and HUA *et al.* (1988), some low-Ca clinopyroxene crystals are interleaved with ferrous olivine in chondrules without such spherules. Some pyroxene crystals, however, did not react with spherules. If reaction occurred after accretion, all low-Ca clinopyroxene and metal-oxide-sulfide spherules would have reacted. GREEN *et al.* (1971) suggested that Allende meteorite had not experienced a temperature greater than 230°C on the basis of retainment of irradiation damages in olivine crystals. At such low temperature, the reaction would not have proceeded remarkably. The reaction of low-Ca clinopyroxene with spherules, thus, took place before accretion.

4.1.2. ALH-77307 (CO3)

ALH-77307 was regarded as one of the least metamorphosed CO3 chondrites by SCOTT *et al.* (1981). Petrological study of chondrules in this meteorite was performed by NAGAHARA and KUSHIRO (1982). Although there are chondrules with interstitial ferrous olivines as those in Allende and the amount of glass is small, the crystallization sequence and primary igneous texture are more easily recognized than in Allende. The pyroxene crystallization sequences deduced from the overgrowth texture are similar to those in Allende. This meteorite contains more abundant pyroxene-bearing porphyritic chondrules than Allende does. Three out of fourteen chondrules contain pigeonite.

4.1.3. ALH-77003 (C3)

ALH-77003 was considered to be a unique C3 by IKEDA (1982), because it has bulk Al/Si and Ca/Si ratios as high as CO but its Fe/Mg ratio is similar to CV. The amount of opaque minerals in chondrules does not match the classification by VAN SCHMUS and HAYES (1974). This chondrite contains many pyroxene-bearing porphyritic chondrules in which interstitial glass is intensively devitrified (Fig. 3). Olivine oikocrysts in porphyritic low-Ca clinopyroxene were more ferrous than those in other investigated CCs. However, the porphyritic low-Ca clinopyroxene crystals contain as little Fs as other CCs. If the bulk Fe content of chondrules was primarily high, the ferrosilite content of pyroxenes would have been high in "high-FeO porphyritic chondrules" (RUBIN and WASSON, 1988). This suggests that the selective introduc-

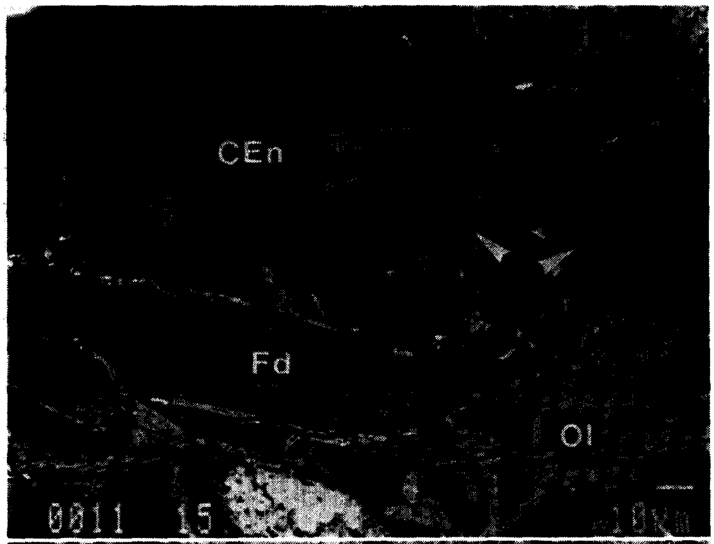

Fig. 1. BEI photograph for pyroxenes in a POP chondrule in Allende showing complex compositional zoning from pigeonite to augite (arrow). Fd; Anhedral plagioclase (An>80).

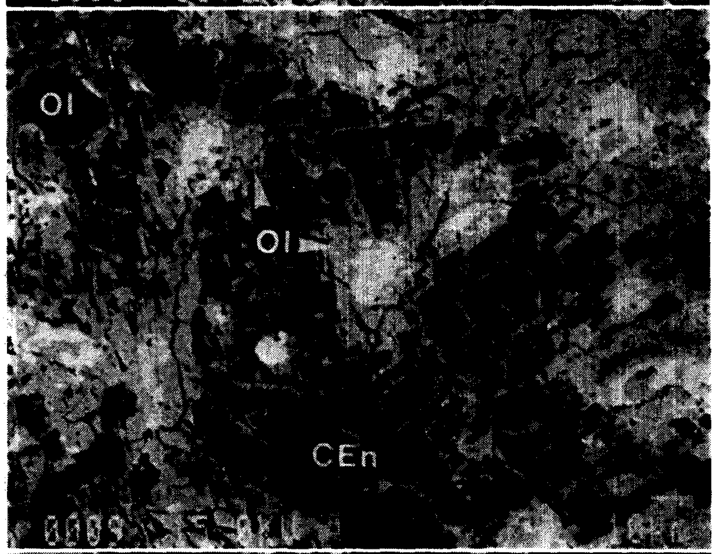

Fig. 2. Ferrous olivine (Ol, pointed by arrows) formed through reaction between Fe-Ni metal-oxide-sulfide spherules and low-Ca clinopyroxene (CEn) in a chondrule in Allende. BEI photo.

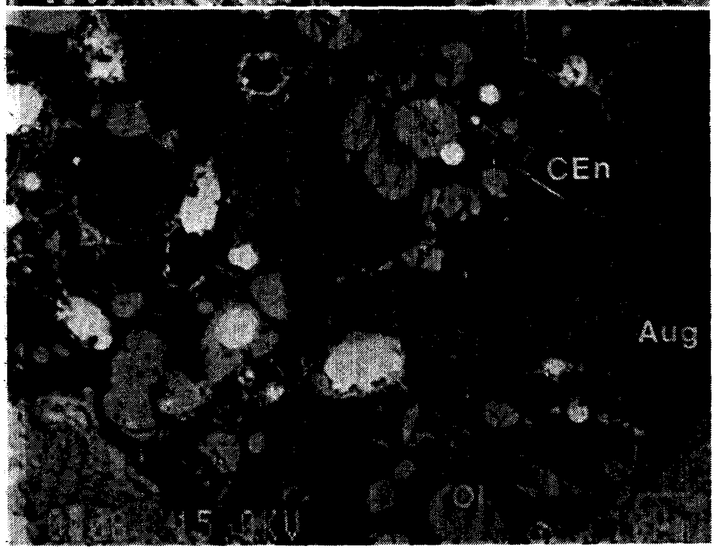

Fig. 3. Overgrowth of augite (Aug) around low-Ca clinopyroxene crystals (CEn) set in devitrified glass in a chondrule in ALH-77003. BEI photo.

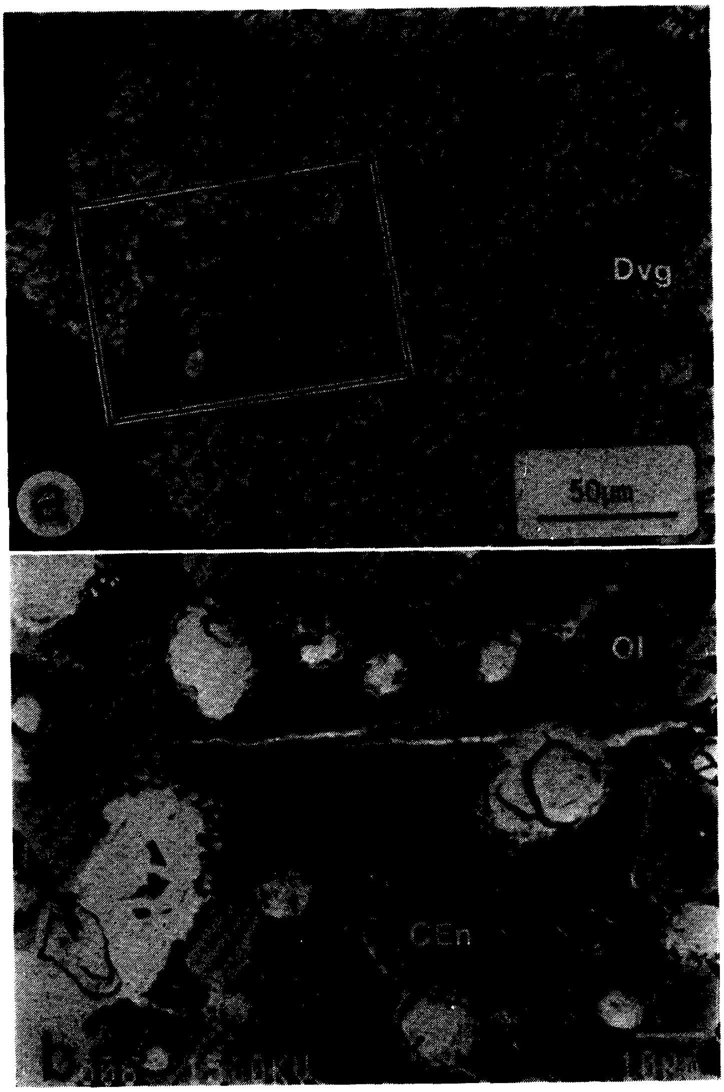

Fig. 4. Lamellae-bearing mineral (pointed by an arrow) in interstices of low-Ca clinopyroxene (CEn) and olivine (Ol) phenocrysts in a chondrule in ALH-77003. Dvg; devitrified glass. (a) transmitted light (open nicol). (b) BEI photo.

tion of Fe into olivine crystals would have occurred after they crystallized, that is, high FeO content of this meteorite resulted from secondarily induced high Fe content in olivine.

A characteristic exsolution texture observed in two of nineteen observed chondrules (Fig. 4) seems to be composed of an intergrowth between two phases with different Ca and Na (and perhaps K) contents. It exists in the interstices between olivine and pyroxene phenocrysts and is different from devitrified glass at different sites in the same chondrules (Fig. 4a). The chemical composition of the intergrowth obtained from broad beam analysis by electron microprobe is SiO_2 47.2, Al_2O_3 33.1, FeO 0.3, MnO 0.4, CaO 12.4, Na_2O 5.7, K_2O 0.7 and total 99.8 wt%. The thin section was too thin to determine optical properties.

4.1.4. Y-790112 (CR)

Y-790112 is classified as a CR. Many chondrules in this meteorite have a small

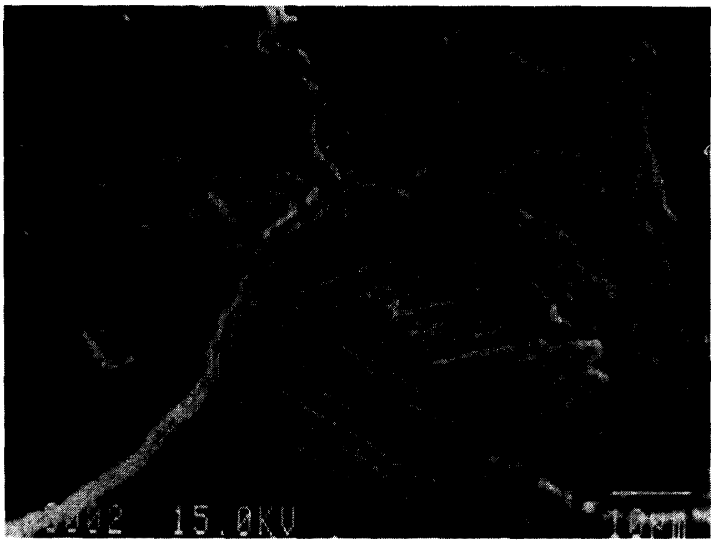

Fig. 5. PCP aggregate in matrix of Y-74662. SEI photo.

amount of igneous glass which is partly altered. Orthopyroxene and/or pigeonite were observed in three chondrules of fourteen.

4.1.5. Y-74662 (CM2)

Y-74662 is a CM2 chondrite. Igneous glass has been completely replaced by phyllosilicates and many PCP aggregates are observed in the matrix (Fig. 5). The amount of igneous glass in chondrules seems to have been primarily relatively high. This meteorite also contains many pyroxene-bearing porphyritic chondrules.

4.2. UOCs

The textures and chemical compositions of pyroxenes in UOCs with subtype lower than 3.5 are briefly described in this chapter. Details of the UOCs will be shown in another paper (T. NOGUCHI, in prep.). Although some meteorites belonging to subtype lower than 3.3 have suffered aqueous alteration (HUTCHISON *et al.*, 1987; GUIMON *et al.*, 1988), the texture of pyroxenes in chondrules has not undergone significant change. Pyroxene-bearing porphyritic chondrules in UOCs have more abundant glass than those in the CCs investigated. The most common crystallization sequence is low-Ca clinopyroxene to augite (rim) (Fig. 6), which is the most abundant type in CCs. Except for low-Ca clinopyroxene without overgrowth of other pyroxenes, the second common pyroxene occurrence is low-Ca clinopyroxene with orthopyroxene or pigeonite to augite rim (Fig. 7). Pyroxenes with core compositions more iron-rich than Fs 5 specifically show this sequence. Oscillatory zoning in low-Ca clinopyroxene (WATANABE *et al.*, 1986) is often found in more ferrous pyroxene.

4.3. Occurrence of pyroxene in chondrules

Low-Ca clinopyroxene occurs as discrete crystals in many chondrules. Orthopyroxene occurs as rims on low-Ca clinopyroxene. It sometimes occurs as discrete crystals, which have Fs content higher than about 10. Pigeonite also occurs as rims on low-Ca clinopyroxene. Discrete crystals of pigeonite are rarer than those of orthopyroxene. Augite occurs as rims on low-Ca clinopyroxene and as minute

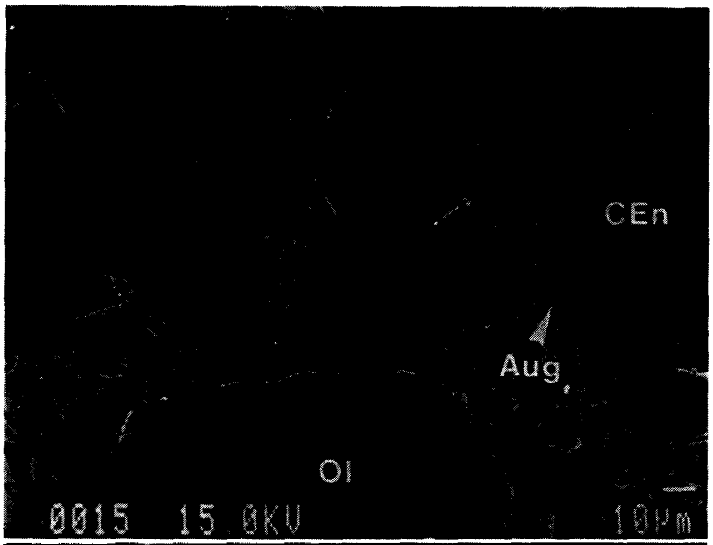

Fig. 6. Overgrowth of augite (Aug) around low-Ca clinopyroxene (CEn) in a chondrule in Krymka. This is the most common occurrence for augite. BEI photo.

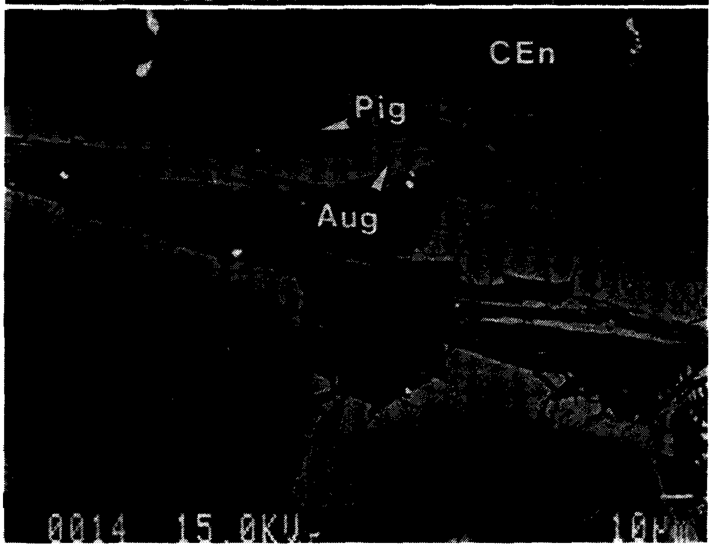

Fig. 7. Pigeonite (Pig) and augite (Aug) overgrowth around low-Ca clinopyroxene (CEn) in Krymka. BEI photo.

Table. 1. Assemblages of pyroxenes in chondrules.

Name	No. of chrls.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Allende	20	4	6	1	3	—	—	—	2	—	3	1	—	—	—
ALH-77307	17	3	11	2	—	1	—	—	—	—	—	—	—	—	—
ALH-77003	14	3	8	—	—	—	—	2	—	1	—	—	—	—	—
Y-790112	15	1	10	1	2	—	—	—	—	—	—	1	—	—	—
Y-74662	14	3	9	—	—	—	—	2	—	—	—	—	—	—	—
Semarkona	12	+	3	2	—	1	—	1	—	2	—	—	3	—	—
Krymka	15	+	9	1	2	—	1	—	—	1	—	—	1	—	—
Chainpur	16	1	7	2	1	—	—	—	—	—	1	—	2	1	1
Sharps	14	1	7	—	3	1	—	—	—	—	—	—	2	—	—

(1): pr, (2): pr-aug, (3): pr-opx-aug, (4): pr-pig-aug, (5): pr-opx, (6): pr-pig, (7): opx, (8): pig, (9): opx-aug, (10): pig-aug, (11): aug, (12): px with oscillatory zoning: opx-pig-aug, pr-opx-pig-aug, pr-aug, (13): ferrous and aluminous opx-aug-pig, (14): ferrous opx-pig-aug.
pr: low-Ca clinopyroxene, opx: orthopyoxene, pig: pigeonite, aug: augite, +: present but not counted. Actual ratio of type (1) is much more abundant.

crystals in glass in chondrules. Sometimes overgrowth of augite occurs as an overgrowth on orthopyroxene and/or pigeonite on a rim of low-Ca clinopyroxene and discrete crystals of pigeonites. Augite seldom occurs as discrete crystals.

Table 1 shows the various crystallization sequences of pyroxenes observed in chondrules, but in some cases the "sequence" represents only the assemblages of pyroxenes in chondrules. The number of cases other than in the first and second columns may be somewhat exaggerated, because of selection of chondrules with different types of pyroxene.

It is clear from the table that the crystallization sequence from low-Ca clinopyroxene (originally protopyroxene) to augite (case 2) is most abundant. The second most common sequences are 3 and 4, low-Ca clinopyroxene through orthopyroxene or pigeonite to augite. The third is the sequence orthopyroxene or pigeonite to augite (cases 9 and 10). The fourth is the sequence low-Ca clinopyroxene to pigeonite (case 6). Oscillatory zoning is more often observed in Fe-rich low-Ca clinopyroxenes than in Mg-rich ones. Case 14 in Table 1 represents a complex zoning pattern; the Ca content first increases to augite and then decreases again to pigeonite. This does not result from sectioning through an irregular crystal.

In Allende and Y-790112, two chondrules with a texture similar to olivine-clinopyroxenite were observed. The clinopyroxene in them is fassaitic (*ca.* 25 wt% CaO and more than 10 wt% Al_2O_3). A similar object was reported by DOMINIK *et al.* (1978) as a coarse-grained inclusion in Allende, but it differs from those in Allende and Y-790112 in having typical CAI minerals such as perovskite, melilite and fremdlinge.

5. Chemical Composition of Pyroxenes

5.1. Major elements: variation and comparison

Most pyroxene-bearing porphyritic chondrules in CCs belong to type I chondrules of MCSWEEN (1977a, b, c, 1983). Figure 8 shows the compositional variation of pyroxenes in the chondrites studied, but the number of plots does not represent the relative abundance. The low-Ca clinopyroxene in these chondrules does not show conspicuous Fe-Mg zoning from core to rim, and augite does not show wide Fe-Mg variation even with variable Wo content. The average Fs content of low-Ca clinopyroxene, orthopyroxene and pigeonite is less than 2 in Allende, ALH-77307 and Y-74662, and between 3 to 4 in ALH-77003 and Y-790112. As shown in Fig. 8c, the higher average Fs content in pyroxenes in ALH-77003 results from ferrous pyroxenes which are shown as solid symbols. The avearge Fs content excluding these two ferrous pyroxenes is reduced to less than 2 and similar to those in the other CCs studied. In contrast with ALH-77003, low-Ca clinopyroxene, orthopyroxene and pigeonite in Y-790112 have a little higher Fs content than the other CCs investigated. The average Fs content in augite is less than 2 in Allende and Y-74662. The average range of Fs content in augite in the other CCs studied is 2.8 to 4.2, which is higher than Allende or Y-74662 because of the presence of ferrous augite. The Fs content of augite in Y-790112 is higher than in the other CCs studied, even if ferrous augite is eliminated (Fig. 8).

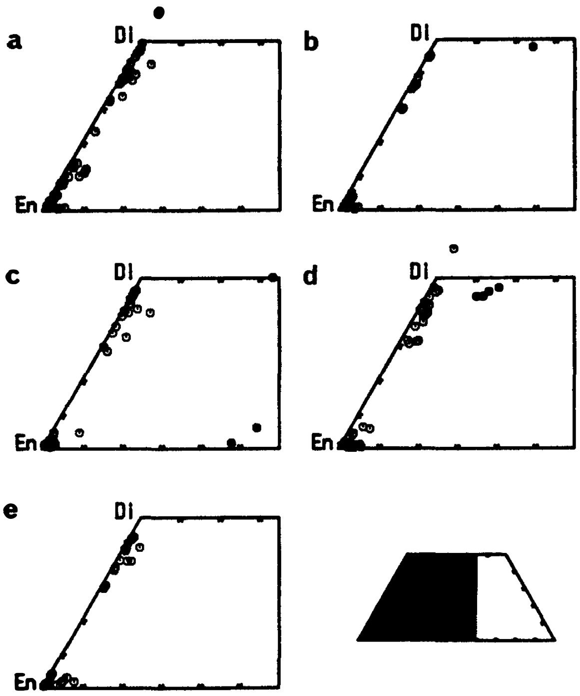

Fig. 8. Pyroxene composition on quadrilaterals for CCs. Solid symbols are pyroxenes in high-FeO porphyritic chondrules a: Allende b: ALH-77307 c: ALH-77003 d: Y-790112 e: Y-74662.

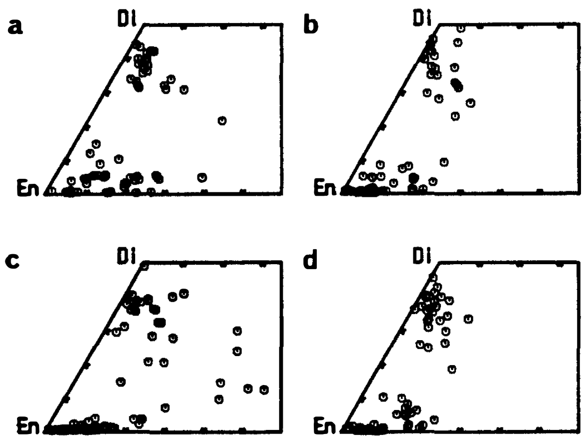

Fig. 9. Pyroxene composition on quadrilaterals for UOCs. a: Semarkona b: Krymka c: Chainpur d: Sharps.

There are three kinds of pyroxene-bearing chondrules in terms of their Fs content. The most common type has pyroxenes with Fs less than 2%. The second type has pyroxene with Fs 3–10 and the third type is chondrules which involve pyroxenes with Fs content more than 10 (typically more than 20), which RUBIN and WASSON (1988) described as "high-FeO porphyritic chondrules". Ferrous augite in ALH-77307, which occurs in a fragment in matrix, would be from chondrule of the third type.

In Y-790112, the Wo content of augite, except for Fe-rich augite, slightly decreases with increase in Fs content (Fig. 8d), which coincides with a higher average Fs content of low-Ca clinopyroxene. High Fs content probably resulted from chondrule formation or initiation of metamorphism at slightly higher oxygen fugactiy than for the other CCs.

The chemical composition of pyroxene in the UOCs with subtype lower than 3.4 are shown in Fig. 9. The most prominent difference in pyroxene composition from

CCs is that the Fs content ranges continuously from 0 to 50.

As mentioned in the previous chapter, orthopyroxene is with Wo 2–5, and pigeonite is with Wo 5–15 (Fig. 9). Ferrosilite content in orthopyroxene and pigeonite ranges from 0 to 20 except for Semarkona. The high Fs content in the Semarkona pyroxene may be due to the presence of orthopyroxene and pigeonite with high Fs content. The ferrosilite content in orthopyroxene and pigeonite ranges from 2 to 40 and from 5 to 50, respectively. The ferrosilite content of augite increases as Wo decreases. Tie lines for coexisting pyroxenes rarely cross each other. If the cooling rate of pyroxene-bearing porphyritic chondrules widely varied, the tie lines would often have crossed each other. The fact shows that cooling rates of chondrules during crystallization were in a relatively narrow range. NAGAHARA (1983) reproduced the texture of POP chondrules at a cooling rate of 5°C/h, so that cooling rates of these chondrules were probably less than several °C/h.

5.2. Minor element contents

Minor element contents in various silicate phases in OC, CV, CO and CM chondrites were compiled by RUBIN (1986). The mean compositions and standard deviations of low-Ca pyroxene in chondrules in this study (Table 2) sometimes differ from those of RUBIN (1986). RUBIN (1986) noted that the Ca content of low-Ca pyroxene (low-Ca pyroxene includes low-Ca clinopyroxene, orthopyroxene and pigeonite) in UOCs is lower than that in CV and CM and similar to that in CO. In the present study, however, the Ca content of low-Ca pyroxene in UOCs was found to be higher than that in CM-COs. The discrepancy in Ca content may result from sampling bias; that is, a difference in the amounts of orthopyroxene and pigeonite analyzed. The same tendency is observed in the Cr content; low-Ca pyroxenes in UOCs have higher Cr content than those in CCs in the present study, but RUBIN (1986) found the opposite. This may result from a similar reason. Manganese and Cr contents in CM and CO are nearly the same in both two studies. The aluminum content of pyroxene is higher in CV and decreases through CO to OC as already shown by RUBIN (1986).

Augites in Y-790112, Allende and Krymka have higher Al_2O_3 content than those in other meteorites studied. Although Al_2O_3 in pyroxene shows a wide variation, the Al_2O_3 content of augite in the UOCs is lower than in CCs. TiO_2, CaO and Na_2O do not show such wide variation as Al_2O_3 does. The TiO_2 contents of augite in the CCs are higher than in the UOCs, and Allende has the highest content of the CCs, which is also the case in low-Ca pyroxene. The CaO content in augite in the CCs is also higher than in the UOCs, and Allende and ALH-77003 are especially high. The UOCs of subtype 3.4 have lower CaO content than those of subtype 3.0. The higher Na_2O content of augite in Y-790112 is due to the presence of ferrous augite. The TiO_2, CaO and Na_2O contents of augite in these meteorites are related to the bulk composition of chondrules (RUBIN, 1986). The Cr_2O_3 content in the UOCs is higher than that in CCs except for Y-790112. Y-790112 has higher Al_2O_3 and Cr_2O_3 and lower TiO_2 contents in both pyroxenes than in the other investigated CCs, and is rather similar to UOCs.

ALH-77003 was classified as a unique C3 chondrite (IKEDA, 1982). The pyroxene

Table 2. Average compositons and standard deviations of pyroxenes in chondrules.

Name	No.	SiO_2	Al_2O_3	TiO_2	FeO	MnO	MgO	CaO	Na_2O	Cr_2O_3	Total
Augite											
Allende	34	51.53±3.19	5.62±4.08	1.57±0.70	0.79±0.71	0.09±0.09	20.02±3.45	19.94±2.48	0.03±0.02	0.88±0.47	100.46
ALH-77307	11	53.06±2.40	3.88±3.05	0.96±0.36	1.95±4.24	0.23±0.10	21.03±4.82	18.54±2.04	0.07±0.22	0.85±0.34	100.57
ALH-77003	22	52.34±2.34	4.40±2.90	0.93±0.38	1.64±3.88	0.51±0.57	19.56±3.99	19.31±2.20	0.07±0.17	1.11±0.47	99.87
Y-790112	24	50.84±2.86	5.99±4.03	0.89±0.63	2.47±2.99	0.54±0.53	18.18±3.51	18.93±2.35	0.21±0.44	1.95±0.79	100.00
Y-74662	17	53.04±1.93	4.35±2.58	0.98±0.43	0.92±0.71	0.40±0.26	20.91±2.27	18.92±1.93	0.01±0.34	1.12±0.34	100.64
Semarkona	22	52.35±1.76	3.30±2.12	0.73±0.57	5.41±4.34	0.56±0.31	18.91±1.78	17.41±2.48	0.27±0.18	1.67±0.79	100.62
Krymka	23	51.04±2.52	5.57±4.45	0.70±0.42	4.00±3.46	0.65±0.44	18.62±1.96	17.34±2.76	0.18±0.17	1.40±0.75	99.49
Chainpur	25	51.51±2.40	4.00±3.78	0.60±0.31	6.13±5.45	1.05±0.61	18.20±2.74	15.71±2.85	0.28±0.19	1.59±0.76	99.07
Sharps	26	52.03±1.53	3.70±2.35	0.61±0.29	3.64±2.36	0.88±0.12	19.89±1.70	16.62±2.18	0.25±0.14	1.83±0.56	99.45
Low-Ca Clinopyroxene+Orthopyroxene+Pigeonite											
Allende	45	57.30±1.21	1.74±0.87	0.41±0.30	1.10±0.90	0.06±0.06	36.45±2.37	2.42±2.18	0.02±0.05	0.72±0.23	100.23
ALH-77307	22	58.42±0.91	1.20±0.65	0.20±0.12	1.26±0.78	0.16±0.12	38.02±0.86	0.98±0.83	0.00±0.00	0.70±0.23	100.94
ALH-77003	44	57.82±1.72	0.97±0.43	0.17±0.07	2.21±5.94	0.16±0.03	37.04±4.90	0.79±0.58	0.03±0.07	0.60±0.16	99.79
Y-790112	40	57.91±2.20	1.42±2.52	0.14±0.11	1.79±0.92	0.24±0.20	37.50±1.78	0.66±0.70	0.00±0.01	0.86±0.38	100.51
Y-74662	19	58.20±0.67	1.17±0.54	0.18±0.07	1.29±1.38	0.14±0.10	37.86±1.51	0.93±0.59	0.00±0.00	0.71±0.26	100.49
Semarkona	43	56.03±1.71	0.96±1.02	0.13±0.12	8.93±4.99	0.59±0.28	31.01±4.20	1.91±1.67	0.03±0.03	1.00±0.35	100.59
Krymka	48	57.02±1.99	1.02±2.20	0.11±0.10	4.93±3.82	0.46±0.43	34.38±4.12	1.08±1.20	0.03±0.03	0.79±0.42	99.82
Chainpur	52	56.05±3.00	1.07±2.68	0.11±0.21	8.01±6.18	0.52±0.24	31.89±6.36	1.16±1.70	0.03±0.05	0.75±0.32	99.60
Sharps	44	56.38±1.23	0.46±0.27	0.07±0.04	6.63±3.49	0.66±0.43	33.31±3.98	1.30±1.78	0.02±0.05	0.94±0.34	99.78

compositions of ALH-77307 (CO3) and ALH-77003 are similar except for the FeO and MgO contents (Table 2). The high average FeO content of augite in ALH-77003 comes from some "high-FeO porphyritic chondrules" and most augite crystals in the two meteorites have similar compositions. This similarity and the higher FeO content in olivine oikocrysts suggest that ALH-77003 is FeO-enriched CO3 chondrite, and this FeO enrichment probably occurred after crystallization of chondrules.

6. Discussion

6.1. Pyroxene composition and the pyroxene phase diagram

Pyroxene-bearing porphyritic chondrules contain four kinds of pyroxenes as described above. They are low-Ca clinopyroxene (protopyroxene), orthopyroxene, pigeonite (sometimes these two are overgrowing low-Ca clinopyroxene) and augite (often overgrowing low-Ca clinopyroxene).

Iron-free pigeonite has been observed in some experiments under 1 atm since 1970s (*e.g.*, KUSHIRO, 1972). LONGHI and BOUDREAU (1980) found a region of orthopyroxene stability at high temperatures. Appearance of two separate orthopyroxene stability regions was confirmed by CARLSON (1988). Wollastonite contents of low-Ca clinopyroxene, orthopyroxene and pigeonite in the present study well correspond to those of protopyroxene, orthopyroxene and pigeonite in these experiments in spite of the existence of non-quadrilateral components of pyroxene. This suggests that these orthopyroxene crystallized from chondrule melts as a liquidus phase at high temperatures.

The pyroxene assemblages in chondrules depend on bulk composition, cooling rate, degree of undercooling and presence or absence of relict grains. For the same bulk compositions slower cooling allows the overgrowth of several pyroxenes according to the degree of reaction with the residual melt. Recent dynamic crystallization experiments have revealed that the effect of cooling rate may be small (*e.g.*, HEWINS, 1988; LOFGREN and RUSSELL, 1986), though NAGAHARA (1983) reported that the porphyritic olivine pyroxene texture could be reproduced by cooling rates less than 5°C/h. These studies were based principally on optical observations, and observation under the SEM will be necessary to estimate more appropriate cooling rates. Preliminary experiments and observation with SEM (T. NOGUCHI, unpublished data) show that slower cooling rates less than several tens °C/h are needed to produce the porphyritic olivine pyroxene texture with rims of augite on orthopyroxene and pigeonite. Some chondrules in Allende show an intense compositional zoning from pigeonite to augite (Fig. 1), clearly suggesting that these chondrules experienced faster cooling because of very irregular boundary between the pyroxenes.

6.2. Interelemental correlations in pyroxene

The compositions of pyroxenes in chondrules depend on the bulk composition of chondrules, the cooling history such as temperature and cooling rate, oxygen fugacity, and the crystal structure of pyroxenes. The minor element contents of pyroxenes, especially of augite, will give important clues to the above factors.

Interelemental correlations for chondrules in CCs and UOCs have been reported

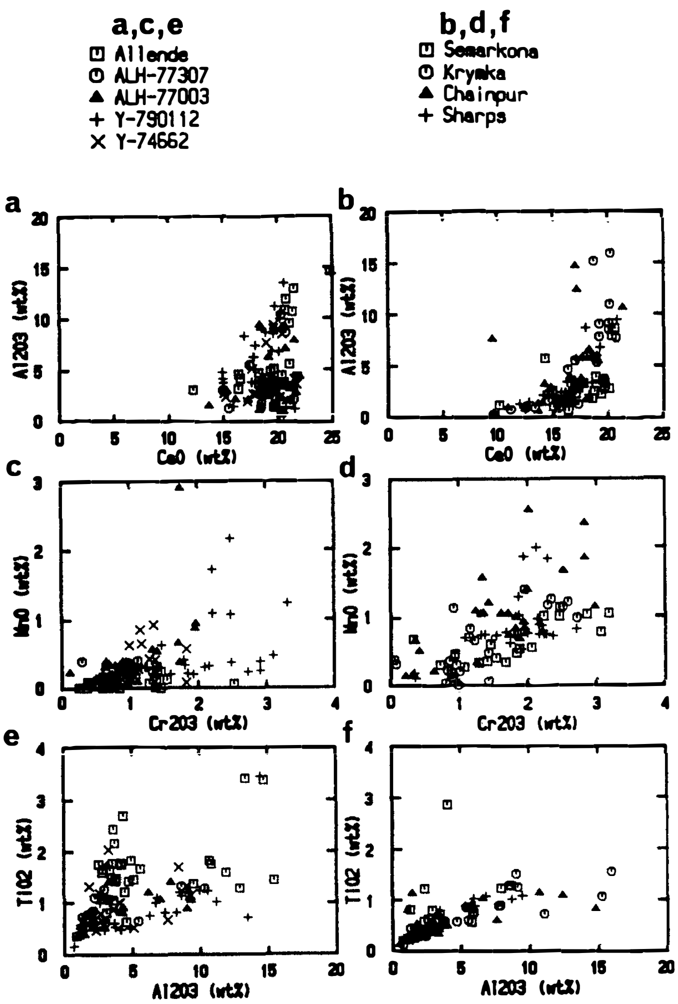

Fig. 10. Interelemental relationships in augites in CC and UOC chondrules. (a) CaO vs. Al_2O_3 in CCs, (b) that in UOCs; (c) Cr_2O_3 vs. MnO in CCs, (d) that in UOCs; (e) TiO_2 and Al_2O_3 in CCs and (f) that in UOC.

for several elements (GROSSMAN and WASSON, 1983a, b; RUBIN and WASSON, 1986, 1987, 1988). Figure 10 shows several interelemental correlations of augite in CCs and UOCs, where r is the correlation coefficient and n is the number of data. The correlation between CaO and Al_2O_3 for augite in UOC chondrules is shown in Fig. 10b (variety in each meteorite, $r=0.38$, $n=25$ (Chainpur) to $r=0.77$, $n=26$ (Sharps)): those in CCs are positive but weak ($r=0.27$, $n=17$ (Y-74662) to $r=0.64$, $n=11$ (Allende)) (Fig. 10a). CaO and TiO_2 of augite in UOC chondrules ($r=0.32$, $n=22$ (Semarkona) to $r=0.85$, $n=26$ (Sharps)) are also positively correlated: those in CCs are also positive but weak ($r=0.29$, $n=22$ (ALH-77003) to $r=0.60$, $n=11$ (ALH-77307)). Cr_2O_3 and MnO of augite in UOC chondrules are positively correlated ($r=0.5$, $n=26$ (Sharps) to $r=0.77$, $n=24$ (Semarkona)) (Fig. 10d), though the positive correlation is weak in augite in CC chondrules ($r=-0.05$, $n=11$ (ALH-77307 to $r=0.53$, $n=22$ (ALH-77003)) (Fig. 10c). Al_2O_3 and TiO_2 correlation of augite is positive in UOC chondrules ($r=0.32$, $n=22$ (Semarkona) to $r=0.85$, $n=26$ (Sharps) (Fig. 10f). Positive correlations between CaO and Al_2O_3, CaO and TiO_2, Cr_2O_3 and

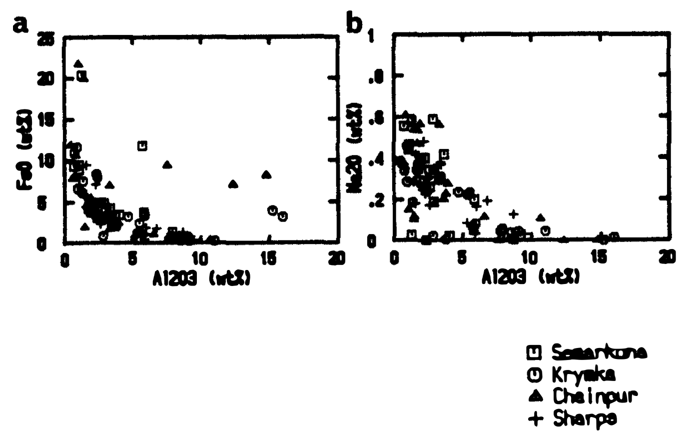

Fig. 11. FeO and Al_2O_3 (a), and Na_2O and Al_2O_3 (b) relationships for augite in UOC chondrules.

MnO, and Al_2O_3 and TiO_2 are similar to those for the bulk composition of chondrules, which suggests that the bulk composition of chondrules largely affects the augite composition.

Ca-poor pyroxenes show a tendency in the interelemental correlations similar to augite. This suggests that bulk composition of chondrules largely affected the composition of Ca-poor pyroxenes, although the degree of correlation is different in low-Ca clinopyroxene, orthopyroxene and pigeonite.

Some elements in augite in OC chondrules are negatively correlated: FeO and Al_2O_3 ($r=-0.23$, $n=25$ (Chainpur) to $r=-0.78$, $n=26$ (Sharps)) (Fig. 11a), and Na_2O and Al_2O_3 ($r=-0.60$, $n=22$ (Semarkona) to $r=-0.72$, $n=26$ (Sharps)) (Fig. 11b). The negative correlation between Na_2O and Al_2O_3 of augite is inconsistent with the rough positive correlation in bulk chondrule composition (GROSSMAN and WASSON, 1983b). The Na_2O content in augite would have been determined by the distribution of Na_2O between augite and melt during crystallization. A melt with high Na_2O concentration must have crystallized augite with high Na_2O, because the olivine and low-Ca pyroxene which crystallized prior to augite contain little Na_2O. Both Na_2O and Al_2O_3 are concentrated in the melt in most chondrules, which should result in their positive correlation in augite. If aluminous spinel crystallized before augite, the Al_2O_3 content in the melt would have decreased. However, aluminous spinel was scarcely observed in the chondrules studied and positive correlation between Na_2O and Al_2O_3 would be shown in augite even in this case. The negative correlation between Na_2O and Al_2O_3 in augite therefore was not produced during crystallization. An alternative possibility is addition of Na to chondrules after crystallization (vaporization and recondensation?), although this possibility was rejected by GROSSMAN and WASSON (1983b). The Na_2O content in augite in CC chondrules is very low (Table 2), despite a fairly high Na_2O content in chondrules (RUBIN, 1986), which supports the above possibility.

Al_2O_3 *vs.* TiO_2 in augite in UOCs has a positive correlation (Fig. 10f), and this is true of bulk chondrules, but in augite in CCs there are two trends (Fig. 10e). The trend with higher TiO_2/Al_2O_3 ratio is made of augite accompanied by pigeonite (1 and 2). This means that the chondrules in CCs except for Y-790112, in which the crystallization sequences are low-Ca clinopyroxene to orthopyroxene or pigeonite to augite or orthopyroxene or pigeonite to augite, follow this trend. Y-790112 does not have augite of this type (Fig. 10e). The trends for pyroxenes in Y-790112 and UOCs are almost the same, but augite accompanied by orthopyroxene or pigeonite in UOCs is plotted near the origin whereas those in Y-790112 are distributed along the trend. It is not clear whether the difference reflects bulk composition or not. Because an average bulk Ti content is 1 mg/g in bulk chondrules in unequilibrated chondrites, it may be difficult to detect the difference by electron microprobe analysis.

Fassaitic pyroxenes in chondrules are not rare, but they are different from those in CAIs (*e.g.*, pyroxenes in type B CAIs: WARK, 1987; pyroxenes in type A CAIs: TESHIMA and WASSERBURG, 1985). Augites in fluffy type A CAIs plot in a similar area to augites with low TiO_2/Al_2O_3 ratio in CC chondrules, but contain lower TiO_2 (GROSSMAN, 1975). Augites in compact type A CAIs and type B CAIs plot in different areas from augite in CC chondrules (TESHIMA and WASSERBURG, 1985; WARK, 1987). Augites in type B CAIs are abundant in both TiO_2 and Al_2O_3. Another conspicuous compositional difference is that the FeO and Cr_2O_3 contents of augites in CC chondrules are higher than those in CAIs, probably because of the different bulk compositions of chondrules and CAIs.

6.3. Oxygen fugacity during and after chondrule formation

Pyroxenes in OC chondrules generally contain more FeO than those in CC chondrules as shown in Figs. 8 and 9, which indicates that OC chondrules formed under more oxidizing conditions. Pyroxenes are the best candidates for giving information on evironments, because olivine easily changes its composition by reaction with gas or solid after crystallization.

The ($Na+{}^{VI}Al$) vs. (${}^{IV}Al+2Ti+Cr$) diagram offers a rough estimation of valence state of the elements (PAPIKE, 1980). If all the Fe in pyroxene is divalent and Ti and Cr are tetravalent and trivalent, respectively, the data will plot on a 45° line, but if Ti and Cr are trivalent and divalent, the data will plot below the line. Augites in both CCs and UOCs plot below the line, suggesting that they formed under reducing condition.

It is suggested that the oxygen fugacity at which pyroxene in CC chondrules crystallized was lower than that for OC chondrules. During cooling (or heating?), the oxygen fugacity around CC chondrules became higher than that around OC chondrules. Reaction of low-Ca clinopyroxene with Fe-Ni metal in chondrules (Fig. 2), oxidation of Fe-Ni metal and formation of ferrous olivine (PECK and WOOD, 1987; HUA *et al.*, 1988) also took place during cooling.

The high ferrosilite content in pyroxene in Y-790112 probably resulted from slightly higher oxygen fugacity during crystallization of chondrules. Ferrous olivine oikocrysts in ALH-77003 may have formed through reaction with ambient gas or initiation of metamorphism at high oxygen fugacity. The model of reaction of chondrules with ambient gas is consistent with the idea of the introduction of FeO and alkalis to chondrules from gas (IKEDA, 1982).

7. Conclusion

(1) Four kinds of pyroxenes can be recognized on the basis of the mode of occurrence and chemical composition in chondrules in UOCs and CCs. Low-Ca clinopyroxene (inverted protopyroxene) (Wo <2) is most common. Orthopyroxene (Wo 2–5) and pigeonite (Wo 5–15) occur as the overgrowth on low-Ca clinopyroxene or as discrete crystals. Augite (Wo >25) occurs as the overgrowth often on low-Ca clinopyroxene and sometimes on orthopyroxene and/or pigeonite.

(2) The most common pyroxene crystallization sequence is low-Ca clinopyroxene to augite. The second most common sequences are low-Ca clinopyroxene through orthopyroxene or pigeonite to augite. The third is orthopyroxene or pigeonite to augite.

(3) Petrographic differences between pyroxene-bearing porphyritic chondrules in CCs and UOCs are: chondrules with shell of low-Ca clinopyroxene crystals and cores of olivine crystals are abundant in CCs; the proportion of glass is smaller in CC chondrules and the original igneous structure of the chondrules was modified more extensively by interstitial ferrous olivine laths and by alteration of glass in CCs.

(4) The pyroxene compositions in CCs are different from those in UOCs. The ferrosilite content of pyroxene in most CC chondrules is less than 2, and some chondrules include pyroxenes with Fs 3 to 10. Chondrules which contain pyroxenes with Fs more than ten (typically more than twenty) are "high-FeO porphyritic chondrules" (RUBIN and WASSON, 1988) which are distinguished from magnesian chondrules. In contrast, pyroxenes in UOCs show a wide and continuous Fs variation from 0 to 50.

(5) Positive interelemental correlations among CaO and Al_2O_3, and TiO_2, positive one between Cr_2O_3 and MnO, and negative interelemental correlation between Al_2O_3 and FeO in augite in chondrules are similar to those for the bulk composition of chondrules, which fact suggests that the bulk composition of chondrules controlled the composition of augite. This is also the case for the composition of Ca-poor pyroxene.

(6) The negative interelemental correlation between Al_2O_3 and Na_2O is inconsistent with the roughly positive correlation in bulk chondrule compositions. The correlation in bulk chondrules is probably related to the introduction of Na into chondrules after crystallization.

(7) The positive correlation between Al_2O_3 and TiO_2 in augite in CCs shows two trends: trend with a high TiO_2/Al_2O_3 ratio and the other with a low TiO_2/Al_2O_3 ratio. Although the augite with a high TiO_2/Al_2O_3 ratio coexists with orthopyroxene and/or pigeonite, the effect of bulk composition on the composition of pyroxene is not yet known.

(8) The oxygen fugacity at which CC chondrules formed was lower than that for UOCs. During cooling and after crystallization of pyroxene, the oxygen fugacity around CC chondrules became higher than that around OC chondrules. The change of oxygen fugacity made the FeO content in the olivines higher than in the pyroxenes.

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References

ASHWORTH, J. R. (1980): Chondrite thermal histories; Clues from electron microscopy of orthopyroxene. Earth Planet. Sci. Lett., **46**, 167–177.

ASHWORTH, J. R. (1981): Fine structure in H-group chondrites. Proc. R. Soc. Lond., **A374**, 179–194.

ASHWORTH, J. R. and BARBER, D. J. (1977): Electron microscopy of some stony meteorites. Phil. Trans. R. Soc. Lond., **A286**, 493–506.

ASHWORTH, J. R., MALLINSON, L. G., HUTCHISON, R. and BIGGAR, G. M. (1984): Chondrite thermal histories constrained by experimental annealing of Quenggouk orthopyroxene. Nature, **308**, 259–261.

CARLSON, W. D. (1988): Subsolidus phase equilibria on the forsterite-saturated join $Mg_2Si_2O_6$–$CaMgSi_2O_6$ at atmospheric pressure. Am. Mineral., **73**, 232–241.

DOMINIK, B., JESSBERGER, E. K., STAUDACHER, Th., NAGEL, K. and EL GORESY, A. (1978): A new type of white inclusion in Allende; Petrography, mineral chemistry, ^{40}Ar–^{39}Ar ages, and genetic implications. Proc. Lunar Planet. Sci. Conf., 9th., 1249–1266.

GOODING, J. L. (1983): Survey of chondrule average properties in H-, L-, and LL-group chondrites; Are chondrules the same in all unequilibrated ordinary chondrites? Chondrules and Their Origins, ed. by E. A. KING. Houston, Lunar Planet. Inst., 61–87.

GOODING, J. L. and KEIL, K. (1981): Relative abundance of chondrule primary textural types in ordinary chondrites and their bearing on conditions of chondrule formation. Meteoritics, **16**, 17–43.

GREEN, H. W., RADCLIFFE, S. V. and HEUER, A. H. (1971): Allende meteorite; A high voltage electron petrographic study. Science, **172**, 936–939.

GROSSMAN, L. (1975): Petrography and mineral chemistry of Ca-rich inclusions in the Allende meteorite. Geochim. Cosmochim. Acta, **39**, 433–451.

GROSSMAN, J. N. and WASSON, J. T. (1982): Evidence for primitive nebular components in chondrules from the Chainpur chondrite. Geochim. Cosmochim. Acta, **46**, 1081–1099.

GROSSMAN, J. N. and WASSON, J. T. (1983a): Refractory precursor components of Semarkona chondrules and the fractionation of refractory elements among chondrites. Geochim. Cosmochim. Acta, **47**, 759–771.

GROSSMAN, J.N. and WASSON, J.T. (1983b): The composition of chondrules in unequilibrated chondrites; An evaluation of models for the formation of chondrules and their precursor materials. Chondrules and Their Origins, ed. by E. A. KING. Houston, Lunar Planet. Inst., 88–118.

GROSSMAN, J.N., RUBIN, A. E., NAGAHARA, H. and KING, E. A. (1988): Properties of chondrules. Meteorites and the Early Solar System, ed. by J. F. KERRIDGE and M. S. MATTEWS. Tucson, Univ. Arizona Press.

GUIMON, R. K., LOFGREN, G. E. and SEARS, D. W. G. (1988): Chemical and physical studies of type 3 chondrites. IX; Thermoluminescence and hydrothermal annealing experiments and their relationship to metamorphism and aqueous alteration in type <3.3 ordinary chondrites. Geochim. Cosmochim. Acta, **52**, 119–127.

HEWINS, R. H. (1988): The evolution of chondrules. Papers Presented to the Thirteenth Symposium on Antarctic Meteorites, 7-9 June 1988. Tokyo, Natl Inst. Polar. Res., 35-37.

HOUSLEY, R. M. and CIRLIN, E. H. (1983): On the alteration of Allende chondrules and the formation of matrix. Chondrules and Their Origins, ed. by E. A. KING. Houston, Lunar Planet. Inst., 145-161.

HUA, X., ADAM, J., PALME, H. and EL GORESY, A. (1988): Fayalite-rich rims, veins, and halos around in forsteritic olivines in CAISs and chondrules in carbonaceous chondrites; Types, compositional profiles and constraints of their formation. Geochim. Cosmochim. Acta, **52**, 1389-1408.

HUTCHISON, R., ALEXANDER, C. M. O. and BARBER, D. J. (1987): The Semarkona meteorite; First recorded occurrence of smectite in an ordinary chondrite, and its implications. Geochim. Cosmochim. Acta, **51**, 1875-1882.

IKEDA, Y. (1982): Petrology of the ALH-77003 chondrite (C3). Mem. Natl Inst. Polar Res., Spec. Issue, **25**, 34-65.

KITAMURA, M., ISOBE, H., WATANABE, S. and MORIMOTO, N. (1984a): Thermal history of relict pyroxene' in the Allende meteorite. Papers Presented to the Ninth Symposium on Antarctic Meteorites, 22-24 March 1984. Tokyo, Natl Inst. Polar Res., 50-51.

KITAMURA, M., YASUDA, M. WATANABE, S. and MORIMOTO, N. (1984b). Cooling history of pyroxene chondrules in the Yamato-74191 chondrite (L3); An electron microscopic study. Earth Planet. Sci. Lett., **63**, 189-201.

KUSHIRO, I. (1972): Determination of liquidus relations in synthetic silicate systems with electron probe analysis; The system forsterite-diopside-silica at 1 atmosphere. Am. Mineral., **57**, 1260-1271.

LOFGREN, G. and RUSSELL, W. J. (1986): Dynamic crystallization of chondrule melts of porphyritic and radial pyroxene composition. Geochim. Cosmochim. Acta, **50**, 1715-1726.

LONGHI, J. and BOUDREAU, A. E. (1980): The orthoenstatite liquidus field in the system forsterite-diopside-silica at one atmosphere. Am. Mineral., **65**, 563-573.

MCSWEEN, H. Y., Jr (1977a): Carbonaceous chondrites of the Ornans type; a metamorphic sequence. Geochim. Cosmochim. Acta, **41**, 477-491.

MCSWEEN, H. Y., Jr. (1977b): Petrographic variations among carbonaceous chondrites of the Vigarano type. Geochim. Cosmochim. Acta, **41**, 1777-1790.

MCSWEEN, H. Y., Jr. (1977c): Chemical and petrographic constraints on the origin of chondrules and inclusions in carbonaceous chondrites. Geochim. Cosmochim. Acta, **41**, 1843-1860.

MCSWEEN, H. Y., Jr., FRONABARGER. A. K. and DRIESE, S. G. (1983): Ferromagnesian chondrules in carbonaceous chondrites. Chondrules and Their Origins, ed. by E. A. KING. Houston, Lunar Planet. Inst., 195-209.

NAGAHARA, H. (1981): Evidence for secondary origin of chondrules. Nature, **292**, 135-136.

NAGAHARA, H. (1983): Chondrules formed through incomplete melting of the pre-existing mineral cluster and the origin of chondrules. Chondrules and Their Origins, ed. by E. A. KING. Houston, Lunar Planet. Inst., 211-222.

NAGAHARA, H. and KUSHIRO, I. (1982): Petrology of chondrules, inclusions and isolated olivine grains in ALH-77307 (CO3) chondrite. Mem. Natl Inst. Polar Res., Spec. Issue, **25**, 66-77.

NAKAMURA, Y. and KUSHIRO, I. (1970): Compositional relations of coexisting orthopyroxene, pigeonite and augite in a tholeiitic andesite from Hakone Volcano. Contrib. Mineral. Petrol., **26**, 265-275.

PAPIKE, J. J. (1980): Pyroxene mineralogy of the Moon and meteorites. Pyroxenes, ed. by C. T. PREWITT. Washington, D. C., Mineral. Soc. America, 495-525.

PECK, J. A. and WOOD, J. A. (1987): The origin of ferrous zoning in Allende chondrule olivines. Geochim. Cosmochim. Acta, **51**, 1503-1510.

RAMBALDI, E. R. (1981): Relict grains in chondrules. Nature, **293**, 558-561.

RUBIN, A. E. (1986): Elemental composition of major silisic phases in chondrules of unequilibrated chondritic meteorites. Meteoritics, **21**, 283-293.

RUBIN, A. E. and WASSON, J. T. (1986): Chondrules in the Murray CM2 meteorite and compositional differences between CM-CO and ordinary chondrules. Geochim. Cosmochim. Acta, **50**, 307–315.

RUBIN, A. E. and WASSON, J. T. (1987): Chondrules, matrix and coarse-grained rims in the Allende meteorite; Origin, interrelationships and possible precursor components. Geochim. Cosmochim. Acta, **51**, 1923–1937.

RUBIN, A. E. and WASSON, J. T. (1988): Chondrules and matrix in the Ornans CO_3 meteorite; Possible precursor components. Geochim. Cosmochim. Acta, **52**, 425–432.

SCOTT, E. R. D., TAYLOR, G. J., MAGGIORE, P. and MCKINEY, S. G. (1981): Three CO_3 chondrites from antarctica; comparison of carbonaceous and ordinary type 3 chondrites. Meteoritics, **16**, 385.

SEARS, D. W. G., GROSSMAN, J. N., MELCHER, C. L., ROSS, L. M. and MILLS, A. A. (1980): Measuring metamorphic history of unequilibrated ordinary chondrites. Nature, **287**, 791–795.

SIMON, S. B. and HAGGERTY, S. E. (1979): Petrography and olivine mineral chemistry of chondrules and inclusions in the Allende meteorite, Proc. Lunar Planet. Sci. Conf., 10th, 871–883.

TESHIMA, J. and WASSERBURG, G. J. (1985): Texture, metamorphism and origin of type A CAI's. Lunar and Planetary Science XVI. Houston, Lunar Planet. Inst., 855–856.

TOPEL-SCHADT, J. and MULLER, W. F. (1985): The submicroscopic structure of the unequilibrated ordinary chondrites Chainpur, Mezo-Madaras and Tieschitz; A transmission electron-microscopic study. Earth Planet. Sci. Lett., **74**, 1–12.

VAN SCHMUS, W. R. and HAYES, J. M. (1974): Chemical and petrographic correlation among carbonaceous chondrites. Geochim. Cosmochim. Acta, **38**, 47–64.

WARK, D. A. (1987): Plagioclase-rich inclusions in carbonaceous chondrite meteorites; Liquid condensates. Geochim. Cosmochim. Acta, **51**, 221–242.

WATANABE, S., KITAMURA, M. and MORIMOTO, N. (1986): Oscillatory zoning of pyroxenes in ALH-77214 (L3). Papers Presented to the Eleventh Symposium on Antarctic Meteorites, 25–27 March 1986. Tokyo, Natl Inst. Polar Res., 74–75.

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Appendix

Chemical composition of pyroxenes in chondrules in the investigated samples.

Allende

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
55.28	0.51	2.32	1.16	0.10	31.99	7.46	0.02	0.74	99.58
51.88	1.46	3.80	1.02	0.03	20.51	20.51	0.02	0.45	99.69
53.62	0.82	3.08	1.10	0.03	28.21	12.21	0.01	0.74	99.82
57.03	0.10	0.85	1.16	0.00	38.56	0.89	0.01	0.39	99.01
47.02	0.00	0.25	27.72	0.65	0.02	22.73	0.03	0.00	98.41
58.64	0.36	1.28	0.28	0.00	38.17	1.62	0.01	0.44	100.79
56.70	0.62	3.62	0.44	0.19	35.76	2.57	0.01	0.89	100.81
51.72	1.68	5.59	0.28	0.14	19.41	21.05	0.04	0.77	100.67
52.62	1.47	5.10	0.84	0.09	20.72	19.58	0.08	0.75	101.25
58.43	0.37	1.33	0.45	0.04	37.05	2.63	0.02	0.68	101.01
57.98	0.43	1.58	0.42	0.00	38.26	0.70	0.00	0.53	99.91
52.73	1.43	4.72	0.43	0.25	21.66	18.22	0.04	0.83	100.29
58.42	0.35	1.27	0.55	0.07	37.78	2.00	0.01	0.59	101.02
58.66	0.30	0.95	0.56	0.01	38.42	1.56	0.01	0.50	100.96
57.46	0.54	1.80	0.71	0.08	35.33	4.45	0.02	0.85	101.23
53.79	1.43	3.77	0.50	0.06	21.78	19.56	0.01	0.64	101.54
53.71	1.65	3.35	0.38	0.07	20.78	21.09	0.00	0.49	101.52
57.46	0.47	2.84	0.87	0.03	34.55	4.13	0.33	0.74	101.42
57.93	0.67	1.73	0.55	0.17	35.29	4.57	0.01	0.76	101.68
53.40	1.78	3.54	0.35	0.04	20.75	20.47	0.02	0.51	100.85
51.42	1.84	4.91	2.15	0.00	19.47	19.33	0.03	1.45	100.59
51.60	1.75	4.22	2.15	0.01	20.33	18.77	0.00	1.37	100.19
54.49	1.05	2.60	3.31	0.07	31.17	5.80	0.01	1.02	99.51
51.23	1.78	4.17	2.13	0.07	22.16	16.56	0.02	1.27	99.39
53.61	1.06	3.60	1.22	0.12	21.62	19.90	0.02	0.63	101.78
58.86	0.14	1.10	1.54	0.04	39.08	0.75	0.00	0.44	101.94

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
58.74	0.14	0.68	1.05	0.03	39.42	0.66	0.02	0.41	101.14
55.72	0.82	2.37	1.02	0.10	32.87	6.81	0.01	0.76	100.47
57.47	0.37	2.15	0.81	0.00	38.03	0.64	0.00	0.59	100.07
55.52	0.48	2.07	1.04	0.09	33.69	5.33	0.00	0.82	99.05
57.21	0.33	1.71	1.09	0.06	38.23	0.74	0.01	0.62	100.00
51.36	2.71	4.36	0.46	0.00	18.50	21.74	0.02	0.84	99.99
52.60	2.45	3.65	0.51	0.00	21.70	19.14	0.02	0.60	100.65
55.40	1.70	2.37	0.67	0.08	32.03	7.16	0.00	0.80	100.21
56.07	0.71	2.41	0.61	0.00	38.15	0.51	0.01	0.55	99.00
56.28	0.68	2.62	0.53	0.00	38.18	0.48	0.00	0.55	99.31
52.05	2.18	3.74	0.52	0.01	22.04	18.58	0.02	0.63	99.76
44.07	1.45	15.43	0.21	0.00	12.70	25.46	0.01	0.25	99.57
43.62	3.39	14.67	0.14	0.00	12.60	24.80	0.01	0.37	99.61
57.68	0.31	1.42	0.58	0.00	38.55	0.68	0.00	0.46	99.67
56.28	0.39	1.88	0.84	0.11	34.76	4.61	0.02	0.80	99.67
52.54	1.49	3.88	0.59	0.06	21.62	19.48	0.03	0.65	100.34
57.14	0.28	1.20	0.67	0.10	35.43	4.47	0.09	0.70	100.07
53.72	1.08	3.19	0.64	0.08	24.44	16.41	0.01	0.61	100.18
58.65	0.12	0.53	0.75	0.17	38.40	0.80	0.01	0.64	100.06
58.38	0.18	0.89	0.82	0.06	38.88	0.64	0.02	0.67	100.53
57.52	0.06	0.55	3.69	0.09	36.19	0.49	0.02	0.93	99.53
57.48	0.08	0.91	2.57	0.00	37.39	0.31	0.00	0.61	99.36
50.73	1.23	4.47	3.60	0.06	17.24	20.34	0.03	2.53	100.22
58.27	0.07	0.67	3.13	0.01	37.01	0.34	0.00	0.84	100.32
57.95	0.07	0.89	2.93	0.00	37.16	0.34	0.00	0.90	100.24
44.89	3.42	13.38	0.33	0.00	12.87	25.17	0.07	0.69	100.82
58.09	0.27	1.33	0.80	0.00	38.01	0.59	0.00	0.63	99.72
57.91	0.17	0.85	0.62	0.00	38.09	0.52	0.00	0.37	98.55

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
58.87	0.13	0.67	0.68	0.00	39.31	0.45	0.01	0.38	100.50
58.23	0.22	1.21	0.57	0.00	38.64	0.54	0.01	0.54	99.94
47.00	1.29	12.98	0.30	0.12	15.65	21.49	0.04	1.54	100.40
53.30	0.64	4.58	0.50	0.15	23.82	16.39	0.03	1.07	100.49
56.60	0.34	2.23	0.48	0.13	37.20	0.81	0.00	1.09	98.87
48.84	1.38	9.53	0.41	0.10	17.20	21.09	0.04	1.38	99.97
55.70	0.36	3.53	0.60	0.07	35.18	2.01	0.05	1.07	98.56
52.18	1.66	2.90	0.49	0.10	21.41	19.23	0.01	0.79	98.75
55.82	0.60	2.21	0.53	0.13	34.59	4.04	0.01	0.76	98.69
53.85	1.76	2.57	0.61	0.20	21.76	18.90	0.04	0.98	100.66
57.02	0.66	2.32	0.52	0.13	34.70	4.07	0.02	0.91	100.34
54.13	1.60	2.82	0.59	0.20	22.01	19.07	0.01	0.84	101.27
48.46	1.83	10.68	0.56	0.31	16.35	21.37	0.08	1.39	101.03
58.59	0.39	1.69	0.58	0.11	38.73	0.60	0.02	0.73	101.43
47.52	1.60	11.95	0.45	0.26	16.10	20.77	0.07	1.40	100.12
48.26	1.76	10.84	0.64	0.25	16.37	20.68	0.09	1.45	100.33
55.71	0.37	0.92	0.51	0.08	22.52	20.32	0.02	0.38	100.82
55.33	0.52	1.35	0.86	0.16	22.30	19.61	0.05	0.60	100.77
54.99	0.72	1.67	0.57	0.07	21.55	21.07	0.02	0.41	101.07
55.57	0.65	1.57	0.72	0.06	22.43	19.76	0.01	0.56	101.33
58.50	0.18	0.83	1.11	0.16	36.91	2.56	0.01	0.74	101.01
58.77	0.23	0.81	0.63	0.10	37.22	2.62	0.01	0.75	101.12
55.76	0.43	2.99	2.76	0.20	31.75	5.24	0.00	1.39	100.53
55.06	0.80	3.30	3.20	0.18	30.62	6.33	0.02	1.27	100.79
57.07	0.41	3.43	0.82	0.00	36.46	2.30	0.00	0.93	101.41
57.65	0.41	2.28	0.86	0.03	37.14	1.94	0.00	0.82	101.12

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SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
49.14	1.28	10.37	0.43	0.23	17.51	20.31	0.00	1.33	100.60
58.48	0.30	1.52	0.49	0.09	38.48	1.29	0.00	0.64	101.29
58.31	0.37	1.83	0.63	0.12	38.76	0.69	0.00	0.80	101.50
50.06	1.32	8.65	0.37	0.17	18.32	20.77	0.00	1.35	101.01
52.71	1.11	2.25	0.44	0.09	22.28	19.84	0.00	0.57	99.29
53.00	0.78	1.73	0.57	0.11	23.93	18.49	0.00	0.50	99.12
55.41	0.51	1.39	0.60	0.16	37.20	2.83	0.00	0.83	98.93
58.08	0.10	0.92	3.11	0.16	37.53	0.50	0.00	0.78	101.19
52.54	0.66	5.48	0.65	0.40	21.74	17.41	0.00	1.11	99.98
58.65	0.17	0.80	1.00	0.07	39.12	0.42	0.00	0.42	100.64
59.66	0.13	0.84	0.98	0.14	38.90	0.57	0.00	0.55	101.76
55.26	0.63	3.04	1.01	0.18	25.39	14.97	0.00	1.01	101.49
58.94	0.25	0.88	1.04	0.16	38.18	0.80	0.00	0.80	101.05
58.33	0.09	0.59	2.18	0.35	37.82	0.51	0.00	0.76	100.64
58.41	0.08	0.58	2.03	0.38	38.11	0.47	0.00	0.74	100.79
55.85	0.73	1.34	0.69	0.29	23.31	18.44	0.00	0.84	101.49
58.27	0.24	1.53	0.85	0.06	38.83	0.49	0.00	0.57	100.85
53.79	1.27	2.98	0.83	0.21	22.41	18.50	0.00	0.93	100.92
58.07	0.21	1.63	0.85	0.11	38.84	0.51	0.00	0.75	100.97
58.08	0.14	1.19	1.29	0.24	38.01	0.52	0.00	0.79	100.25
59.76	0.08	0.49	1.29	0.07	38.82	0.30	0.00	0.49	101.29
57.75	0.23	2.37	1.07	0.33	36.88	1.88	0.00	1.31	101.82
57.59	0.21	2.26	1.18	0.45	36.21	2.16	0.00	1.21	101.27
58.65	0.29	1.52	0.66	0.11	37.15	2.65	0.00	0.68	101.72
54.25	1.51	3.52	0.71	0.18	22.23	18.24	0.00	0.72	101.36
59.44	0.14	0.85	0.80	0.06	39.19	0.54	0.00	0.42	101.45

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
56.49	0.39	1.24	1.08	0.33	25.61	15.51	0.00	0.65	101.29
59.24	0.14	0.79	0.86	0.02	39.06	0.56	0.00	0.40	101.08
57.54	0.33	2.53	0.67	0.12	36.91	2.06	0.00	0.81	100.96
58.66	0.22	1.29	0.71	0.06	37.50	1.62	0.00	0.64	100.71
59.03	0.04	0.26	2.77	0.16	37.35	0.14	0.00	0.52	100.29
58.85	0.04	0.26	2.71	0.17	37.57	0.15	0.00	0.51	100.25
50.57	0.85	2.12	14.71	0.38	8.64	21.47	0.73	0.30	99.76

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SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
59.04	0.10	0.70	0.57	0.09	38.54	0.55	0.00	0.51	100.11
58.86	0.11	0.75	1.03	0.10	37.92	0.58	0.01	0.46	99.81
58.94	0.15	1.07	0.64	0.11	39.05	0.55	0.00	0.54	101.04
58.59	0.22	1.41	0.51	0.14	38.20	0.70	0.00	0.66	100.43
57.34	0.23	1.44	1.24	0.13	37.33	0.84	0.02	0.74	99.31
57.21	0.16	1.06	0.59	0.12	38.03	0.63	0.00	0.55	98.35
55.04	0.51	2.07	0.47	0.38	23.90	17.27	0.00	0.94	100.58
58.22	0.17	1.72	0.65	0.12	36.86	2.18	0.00	0.70	100.63
57.44	0.27	2.67	0.50	0.20	36.05	2.55	0.01	0.95	100.64
55.26	0.40	1.23	0.42	0.38	22.01	19.67	0.01	0.65	100.02
54.53	0.65	2.21	0.31	0.32	21.17	20.10	0.02	0.78	100.10
58.90	0.10	0.64	0.57	0.08	38.74	0.65	0.00	0.47	100.15
58.97	0.17	0.92	0.44	0.07	38.89	0.58	0.00	0.45	100.49
53.96	1.12	2.76	0.36	0.38	19.74	21.68	0.01	0.98	100.99
58.03	0.22	1.41	0.54	0.15	38.46	0.58	0.00	0.52	99.90

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
49.50	1.05	9.34	0.35	0.32	19.25	18.30	0.11	1.02	99.24
57.74	0.25	1.40	0.60	0.17	38.35	0.51	0.00	0.58	99.60
58.56	0.13	0.64	0.78	0.07	38.67	0.33	0.00	0.50	99.68
49.37	1.22	9.14	0.25	0.36	17.92	20.43	0.02	0.92	99.62
57.15	0.28	1.39	0.63	0.23	37.60	0.88	0.03	0.62	98.80
58.97	0.12	0.53	0.50	0.03	39.18	0.45	0.07	0.45	100.30
59.06	0.15	0.61	0.51	0.11	38.55	0.56	0.29	0.64	100.48
49.67	1.09	9.23	0.23	0.23	17.63	20.65	0.01	1.07	99.81
54.80	0.38	1.50	1.29	2.90	23.91	13.68	0.06	1.74	100.26
58.49	0.07	0.40	2.12	0.67	37.24	0.51	0.01	0.69	100.20
58.66	0.05	0.43	1.70	0.38	37.66	0.58	0.03	0.58	100.06
58.81	0.09	0.47	1.41	0.32	38.09	0.40	0.03	0.61	100.22
59.26	0.04	0.35	1.30	0.39	38.26	0.35	0.02	0.63	100.61
51.55	1.08	7.03	0.20	0.13	18.93	20.66	0.01	0.99	100.57
55.30	0.51	2.96	0.38	0.21	25.67	15.34	0.01	1.02	101.39
58.26	0.17	0.95	0.46	0.06	38.65	0.55	0.00	0.54	99.64
49.78	1.40	7.85	0.34	0.09	17.61	21.48	0.04	1.10	99.69
58.48	0.18	0.92	0.51	0.12	38.69	0.65	0.00	0.57	100.11
51.57	1.06	3.20	2.20	0.65	18.95	19.47	0.01	1.70	98.80
57.79	0.11	0.89	1.57	0.11	37.89	0.48	0.00	0.66	99.49
55.64	0.21	1.31	4.66	0.49	32.62	2.45	0.01	1.23	98.61
53.86	0.58	2.13	3.05	0.56	22.17	16.11	0.03	1.32	99.81
51.03	1.75	3.18	4.47	0.87	17.88	18.75	0.08	1.95	99.93
57.61	0.14	1.12	2.05	0.09	36.79	0.61	0.00	0.85	99.25
52.33	1.18	2.79	1.16	0.54	20.31	19.31	0.07	1.39	99.08
57.73	0.21	1.02	0.55	0.08	38.57	0.46	0.00	0.51	99.13
56.93	0.13	0.80	0.52	0.10	38.83	0.45	0.00	0.47	98.23
50.46	0.09	0.33	29.84	0.40	13.85	2.77	0.30	0.81	98.84

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
51.05	0.02	0.28	27.93	0.28	17.01	0.76	0.14	0.66	98.14
55.53	0.35	1.04	0.47	0.30	23.29	18.23	0.02	0.63	99.86
58.07	0.34	1.35	0.66	0.21	37.94	0.77	0.00	0.92	100.26
59.03	0.14	1.06	0.55	0.07	38.90	0.51	0.00	0.55	100.80
53.87	0.85	1.95	0.53	0.35	20.17	20.88	0.03	0.69	99.31
58.18	0.24	0.94	0.53	0.07	38.61	0.52	0.01	0.51	99.61
57.21	0.25	1.38	0.86	0.13	38.17	0.71	0.00	0.44	99.15
52.34	0.91	4.34	0.18	0.35	18.30	22.01	0.02	0.87	99.31
58.44	0.19	1.01	1.06	0.06	38.70	0.53	0.00	0.35	100.35
53.42	0.81	4.29	0.21	0.39	19.07	21.78	0.03	0.88	100.86
57.60	0.28	1.22	0.41	0.06	38.49	0.46	0.00	0.45	98.97
57.45	0.22	0.99	1.19	0.12	38.17	0.72	0.00	0.42	99.28
58.00	0.15	0.74	1.27	0.06	38.16	0.73	0.01	0.40	99.52
51.21	1.21	6.20	0.54	0.94	18.17	19.11	0.24	1.96	99.57
58.37	0.15	0.68	0.83	0.11	38.68	0.62	0.00	0.51	99.94
58.34	0.13	0.79	1.69	0.18	37.66	0.80	0.16	0.56	100.31
49.58	0.89	9.02	0.37	0.37	19.25	18.44	0.01	1.72	99.64
58.07	0.19	1.04	0.61	0.10	38.11	1.49	0.00	0.67	100.28
58.09	0.20	1.15	0.41	0.04	38.46	0.53	0.01	0.59	99.48
58.51	0.09	0.69	0.42	0.19	38.73	0.71	0.16	0.62	100.11
58.47	0.15	0.94	0.48	0.08	39.10	0.38	0.02	0.52	100.12
48.09	1.41	3.31	18.34	0.22	5.06	21.43	0.78	0.12	98.77
58.08	0.24	0.98	1.52	0.10	37.46	1.13	0.13	0.67	100.30

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SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
52.22	0.52	1.17	10.20	0.31	11.71	21.55	1.04	1.16	99.88
53.30	0.16	0.73	7.69	0.32	14.01	20.52	1.04	2.16	99.92
51.08	0.58	1.22	8.81	0.30	12.46	20.71	1.39	2.09	98.64
53.67	0.36	0.90	8.54	0.41	13.28	20.31	1.19	1.79	100.44
46.71	1.24	10.58	1.30	0.38	16.02	20.23	0.03	2.91	99.39
56.68	0.10	1.03	2.48	0.21	36.97	0.51	0.02	1.08	99.07
48.25	0.82	8.27	1.79	0.37	19.67	16.94	0.01	2.49	98.60
58.87	0.09	0.67	2.18	0.23	37.59	0.41	0.00	0.98	101.00
45.06	0.71	13.52	0.49	0.20	16.26	20.55	0.00	1.59	98.38
49.40	0.38	12.51	1.02	0.24	32.58	1.97	0.00	1.27	99.37
48.99	0.57	11.09	0.97	0.26	32.31	2.17	0.00	1.67	98.02
48.92	1.02	11.19	0.65	0.20	17.47	19.73	0.00	1.93	101.11
58.78	0.22	1.27	1.15	0.07	38.60	0.41	0.00	0.76	101.27
58.67	0.21	1.40	0.82	0.11	38.86	0.58	0.00	0.91	101.56
58.89	0.08	0.63	1.85	0.35	37.81	0.45	0.00	0.70	100.74
58.16	0.10	0.59	2.43	0.35	37.39	0.55	0.00	0.71	100.27
49.03	1.14	8.63	1.29	0.47	18.00	18.88	0.03	3.10	100.56
58.08	0.10	0.87	1.73	0.41	37.77	0.43	0.00	0.88	100.27
58.71	0.10	0.69	1.68	0.29	38.07	0.42	0.00	0.69	100.65
57.58	0.04	0.27	4.08	0.27	37.38	0.21	0.02	0.63	100.48
57.22	0.02	0.21	2.16	0.17	38.65	0.14	0.00	0.60	99.18
58.94	0.06	0.25	2.10	0.16	38.73	0.16	0.00	0.48	100.88
59.30	0.04	0.23	2.07	0.22	38.27	0.19	0.00	0.54	100.87
59.24	0.11	0.78	1.46	0.21	38.20	0.93	0.01	0.56	101.52
59.33	0.08	0.62	1.11	0.16	39.24	0.48	0.00	0.58	101.59
59.25	0.09	0.55	1.02	0.04	39.16	0.38	0.00	0.50	100.99

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
50.26	1.21	8.52	0.72	0.21	18.58	19.60	0.00	1.84	100.94
52.50	0.48	4.17	2.58	1.09	22.18	14.98	0.04	2.21	100.22
58.05	0.08	0.70	2.68	0.42	37.14	0.42	0.00	1.00	100.49
58.71	0.09	0.55	2.60	0.28	37.73	0.30	0.00	0.79	101.05
51.91	0.51	4.83	2.79	1.07	21.67	14.91	0.07	2.48	100.23
56.90	0.14	1.32	3.48	1.10	33.21	2.99	0.00	1.46	100.61
57.74	0.11	0.98	3.31	0.74	35.70	0.63	0.00	1.04	100.26
59.02	0.08	0.41	2.58	0.23	38.12	0.24	0.00	0.67	101.35
58.86	0.06	0.38	2.60	0.18	38.05	0.22	0.00	0.62	100.97
50.14	0.83	7.39	1.32	0.23	19.43	17.88	0.02	2.73	99.96
55.03	0.43	4.76	2.11	0.32	32.71	3.17	0.00	2.51	101.04
59.18	0.07	0.56	1.43	0.14	38.14	0.30	0.00	0.82	100.64
48.39	1.25	9.98	1.15	0.25	16.52	20.20	0.01	2.91	100.65
53.91	0.53	3.77	1.69	0.34	23.50	15.00	0.02	1.80	100.54
58.75	0.11	0.53	1.73	0.14	38.04	0.21	0.00	0.88	100.39
58.99	0.08	0.40	1.63	0.15	38.35	0.20	0.00	0.94	100.74
44.30	3.47	14.43	0.14	0.03	12.57	24.98	0.00	0.48	100.40
49.93	0.77	6.28	1.35	1.23	18.73	17.74	0.03	3.31	99.37
57.18	0.10	0.85	2.80	0.13	37.45	0.41	0.00	0.85	99.77
58.70	0.29	1.33	0.43	0.08	38.56	0.45	0.00	0.49	100.32
53.57	0.86	3.85	1.16	0.20	22.22	17.61	0.00	0.74	100.20
58.45	0.22	0.95	0.49	0.13	38.24	1.05	0.00	0.59	100.11
54.18	1.01	2.62	0.38	0.14	20.98	20.11	0.00	0.50	99.93
52.82	0.49	2.98	1.72	1.71	19.28	18.66	0.08	2.21	99.94
57.13	0.07	0.89	3.36	0.17	36.57	0.29	0.02	0.97	99.46
52.18	0.62	3.73	1.61	2.18	19.08	17.87	0.09	2.47	99.83
58.51	0.12	0.70	2.01	0.56	37.03	0.56	0.00	1.53	101.01
58.91	0.05	0.27	1.72	0.17	37.82	0.36	0.00	0.87	100.17

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
58.40	0.14	0.76	1.17	0.07	37.84	0.58	0.00	0.75	99.70
58.21	0.12	1.00	1.95	0.10	37.45	0.66	0.03	0.69	100.21
58.78	0.26	1.23	0.36	0.11	38.80	0.57	0.00	0.64	100.75
58.74	0.26	1.33	0.52	0.15	38.77	0.66	0.00	0.66	101.09
51.21	1.01	6.73	0.37	0.31	19.05	20.07	0.01	1.24	100.00
58.39	0.23	1.34	0.47	0.13	38.52	0.58	0.00	0.63	100.29
51.36	1.11	6.81	0.44	0.31	19.57	19.45	0.00	1.22	100.27
55.25	0.59	1.44	1.21	0.63	24.07	15.96	0.00	1.46	100.61
53.05	1.32	3.69	0.79	0.44	20.33	19.25	0.00	1.79	100.66
58.86	0.14	0.87	0.85	0.16	39.18	0.53	0.00	0.74	101.34
58.81	0.14	0.87	0.87	0.14	38.84	0.50	0.00	0.74	100.91

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SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
58.78	0.36	1.33	0.48	0.08	39.25	0.66	0.00	0.43	101.37
50.33	1.70	8.45	0.59	0.10	18.62	20.44	0.00	0.84	101.08
55.46	0.66	2.76	0.61	0.14	25.85	15.09	0.00	0.60	101.18
41.67	0.11	0.38	0.18	0.03	57.16	0.76	0.00	0.07	100.35
53.15	0.69	3.01	0.73	0.32	20.82	19.80	0.01	1.05	99.56
53.61	0.90	3.63	0.64	0.28	21.74	18.30	0.00	1.12	100.21
58.02	0.13	0.75	0.62	0.06	38.86	0.50	0.00	0.54	99.46
49.59	1.33	9.02	0.50	0.57	17.84	19.61	0.02	1.82	100.29
57.20	0.21	1.10	0.54	0.10	38.83	0.58	0.00	0.74	99.29
55.35	0.47	2.36	0.73	0.65	25.13	15.25	0.00	1.17	101.10
58.40	0.20	1.11	0.45	0.10	38.35	0.52	0.00	0.67	99.78

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
58.20	0.14	1.32	3.38	0.22	35.62	1.67	0.00	1.01	101.55
57.41	0.07	0.82	3.14	0.19	35.68	1.11	0.00	0.85	99.27
51.66	2.05	3.31	2.60	0.41	18.90	19.74	0.02	1.37	100.06
57.96	0.23	1.89	0.53	0.20	37.38	2.01	0.00	0.73	100.93
57.78	0.21	1.44	0.52	0.10	37.43	1.89	0.00	0.55	99.92
50.91	0.68	7.61	0.48	0.43	19.74	18.94	0.00	1.28	100.06
57.39	0.26	2.96	0.51	0.20	36.69	2.31	0.00	0.89	101.20
54.49	0.56	2.32	0.59	0.85	20.44	20.19	0.01	1.14	100.59
58.01	0.27	1.42	0.77	0.46	38.08	0.83	0.00	0.93	100.76
54.42	0.80	2.69	0.63	0.29	23.09	17.74	0.00	0.97	100.63
58.96	0.18	0.96	0.42	0.09	39.11	0.46	0.00	0.53	100.70
53.71	1.19	2.66	2.57	0.93	20.56	18.02	0.03	1.34	101.01
58.38	0.14	0.96	2.57	0.21	37.43	0.47	0.00	0.71	100.87
55.23	0.79	2.02	0.51	0.30	21.33	20.80	0.00	0.66	101.62
59.00	0.19	0.85	0.53	0.06	39.22	0.63	0.00	0.50	100.98
54.77	1.33	1.90	0.74	0.63	23.24	17.24	0.00	0.99	100.83
58.40	0.21	0.67	0.61	0.10	39.14	0.68	0.00	0.51	100.30
50.12	1.15	9.35	0.31	0.06	18.89	19.62	0.00	0.94	100.44
59.45	0.08	0.53	0.34	0.04	39.63	0.32	0.00	0.45	100.83
51.87	0.53	5.11	1.85	0.08	20.47	17.63	0.00	1.82	99.35
57.84	0.12	0.95	3.03	0.09	36.36	0.99	0.00	0.90	100.28
57.05	0.10	1.41	5.01	0.20	34.33	0.95	0.00	1.51	100.57
58.85	0.19	0.88	0.56	0.07	38.86	0.48	0.00	0.49	100.38
53.42	0.88	3.61	0.81	0.34	19.24	21.75	0.03	0.98	101.06
58.77	0.16	0.89	0.62	0.11	39.06	0.67	0.00	0.56	100.84
53.55	1.02	4.11	0.71	0.37	19.61	21.50	0.02	0.95	101.84

Semarkona

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
53.32	0.83	2.92	3.05	0.32	18.52	20.11	0.59	0.72	100.38
56.51	0.12	0.91	8.29	0.52	30.86	2.58	0.03	1.02	100.85
56.23	0.15	0.96	6.35	0.57	31.65	2.78	0.04	1.04	99.78
56.96	0.22	0.88	5.98	0.52	32.99	1.64	0.07	0.94	100.21
56.86	0.23	0.91	6.06	0.48	33.21	1.67	0.06	1.04	100.51
53.91	0.75	3.49	2.20	0.28	20.01	19.70	0.30	1.07	101.71
54.61	0.45	1.94	3.84	0.34	19.98	18.55	0.29	1.29	101.28
57.15	0.09	0.51	6.61	0.50	32.19	2.95	0.03	0.91	100.94
57.03	0.14	0.80	5.23	0.68	33.55	2.43	0.03	0.98	100.87
55.33	0.27	0.96	12.19	0.45	28.81	1.54	0.10	0.59	100.23
55.46	0.29	0.94	12.24	0.42	29.00	1.59	0.11	0.63	100.68
55.54	0.08	0.24	12.33	0.85	28.86	1.06	0.04	1.02	100.02
55.13	0.02	0.37	12.78	0.72	29.07	1.60	0.03	0.61	100.33
48.61	1.24	8.01	1.43	0.18	18.27	20.36	0.02	0.89	99.02
58.48	0.09	0.56	1.11	0.09	39.34	0.49	0.00	0.55	100.70
41.68	0.02	0.04	0.87	0.10	57.07	0.18	0.00	0.54	100.50
50.39	1.30	8.74	0.56	0.14	18.48	20.64	0.01	0.92	101.15
55.06	0.07	0.26	13.50	0.89	27.45	2.04	0.08	1.02	100.37
56.03	0.03	0.20	10.74	0.47	31.78	0.20	0.00	0.69	100.15
54.15	0.24	0.76	9.39	0.61	17.70	16.46	0.56	1.47	101.32
55.30	0.05	0.27	13.48	0.81	27.11	2.64	0.08	0.94	100.67
56.62	0.02	0.42	10.34	0.50	31.70	0.25	0.03	0.65	100.53
53.45	0.10	1.19	17.25	0.79	24.88	2.23	0.02	1.03	100.94
56.37	0.04	0.73	11.11	0.36	31.59	0.36	0.00	0.71	101.27
50.43	0.79	5.91	3.84	1.05	16.52	18.90	0.20	3.18	100.82
57.69	0.14	1.20	4.03	0.76	35.04	0.57	0.02	1.23	100.66

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
58.51	0.10	0.60	3.62	0.59	36.29	0.40	0.00	0.91	101.02
52.87	0.05	0.33	23.14	1.12	19.94	2.34	0.02	1.05	100.86
54.78	0.00	0.13	17.37	0.78	26.52	0.31	0.01	0.77	100.67
55.49	0.00	0.17	15.04	0.59	28.26	0.20	0.02	0.78	100.55
50.00	2.88	4.09	3.49	0.56	18.40	18.93	0.03	2.06	100.44
53.96	1.25	2.44	3.14	0.31	22.17	17.09	0.00	0.96	101.33
56.45	0.41	1.90	3.69	0.19	31.06	6.33	0.00	1.16	101.19
55.97	0.27	4.08	3.17	0.15	34.56	2.05	0.00	1.35	101.60
55.77	0.64	2.54	3.78	0.27	29.94	7.72	0.00	1.22	101.87
52.23	0.43	2.98	4.89	1.02	19.16	17.32	0.19	2.23	100.45
56.01	0.08	0.70	8.34	1.18	30.20	2.73	0.01	1.49	100.75
58.39	0.04	0.27	4.59	0.33	36.87	0.21	0.00	0.63	101.32
53.84	0.28	1.16	8.94	0.54	18.68	15.56	0.44	1.89	101.33
54.02	0.28	1.16	9.52	0.48	18.79	15.09	0.47	1.85	101.66
55.60	0.08	0.41	12.60	0.67	27.96	2.51	0.05	1.31	101.18
50.60	0.84	1.35	20.29	0.69	14.76	10.18	0.03	0.34	99.08
49.66	0.58	5.87	11.87	0.47	16.35	14.28	0.05	0.95	100.07
52.61	0.19	2.67	15.95	0.58	24.31	2.73	0.00	1.30	100.34
51.34	0.29	5.10	15.78	0.53	23.59	2.41	0.00	1.67	100.71
53.67	0.13	2.19	13.72	0.46	26.18	2.08	0.00	1.29	99.71
51.59	0.60	3.76	3.48	0.78	17.14	19.55	0.42	3.07	100.40
56.01	0.01	0.80	5.56	0.96	32.45	2.45	0.02	1.72	99.99
57.47	0.05	0.41	3.62	0.39	36.47	0.31	0.00	0.82	99.53
51.53	0.49	3.43	4.32	1.04	18.46	17.76	0.31	2.86	100.19
52.46	0.45	2.72	5.00	1.14	20.68	14.95	0.26	2.47	100.14
55.11	0.11	1.29	6.19	1.14	29.77	4.53	0.05	1.81	100.00
58.13	0.10	0.52	4.23	0.59	36.08	0.46	0.00	1.01	101.12
58.77	0.04	0.40	3.77	0.36	36.86	0.26	0.00	0.70	101.15

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
58.55	0.06	0.34	3.83	0.46	36.79	0.32	0.00	0.81	101.15
53.04	0.47	3.04	4.32	1.01	19.57	16.99	0.35	2.46	101.25
52.04	0.66	2.70	2.87	0.33	20.06	18.78	0.35	1.31	99.09
55.84	0.11	0.79	7.17	0.40	31.75	2.91	0.08	0.96	100.00
55.21	0.28	0.40	12.62	0.39	29.34	1.74	0.06	0.42	100.45
54.09	0.32	1.84	4.81	0.41	21.50	15.94	0.35	1.55	100.81
53.24	0.62	2.37	3.58	0.36	19.41	19.45	0.40	1.42	100.85
54.01	0.41	1.90	4.29	0.34	21.40	16.41	0.37	1.69	100.82
66.97	0.51	13.94	5.85	0.16	0.84	5.28	5.37	0.00	98.92
53.59	0.22	1.54	8.70	1.17	27.31	5.12	0.07	1.70	99.42
55.92	0.10	0.69	8.15	1.08	29.98	2.87	0.05	1.43	100.25
57.68	0.06	0.41	5.53	0.45	35.13	0.28	0.03	0.73	100.31
58.42	0.03	0.16	4.34	0.25	36.62	0.16	0.02	0.51	100.52

Krymka

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
52.72	0.28	1.44	7.57	1.41	18.40	15.42	0.19	1.97	99.40
54.79	0.07	0.48	9.92	1.47	27.85	2.37	0.04	1.76	98.74
57.38	0.01	0.17	5.33	0.37	35.14	0.20	0.01	0.59	99.20
56.70	0.00	0.31	7.36	0.77	32.78	0.37	0.03	0.99	99.30
57.84	0.00	0.14	5.69	0.43	35.00	0.12	0.01	0.59	99.81
52.52	0.36	2.42	8.39	1.26	18.07	14.52	0.25	2.34	100.11
55.19	0.08	0.70	10.21	1.43	27.58	2.22	0.03	1.79	99.23
57.69	0.01	0.20	5.19	0.31	35.11	0.17	0.03	0.56	99.27
57.89	0.02	0.10	4.85	0.31	35.28	0.14	0.01	0.55	99.14

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
48.64	0.75	11.07	0.31	0.22	17.13	20.20	0.05	1.02	99.38
58.06	0.19	1.38	0.70	0.11	38.16	0.65	0.02	0.56	99.85
58.29	0.25	1.37	0.48	0.08	38.34	0.50	0.01	0.49	99.80
49.64	1.27	9.25	0.34	0.11	18.13	20.08	0.03	0.92	99.76
58.65	0.14	0.71	0.53	0.05	38.81	0.57	0.03	0.55	100.03
58.86	0.12	0.65	0.60	0.01	38.80	0.41	0.00	0.41	99.86
51.82	0.62	3.88	2.09	0.07	19.49	19.66	0.01	1.45	99.09
52.89	0.58	2.91	0.88	0.00	21.14	19.71	0.03	1.01	99.15
55.79	0.13	1.10	5.15	0.17	32.89	2.66	0.02	0.93	98.83
56.29	0.11	1.03	3.83	0.09	34.56	2.55	0.01	0.86	99.33
56.20	0.25	1.74	2.08	0.00	35.10	2.75	0.01	1.09	99.22
50.31	0.62	5.60	2.51	0.99	18.92	17.00	0.23	2.71	98.90
55.89	0.20	1.82	3.67	1.25	30.86	4.28	0.05	1.83	99.84
57.72	0.10	0.70	3.10	0.63	35.98	0.51	0.02	1.07	99.83
58.49	0.05	0.33	2.78	0.26	36.90	0.19	0.00	0.61	99.60
53.15	0.35	2.11	4.20	0.80	19.49	16.46	0.39	1.96	98.90
57.35	0.07	0.67	4.84	0.43	34.03	0.90	0.06	0.79	99.14
57.34	0.05	0.38	5.47	0.66	34.10	0.46	0.03	1.00	99.48
54.97	0.14	0.94	8.33	1.38	28.05	4.05	0.06	1.14	99.06
57.58	0.03	0.22	5.44	0.30	35.40	0.15	0.02	0.66	99.79
50.55	0.87	5.43	1.27	1.15	18.21	19.00	0.22	2.52	99.22
58.26	0.07	0.48	1.68	0.30	37.47	0.38	0.01	0.56	99.23
58.32	0.08	0.49	1.66	0.42	37.52	0.40	0.01	0.69	99.58
53.74	0.07	0.53	13.26	0.64	23.93	4.53	0.17	1.22	98.09
55.70	0.03	0.21	11.27	0.54	29.80	0.72	0.06	0.86	99.19
54.78	0.03	0.35	13.80	0.63	26.72	1.69	0.10	1.08	99.17
51.71	0.32	2.49	8.04	1.17	18.13	14.96	0.24	2.29	99.35
54.82	0.07	0.65	10.38	1.39	28.33	2.06	0.05	1.83	99.57

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
57.50	0.00	0.23	5.60	0.38	35.55	0.16	0.04	0.73	100.19
58.57	0.01	0.12	4.14	0.21	36.95	0.10	0.02	0.28	100.41
50.43	0.77	6.03	3.46	0.44	20.10	18.08	0.08	0.95	100.33
59.23	0.16	0.94	0.64	0.07	39.43	0.58	0.03	0.49	101.55
59.07	0.20	1.28	0.48	0.04	39.58	0.49	0.02	0.50	101.66
51.04	0.91	7.79	0.52	0.05	18.96	20.75	0.04	0.83	100.89
59.11	0.23	1.33	0.62	0.06	39.45	0.68	0.02	0.49	101.98
59.55	0.17	0.85	0.64	0.00	39.84	0.39	0.02	0.42	101.88
56.55	0.31	2.80	3.71	0.12	33.97	2.59	0.02	1.40	101.46
51.81	0.59	4.76	3.23	1.22	19.89	16.37	0.24	2.59	100.69
58.71	0.03	0.31	2.88	0.28	38.10	0.24	0.03	0.57	101.16
54.32	0.29	1.75	4.44	0.77	22.28	14.61	0.34	1.81	100.61
58.03	0.05	0.40	4.43	0.41	36.33	0.63	0.04	1.02	101.34
57.80	0.05	0.38	4.54	0.58	35.35	0.81	0.04	1.06	100.60
55.89	0.13	0.72	7.67	1.69	29.09	3.68	0.05	1.33	100.26
53.50	0.13	0.84	10.97	0.48	20.79	11.28	0.34	1.44	99.77
56.19	0.04	0.22	11.81	0.56	30.51	0.69	0.05	0.73	100.80
58.15	0.04	0.27	6.10	0.43	34.83	0.29	0.01	0.52	100.65
58.19	0.04	0.20	5.73	0.44	35.09	0.25	0.01	0.38	100.33
53.61	0.48	1.37	6.19	0.71	17.52	17.31	0.59	1.16	98.94
53.94	0.24	1.05	6.66	0.84	20.85	13.42	0.46	1.17	98.64
56.49	0.02	0.40	6.87	0.53	33.23	0.44	0.04	0.57	98.59
49.21	1.31	8.61	0.38	0.38	18.01	20.10	0.04	0.87	98.89
57.40	0.31	1.51	0.48	0.12	38.67	0.55	0.00	0.36	99.41
57.67	0.24	1.28	0.83	0.09	38.09	0.51	0.00	0.32	99.03
44.48	1.54	16.03	3.23	0.33	13.41	20.25	0.02	0.09	99.39
45.49	1.05	15.30	4.00	0.39	14.50	18.70	0.00	0.06	99.49
47.39	0.53	15.49	6.78	0.47	27.34	1.37	0.00	0.06	99.43

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
52.76	0.25	1.01	11.62	1.14	18.02	12.57	0.29	0.94	98.59
55.20	0.03	0.29	13.05	0.77	28.39	0.65	0.01	0.49	98.87
50.12	0.91	7.93	0.89	0.66	18.38	19.21	0.06	1.24	99.39
57.22	0.20	1.20	1.12	0.30	37.96	0.54	0.00	0.56	99.10
58.32	0.14	0.85	1.05	0.16	38.02	0.37	0.00	0.37	99.27
49.24	1.52	9.14	0.79	0.24	18.50	19.19	0.05	0.84	99.50

Chainpur

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
57.03	0.02	0.21	8.73	0.36	32.87	0.36	0.00	0.73	100.29
57.12	0.00	0.14	7.38	0.36	33.62	0.24	0.00	0.57	99.42
56.97	0.05	0.21	7.80	0.64	32.64	0.48	0.00	0.82	99.60
57.30	0.03	0.20	7.65	0.55	33.54	0.44	0.02	0.94	100.67
55.68	0.04	0.31	9.37	0.87	30.85	0.88	0.00	1.22	99.22
56.65	0.05	0.24	7.90	0.88	32.36	0.93	0.01	0.69	99.70
53.33	0.22	0.78	7.99	1.05	18.61	15.41	0.38	1.32	99.08
57.07	0.03	0.15	7.23	0.30	33.87	0.26	0.00	0.53	99.43
57.08	0.03	0.14	6.91	0.37	34.06	0.18	0.00	0.46	99.22
53.88	0.21	0.67	7.87	1.21	20.27	13.74	0.37	1.45	99.66
57.13	0.00	0.01	7.63	0.45	33.65	0.36	0.00	0.59	99.83
56.78	0.03	0.23	8.46	0.69	32.24	0.63	0.00	0.97	100.02
52.27	0.77	3.36	1.76	2.36	18.89	17.32	0.29	2.83	99.85
57.89	0.06	0.29	2.14	0.74	36.98	0.38	0.02	1.13	99.62
58.33	0.03	0.37	1.86	0.35	37.73	0.36	0.02	0.68	99.72
53.79	0.32	1.53	1.95	2.55	22.89	13.99	0.12	2.04	99.16

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
53.49	0.31	1.53	5.98	1.01	18.12	16.90	0.54	1.84	99.71
56.35	0.05	0.31	7.08	0.91	31.49	2.10	0.06	1.16	99.51
53.19	0.36	1.97	5.51	0.85	17.79	16.60	0.57	1.83	98.65
57.45	0.03	0.42	5.93	0.41	34.71	0.42	0.09	0.75	100.22
57.21	0.03	0.30	6.82	0.40	34.44	0.22	0.07	0.53	100.03
44.47	0.81	14.81	8.06	0.15	13.19	17.03	0.00	0.23	98.75
49.44	0.62	7.66	9.48	0.22	21.09	9.61	0.00	0.64	98.77
48.64	1.06	3.32	25.89	0.46	13.46	5.67	0.13	0.00	98.63
47.42	0.47	13.33	11.63	0.17	23.94	1.65	0.00	0.26	98.86
46.22	0.46	14.46	12.31	0.19	22.73	1.58	0.00	0.22	98.16
46.23	1.11	12.41	7.01	0.18	14.71	17.25	0.00	0.34	99.23
51.36	0.92	5.82	1.06	0.84	20.26	17.59	0.08	1.96	99.89
58.30	0.06	0.66	1.25	0.19	38.54	0.38	0.00	0.71	100.09
58.73	0.05	0.32	1.24	0.14	39.04	0.18	0.00	0.51	100.21
50.36	1.05	6.64	1.10	0.94	18.79	18.28	0.12	1.95	99.21
58.89	0.05	0.28	1.31	0.13	38.82	0.23	0.00	0.48	100.20
52.92	0.23	0.93	10.71	1.40	17.35	12.53	0.61	2.00	98.68
55.68	0.04	0.36	10.59	0.91	29.90	0.72	0.03	0.81	99.03
56.56	0.00	0.12	8.24	0.58	32.71	0.39	0.00	0.54	99.13
54.10	0.14	0.54	11.90	1.57	19.86	9.64	0.38	1.36	99.48
56.36	0.05	0.29	10.12	0.74	31.47	0.57	0.01	0.84	100.44
57.08	0.00	0.13	8.19	0.56	33.06	0.26	0.01	0.64	99.93
57.17	0.05	0.33	6.09	0.53	33.86	0.47	0.04	0.85	99.39
57.28	0.04	0.23	4.89	0.51	34.71	0.43	0.01	0.78	98.87
56.66	0.04	0.31	5.55	0.65	33.23	1.08	0.01	1.03	98.56
53.00	0.48	1.80	4.07	0.74	18.16	18.01	0.47	1.73	98.46
56.61	0.09	0.46	6.41	0.73	32.52	1.59	0.05	1.07	99.51
53.02	0.56	1.83	3.96	0.69	18.09	18.23	0.54	1.90	98.81

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
49.74	1.16	1.50	19.83	0.52	11.83	13.64	0.10	0.43	98.75
50.64	0.50	1.37	22.43	0.64	16.13	6.72	0.00	0.30	98.72
50.17	0.82	1.11	21.75	0.67	12.85	10.96	0.15	0.37	98.86
50.36	0.40	1.61	23.26	0.74	16.84	4.42	0.03	0.39	98.03
49.29	0.87	0.73	28.86	0.70	12.38	5.62	0.02	0.20	98.67
53.48	0.11	2.00	14.61	0.42	26.32	1.83	0.00	1.10	99.87
51.66	0.20	3.28	16.50	0.45	22.59	3.43	0.00	1.09	99.19
52.37	0.73	3.28	3.04	1.06	18.85	17.79	0.29	1.62	99.03
57.41	0.07	0.68	4.21	0.84	34.73	1.19	0.01	0.92	100.07
58.35	0.08	0.40	3.78	0.45	36.17	0.49	0.00	0.78	100.48
52.61	0.58	2.94	3.09	1.05	20.04	16.77	0.34	1.72	99.14
58.08	0.02	0.31	3.65	0.31	36.97	0.20	0.02	0.54	100.08
51.20	0.52	4.04	2.48	1.84	19.18	16.50	0.28	2.84	98.88
57.76	0.03	0.53	2.92	0.65	36.67	0.41	0.00	1.06	100.03
57.94	0.04	0.29	2.72	0.45	36.92	0.20	0.01	0.68	99.24
51.46	0.52	3.87	2.17	1.65	18.67	17.57	0.23	2.53	98.67
57.82	0.07	0.62	2.64	0.52	36.31	0.41	0.02	0.97	99.39
58.30	0.04	0.32	2.25	0.31	37.68	0.32	0.00	0.59	99.81
56.07	0.01	0.38	10.69	0.44	30.52	0.70	0.01	0.87	99.70
54.49	0.04	0.64	14.62	0.62	27.02	1.10	0.27	1.03	99.81
55.93	0.00	0.29	11.33	0.41	30.27	0.52	0.00	0.95	99.69
57.98	0.09	0.66	4.06	0.43	35.70	0.39	0.00	0.96	100.27
57.42	0.07	0.65	4.00	0.51	35.50	0.40	0.04	1.00	99.59
54.70	0.09	0.88	7.40	1.51	25.63	7.16	0.09	1.98	99.44
57.69	0.02	0.19	5.17	0.47	35.17	0.25	0.07	0.65	99.68
57.61	0.03	0.34	4.74	0.42	35.96	0.22	0.05	0.77	100.15
51.27	0.37	3.39	7.03	1.15	17.41	14.26	0.56	2.98	98.42
57.70	0.03	0.29	4.76	0.38	35.67	0.30	0.09	0.66	99.89

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
53.03	0.48	3.01	2.75	1.09	21.97	14.80	0.18	1.25	98.56
57.76	0.04	0.45	2.88	0.46	36.77	0.35	0.00	0.58	99.30
52.66	0.65	3.73	2.31	1.06	20.34	16.92	0.20	1.36	99.23
58.29	0.07	0.50	3.05	0.45	36.99	0.43	0.00	0.78	100.56
48.45	1.17	10.74	0.45	0.34	15.86	21.38	0.11	1.26	99.75
58.46	0.15	0.73	0.57	0.08	39.00	0.46	0.01	0.50	99.95

Sharps

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
57.68	0.04	0.52	4.35	0.50	35.59	0.38	0.00	0.86	99.91
57.93	0.05	0.43	4.28	0.39	35.93	0.28	0.00	0.68	99.96
57.24	0.05	0.36	3.84	0.44	35.78	0.29	0.00	0.63	98.61
51.14	0.84	3.51	3.33	0.73	18.23	18.62	0.38	2.37	99.14
57.16	0.02	0.40	4.24	0.35	36.74	0.27	0.00	0.67	99.85
57.25	0.03	0.20	3.69	0.25	37.24	0.22	0.00	0.57	99.45
52.18	0.50	2.54	3.52	0.74	21.19	16.12	0.30	1.82	98.92
54.96	0.11	0.52	7.33	0.53	34.63	0.40	0.02	1.13	99.62
56.40	0.07	0.45	4.40	0.38	36.68	0.24	0.00	0.71	99.33
52.89	0.52	2.61	3.51	0.78	21.37	15.77	0.28	1.70	99.43
51.08	0.57	3.05	3.46	0.75	19.39	17.51	0.35	2.27	98.43
51.88	0.48	2.65	3.53	0.78	20.28	16.96	0.31	2.00	98.87
55.95	0.09	0.40	4.22	0.39	35.96	0.33	0.00	0.67	98.01
56.40	0.05	0.33	4.18	0.33	36.44	0.20	0.00	0.62	98.54
53.06	0.51	3.56	2.61	1.87	19.11	16.28	0.37	1.96	99.32
58.18	0.06	0.36	3.18	0.95	36.87	0.32	0.00	0.96	100.89

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
52.60	0.53	2.67	2.38	2.01	19.90	16.46	0.17	2.13	98.84
58.27	0.04	0.32	3.14	0.86	36.50	0.36	0.00	1.06	100.54
57.86	0.04	0.33	3.06	0.78	36.44	0.32	0.00	0.94	99.77
52.18	0.74	3.40	2.69	1.84	18.78	17.66	0.29	2.30	99.88
56.04	0.12	0.90	3.73	2.43	30.44	5.18	0.04	1.70	100.58
58.54	0.04	0.32	2.63	0.40	37.94	0.26	0.00	0.57	100.71
57.08	0.05	0.38	5.30	0.45	34.73	0.25	0.00	0.74	98.97
55.27	0.07	0.57	7.30	0.93	29.94	2.50	0.05	1.48	98.12
52.60	0.30	1.76	4.90	0.73	19.37	16.20	0.40	2.18	98.44
57.18	0.03	0.24	5.42	0.40	35.47	0.25	0.00	0.74	99.72
53.99	0.21	1.49	5.97	0.98	22.65	12.04	0.29	2.15	99.76
55.61	0.12	0.79	6.86	1.03	28.79	5.01	0.12	1.13	99.46
57.40	0.04	0.36	5.17	0.46	35.24	0.25	0.00	0.74	99.65
52.93	0.38	1.91	5.31	0.80	19.71	15.51	0.41	2.23	99.19
55.59	0.10	0.61	7.66	0.95	30.50	2.58	0.05	1.44	99.47
57.72	0.04	0.26	5.28	0.40	35.70	0.25	0.00	0.84	100.48
52.86	0.37	2.28	5.02	0.76	17.87	18.28	0.48	2.24	100.16
57.20	0.05	0.38	5.34	0.40	35.48	0.24	0.01	0.80	99.89
57.60	0.05	0.30	4.97	0.35	35.77	0.20	0.00	0.61	99.86
52.16	0.38	1.40	6.09	0.75	18.86	16.14	0.56	2.17	98.49
56.17	0.05	0.38	7.02	0.53	33.93	0.59	0.04	0.68	99.37
55.95	0.02	0.26	6.89	0.48	34.15	0.30	0.01	0.80	98.86
54.47	0.13	0.82	8.40	1.42	28.96	3.51	0.03	1.54	99.26
56.58	0.03	0.18	5.73	0.48	35.59	0.19	0.00	0.57	99.34
57.03	0.03	0.27	5.44	0.54	35.59	0.21	0.00	0.73	99.83
51.76	0.39	2.36	7.18	1.30	19.96	14.12	0.23	1.88	99.17
54.37	0.11	0.78	8.24	1.44	28.07	4.07	0.05	1.59	98.71
56.30	0.05	0.44	5.27	0.56	33.48	1.18	0.00	0.73	98.01
54.35	0.31	1.64	4.47	0.75	23.89	12.83	0.18	1.33	99.74
56.83	0.06	0.48	5.10	0.50	34.59	1.18	0.01	0.76	99.50
57.25	0.06	0.49	4.73	0.52	35.91	0.56	0.00	0.87	100.38
54.18	0.32	2.16	4.23	0.67	21.93	15.04	0.25	1.48	100.27

SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	Cr2O3	total
53.45	0.40	2.08	4.23	0.74	21.79	15.00	0.26	1.55	99.50
55.02	0.12	0.72	9.81	1.25	28.62	2.77	0.04	1.44	99.78
57.42	0.03	0.19	6.43	0.42	34.92	0.13	0.00	0.68	100.23
55.02	0.11	0.76	9.15	1.24	29.13	2.29	0.01	1.70	99.41
55.66	0.13	0.75	9.16	1.41	29.47	2.66	0.02	1.57	100.81
57.32	0.00	0.15	6.69	0.41	34.69	0.16	0.00	0.66	100.09
53.57	0.17	1.04	11.73	0.65	21.39	8.86	0.29	1.26	98.96
56.11	0.05	0.25	10.96	0.52	30.64	1.00	0.04	0.89	100.46
55.28	0.05	0.31	12.98	0.55	29.47	0.50	0.04	1.01	100.19
54.69	0.06	0.44	14.23	0.71	26.88	1.78	0.04	1.42	100.24
52.52	0.37	1.69	9.53	0.54	17.32	15.82	0.42	1.91	100.10
54.81	0.06	0.51	14.30	0.59	27.04	1.83	0.03	1.15	100.32
56.09	0.04	0.27	11.03	0.47	31.03	0.68	0.01	0.72	100.33
55.25	0.05	0.26	13.36	0.59	29.15	0.96	0.01	0.85	100.48
53.27	0.83	5.98	0.46	0.20	22.15	17.66	0.04	0.36	100.94
58.40	0.17	1.30	0.71	0.11	39.19	0.64	0.01	0.59	101.11
50.03	1.09	9.58	0.44	0.12	17.74	20.84	0.03	0.38	100.26
48.86	1.03	8.78	1.40	0.89	18.51	17.97	0.13	2.17	99.73
50.37	0.83	5.79	1.24	1.03	20.26	17.10	0.06	1.88	98.55
57.18	0.13	0.93	1.54	0.48	37.78	0.95	0.01	1.07	100.06
51.33	0.90	5.39	0.92	0.75	19.90	19.13	0.09	1.39	99.79
57.73	0.11	0.61	1.12	0.33	38.26	0.66	0.00	0.81	99.64
50.57	1.05	5.99	1.15	0.63	19.61	18.46	0.03	1.75	99.23
49.16	1.09	6.88	1.89	0.83	17.56	19.30	0.19	2.71	99.61
56.85	0.06	0.59	3.01	0.48	36.35	0.68	0.04	0.80	98.85
50.01	0.90	6.07	1.98	0.88	18.44	19.02	0.17	2.21	99.67
54.60	0.08	0.21	10.48	1.06	28.05	3.18	0.06	1.07	98.78
56.61	0.02	0.16	6.34	0.35	35.71	0.16	0.00	0.54	99.88
54.06	0.22	0.86	8.17	0.71	20.75	12.57	0.35	1.10	98.78
56.24	0.02	0.16	7.26	0.36	34.38	0.23	0.06	0.67	99.37
57.05	0.03	0.10	6.28	0.36	35.12	0.13	0.00	0.60	99.66