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PETROCHEMICAL STUDY OF THE YAMATO-691 ENSTATITE CHONDRITE (E3) I: MAJOR ELEMENT CHEMICAL COMPOSITIONS OF CHONDRULES AND INCLUSIONS

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Abstract: The major element chemical compositions of more than 120 chondrules and inclusions in Yamato (Y)-691 were obtained using a defocussed beam of an electron-probe micro-analyzer. Most chondrules in Y-691 are depleted in Fe, Mn, Cr, and Ca in comparison to the Y-691 whole rock composition, indicating that the depleted elements reside in sulfides and/or metals occurring outside chondrules. Compared with the solar system abundances, radial-Px, porphyritic and granular chondrules are depleted in all elements studied except for Si, but the Si-normalized contents of Al, Ti, Mg, and alkalies are similar to the Y-691 whole rock composition. On the other hand, barred-Ol-Px chondrules are enriched in refractory and moderately-refractory lithophiles (Al, Ti, Ca, and Mg) and poor in moderately-volatile elements (Mn, K, and Na). Some inclusions show chemical compositions similar to fine-grained CAI's and amoeboid olivine inclusions in carbonaceous chondrites.

1. Introduction

Consortium on the Yamato (Y)-691 chondrite was approved by the Antarctic Meteorite Research Committee of NIPR in 1984, and after that, the meteorite has been studied for three years by many scientists. This work is one of the consortium studies, concentrating on petrochemical study of Y-691. This paper (Part I) will deal with the major element chemical compositions of chondrules and inclusions in Y-691, and the following papers (Part II, Part III and Part IV) will present the petrology and mineral chemistry of unusual silicate-inclusions, chondrules and opeque-mineral nodules, respectively.

Although the major element chemical compositions of chondrules in unequilibrated ordinary and carbonaceous chondrites were already reported (WALTER, 1969; OSBORN *et al.*, 1973, 1974; MCSWEEN, 1977; DODD, 1978; FODOR and KEIL, 1978; IKEDA, 1983), those in enstatite chondrites are not studied except for IKEDA (1983) and BISCHOFF *et al.* (1985). In this paper, more than 120 chondrules and inclusions in Y-691 were analyzed, and the correlation between the chemical compositions and the textural types will be discussed.

2. Analytical Method

The major element chemical compositions of chondrules and inclusions were measured using a defocussed beam (about 30–50 microns across) of an electron-probe microanalyzer (EPMA; JEOL-733-Superprobe, accelerating voltage of 15 kV, sample current of about 5 nA). The broad beam was fixed in a chondrule for 10 s in a way to avoid opaque phases such as metals and sulfides, and the major element compositions of a silicate-oxide portion were obtained with the correction method of BENCE and ALBEE (1967). The same procedure was repeated in different portions of a chondrule to cover the whole area of the chondrule. The compositions obtained from different portions in a chondrule were averaged, and the average composition was further corrected using the broad beam correction method of IKEDA (1980). In this paper, the broad beam correction factor for Cr_2O_3 was modified from that of IKEDA (1980); it is assumed that the correction factor for Cr_2O_3 is the same as that for FeO, because chromite does not occur in chondrules of Y-691 and the Cr_2O_3 in chondrules resides mainly in silicates and glass.

The obtained chemical compositions of chondrules and inclusions represent mainly the silicate and glass portions. However, very fine-grained opaque phases (smaller than a few microns) such as metals and/or sulfides are sometimes included in chondrules and inclusions, and some of them could not be prevented from the broad beam of an EPMA. Therefore, small fractions of obtained FeO contents might be "Fe" of Fe-Ni metals and/or Fe-bearing sulfides.

Generally speaking, most chondrules and inclusions in Y-691 include small amounts of Fe-metal and/or troilite less than several percents in volume, although a few chondrules contain those more than ten percents. The existence of 2.5 vol% Fe-metal and 2.5 vol% troilite in a chondrule results in increase of the Fe abundance corresponding to about 2 wt%. Other sulfides such as oldhamite and niningerite occur very rarely in some chondrules of Y-691 and the amounts are less than a few percents. Considering these observations, the chemical compositions of silicate-oxide portion of most chondrules and inclusions obtained in this paper, except for Fe, may be nearly equal to those of the bulk chondrules and inclusion. In this paper, the FeO contents of chondrules and inclusions will be presented and the Fe contents in metals and sulfides are not discussed.

3. Brief Description

A detailed description of chondrules and inclusions will be given in the companion papers (IKEDA, 1988a, b), and a brief description of textural types of chondrules and inclusions will be presented here.

The Y-691 chondrite includes various kinds of chondrules, the main types being radial-Px, porphyritic and granular chondrules. Barred-Ol-Px chondrules, which consist mainly of barred or blebby olivine and low-Ca pyroxene with minor amounts of groundmass, are rare. Cryptocrystalline chondrules sometimes occur and include two subtypes; spherulitic and massive. Spherulitic cryptocrystalline chondrules are usually small (less than 200 microns across) and often show spherical outlines. On the other hand, the massive subtype ranges up to 1 mm in size and show various outlines in shape.

Transparent-SiO_2 chondrules are smaller than about 150 microns in diameter and always show spherical outlines.

In addition to the above-stated textural types of chondrules, some kinds of unusual silicate-inclusions occur in Y-691. They are glassy objects and dark or opaque massive objects. The former consists of a glassy material with small pyroxene laths, and the latter is dark or opaque and massive under the microscope. For example, an unusual silicate-inclusion No. 172 consists of glassy groundmass and small fassaitic pyroxene

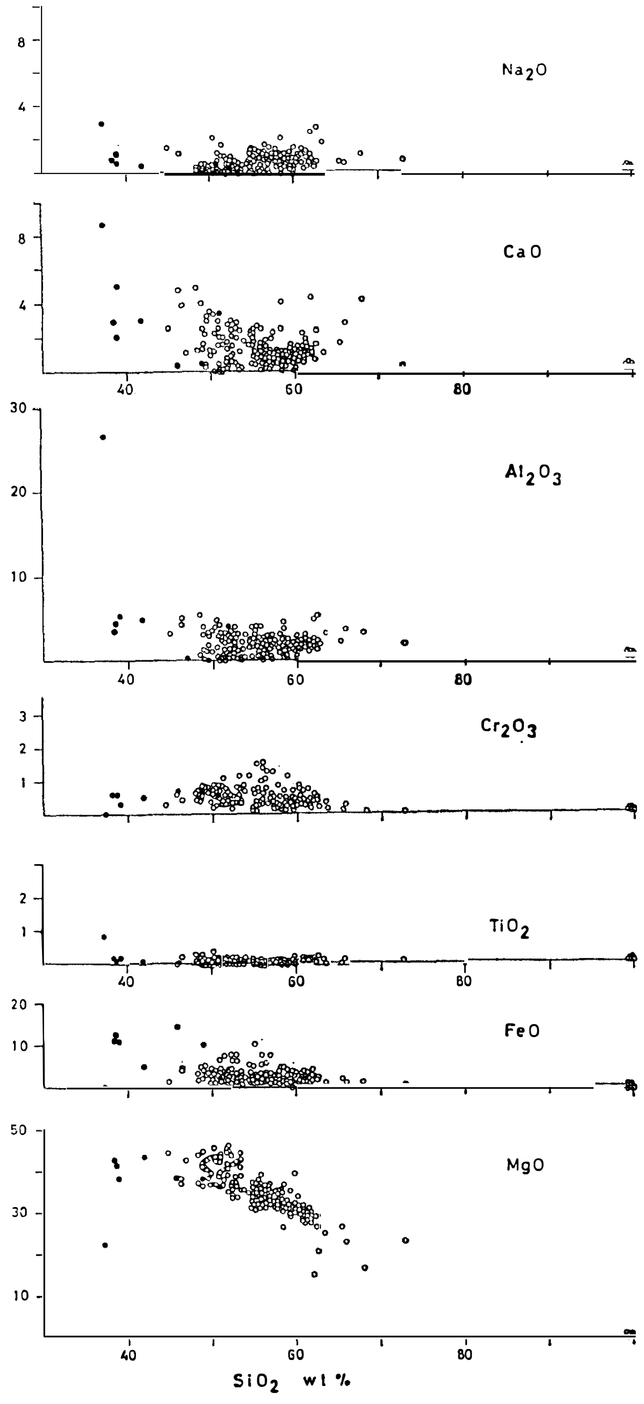
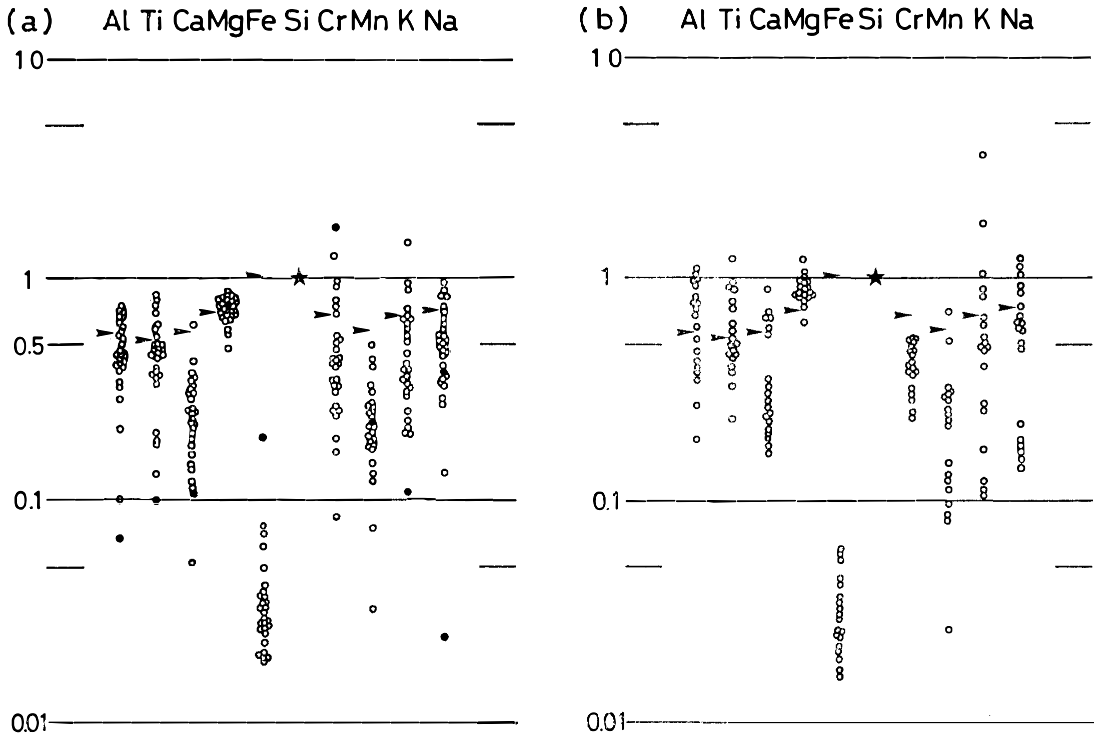


Fig. 1. Chemical compositions (in wt%) of chondrules and inclusions in Y-691 are plotted against the SiO_2 wt%. Eight solid circles are unusual silicate-inclusions.

laths set in the groundmass. Back-scattered-electron images reveal that an opaque massive inclusion No. 152 consists mainly of decomposed-olivine and minor amounts of fassaite, augite, pigeonite, spinel, and plagioclase.



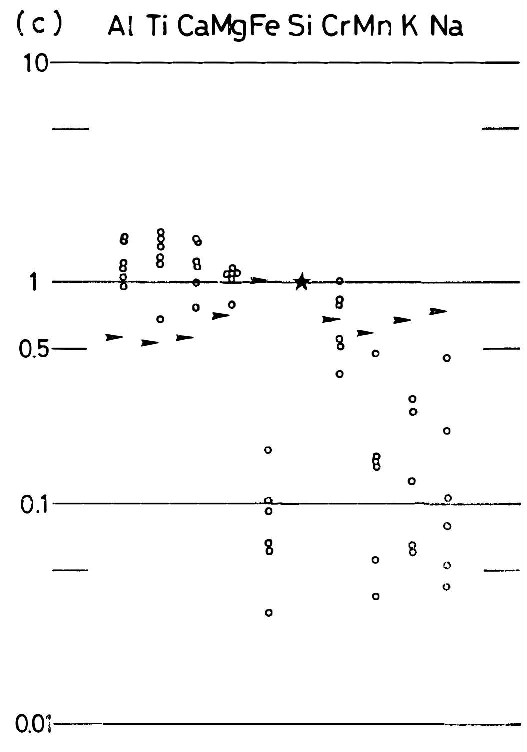
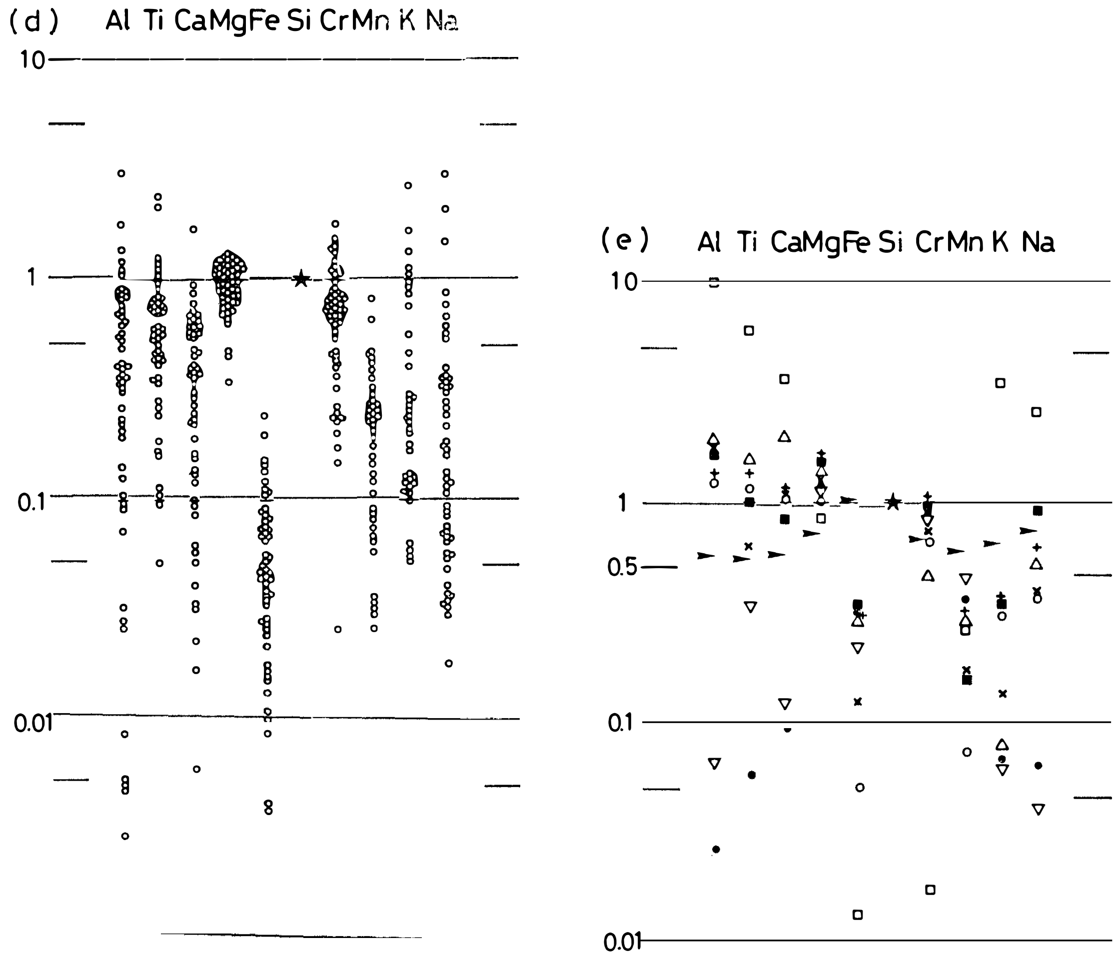


Fig. 2. Chemical compositions of chondrules and inclusions normalized by the solar system abundances (CAMERON, 1973) and Si. (a): Radial-Px chondrules (open circle) and a ferroan radial-Px chondrule No. 154 (solid circle). (b): Porphyritic or granular chondrules. (c): Barred-Ol-Px chondrules. (d): Cryptocrystalline chondrules. (e): Unusual silicate-inclusions Nos. 172 (open square), 152 (normal triangle), 300 (upside-down triangle), 167 (open circle), 114 (solid circle), 237 (×), 302 (cross), and 303 (solid square). Horizontal arrows indicate bulk composition of the Y-691 chondrite (SHIMA and SHIMA, 1975).

4. Results and Discussion

The chemical compositions of chondrules and inclusions in Y-691 newly obtained are tabulated in the Appendix and are plotted in Fig. 1 together with the data of IKEDA (1983). All chondrules except for transparent-SiO_2 chondrules and unusual silicate-inclusions form a cluster in Fig. 1, showing a main compositional trend between 45 and 65 wt% of the SiO_2 contents. The main trend shows that the MgO contents decrease remarkably with increasing SiO_2 and *vice versa* for Na_2O. On the other hand, transparent-SiO_2 chondrules are nearly pure SiO_2 in chemical composition, forming another cluster as shown in Fig. 1. An inclusion No. 172 is the poorest in SiO_2 content and deviates from the extension of the main compositional trend. Unusual silicate-inclusions except for glassy inclusions Nos. 172 and 167 are enriched in FeO, ranging from 5 to 14 wt%.

The chemical compositions of textural types of chondrules and inclusions are separately shown in Fig. 2, where they are normalized by the solar system abundances (CAMERON, 1973) and Si. Mg and Si are the most abundant elements of radial-Px chondrules and Si-normalized Mg forms a cluster in Fig. 2a, suggesting that most radial-Px chondrules consist of magnesian pyroxenes with minor components of plagioclase,



olivine, or silica minerals. Compared with the Y-691 whole rock composition (SHIMA and SHIMA, 1975), radial-Px chondrules are depleted in Ca, Fe, and Mn. This depletion may be explained by the fact that Ca, Fe, or Mn reside in sulfides or metals outside chondrules; oldhamite is a main sulfide carrying Ca outside chondrules, troilite and Fe-metals are main Fe-bearing phases, and niningerite and sphalerite comprise most of Mn outside chondrules. This suggests that the precursors of most radial-Px chondrules had been depleted in Ca, Fe, and Mn prior to the formation of chondrule-melt droplets. Si-normalized contents of Al, Ti, Cr, and alkalies are similar to those of the Y-691 whole rock although the former seems to be slightly poorer than the latter.

One radial-Px chondrule No. 154 contains fairly large amounts of FeO (10.68 wt%) and Cr_2O_3 (1.55 wt%) although it is depleted in Al, Ti, and alkalies, suggesting that the precursor of the ferroan chondrule may have consisted merely of ferroan low-Ca pyroxene.

Porphyritic or granular chondrules in Y-691 show chemical compositions similar to those of radial-Px chondrules except that the Mg contents of the former are higher as a whole than those of the latter (Fig. 2b). This suggests that the precursors of porphyritic or granular chondrules included olivines more abundantly than the precursors of radial-Px chondrules. In comparison to the Y-691 whole rock, the Cr contents are low, and this may be due to the abundant occurrence of Cr-bearing troilite and daubreelite outside chondrules.

On the other hand, barred-Ol-Px chondrules are quite different in chemical composition from radial-Px, porphyritic and granular chondrules (Fig. 2c). They are enriched in refractory (Al, Ti, and Ca) and moderately-refractory (Mg) lithophiles whereas moderately-volatile elements (Mn, K, and Na) are depleted in comparison to the Y-691 whole rock. Compared with radial-Px, porphyritic and granular chondrules, the barred-Ol-Px chondrules seem to be slightly richer in FeO and Cr_2O_3 as a whole. Their chemical compositions suggest that the most precursors formed under more-oxidized conditions and included more abundant high-temperature components than those of radial-Px, porphyritic and granular chondrules.

Cryptocrystalline chondrules show a very wide compositional range (Fig. 2d), covering the whole range of radial-Px, porphyritic, granular and barred-Ol-Px chondrules. Considering that most of them are smaller than 200 microns across and that the spherulitic cryptocrystalline type shows always spherical outlines, their wide chemical compositions may be explained by the following two alternative hypotheses; First, when large melt droplets splashed out during the collision of two planetesimals (KIEFFER, 1975) in a nebular gas, small cryptocrystalline chondrules showing spherical outlines might have formed as small melt droplets which were stripped off from various kinds of larger melt droplets by friction during flying with cosmic speed through the nebular gas. Second, if the precursors of cryptocrystalline chondrules consisted mainly of coarse-grained (larger than about 200 microns) olivine and pyroxene with minor plagioclase, some melt droplets smaller than 200 microns across may have formed from one kind of the constituent mineral of the precursors, and other melt droplets may have formed from two or three kinds of the constituent minerals in the precursors, resulting in the wide compositional variation of spherulitic cryptocrystalline chondrules.

Unusual silicate-inclusions also show a wide compositional range (Fig. 2e). An inclusion No. 172 is extremely enriched in both refractory lithophiles (Al, Ti, and Ca) and moderately-volatiles (K and Na). The chemical composition of the inclusion is similar to those of fine-grained CAI's in carbonaceous chondrites (IKEDA, 1982) except for the low FeO content of the former, whereas the texture of the inclusion is quite different from those of fine-grained CAI's (IKEDA, 1988a). The inclusion may have originally formed in the same way as fine-grained CAI's and then it may have been melted by a high-temperature event such as shock heating without loss of alkalies, and finally it cooled rapidly, resulting in a quenched texture.

Other unusual silicate-inclusions Nos. 152, 237, 302 and 303 show high contents of Al, Ti, Ca, Mg, and Fe. They are similar in chemical composition to amoeboid olivine inclusions in carbonaceous chondrites (IKEDA, 1982), although the textures are quite different from the latter (IKEDA, 1988a). They may have originally formed in the same way as amoeboid olivine inclusions, and then the original textures have been lost by a high temperature event without loss of the FeO component. Two unusual silicate-inclusions Nos. 300 and 114 are moderately rich in Mg and Fe (Fig. 2e), and poor in Al, Ti, Ca, and alkalies. The precursors may have consisted mainly of ferroan olivine and pyroxene with a negligible amount of plagioclase.

5. Summary

(1) Most chondrules in Y-691 are extremely depleted in FeO although some chondrules and inclusions contain FeO in various amounts up to 14 wt%.

(2) The main textural types of Y-691 chondrules, radial-Px, porphyritic and granular chondrules, are similar in Si-normalized contents of Al, Ti, Mg, K, and Na to the Y-691 whole rock, but are depleted in Ca, Fe, Cr, and Mn. The depleted components reside in sulfides and metals occurring outside chondrules.

(3) In comparison to the solar system abundance, most of radial-Px, porphyritic and granular chondrules are depleted in all components studied except for SiO_2, suggesting that their precursors were depleted in both refractory lithophiles and moderately-volatiles.

(4) In comparison to the solar system abundances and the Y-691 whole rock composition, barred-Ol-Px chondrules are enriched in refractory and moderately-refractory lithophiles (Al, Ti, Ca, and Mg), and are depleted in moderately-volatiles (Mn, K, and Na), suggesting that the precursors contained high-temperature components more abundantly.

(5) Y-691 includes unusual silicate-inclusions similar in chemical composition to fine-grained CAI's and amoeboid olivine inclusions in carbonaceous chondrites.

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Appendix

Chemical compositions of chondrules and inclusions in Y-691. Textural types are shown by R (radial-Px), P (porphyritic or granular), C (spherulitic or massive cryptocrystalline), B (barred-Ol-Px), T (transparent-SiO_2), and U (unusual silicate-inclusions).

	100	101	102	103	104	105	106	107	108	109
	R	R	R	C	C	R	P	P	C	P
SiO2	60.34	60.35	58.00	52.93	61.05	57.65	55.87	56.51	55.19	55.62
TiO2	0.11	0.11	0.04	0.09	0.09	0.11	0.10	0.13	0.17	0.15
Al2O3	2.32	1.68	0.88	0.27	1.37	1.64	1.90	3.12	2.15	2.75
Cr2O3	0.73	0.79	0.91	0.87	0.24	0.91	0.45	0.28	0.60	0.32
FeO	2.29	2.23	4.12	3.46	1.73	1.88	3.34	3.22	2.01	0.96
MnO	0.12	0.28	0.15	0.12	0.00	0.28	0.08	0.06	0.05	0.09
MgO	29.77	31.98	31.80	42.53	32.12	34.48	34.75	32.44	36.38	34.96
CaO	1.47	0.99	0.48	0.47	0.49	1.14	0.63	0.75	2.13	1.20
Na2O	0.76	0.91	0.50	0.03	0.74	0.51	1.02	1.79	0.44	1.49
K2O	0.06	0.08	0.04	0.00	0.08	0.07	0.10	0.15	0.03	0.32
Total	97.97	99.40	96.92	100.77	97.91	98.67	98.24	98.45	99.15	97.86

110	112	113	114	115	116	117	118	119	120	121	122
P	C	C	U	P	R	P	R	P	B	C	C
55.63	51.28	50.47	46.11	55.19	57.23	50.11	58.75	55.14	49.10	51.33	50.16
0.11	0.02	0.00	0.01	0.16	0.04	0.07	0.08	0.08	0.23	0.02	0.13
1.69	0.01	0.00	0.09	3.85	0.40	1.25	2.16	3.89	3.65	0.02	1.14
0.33	0.91	0.79	0.66	0.37	1.15	0.41	0.23	0.25	0.65	1.09	0.74
2.37	4.26	3.46	13.91	1.84	4.28	1.08	1.09	1.95	2.97	7.55	4.34
0.15	0.13	0.06	0.18	0.15	0.11	0.07	0.18	0.18	0.03	0.11	0.06
34.79	43.90	45.71	38.08	32.44	34.06	43.17	33.24	32.38	37.86	38.10	39.59
0.96	0.06	0.00	0.30	2.11	0.20	0.92	0.99	2.46	3.77	0.14	1.31
0.81	0.25	0.09	0.09	1.26	0.23	0.23	1.32	1.02	0.16	0.12	0.09
0.19	0.01	0.00	0.01	0.11	0.04	0.02	0.12	0.09	0.00	0.01	0.01
97.03	100.83	100.58	99.44	97.48	97.74	97.33	98.16	97.44	98.42	98.49	97.57

123	124	125	126	127	128	129	130	131	132	133	134
C	R	R	R	R	R	R	R	C	P	C	C
53.06	63.50	57.54	60.41	59.89	60.73	61.54	61.37	50.92	58.10	50.29	51.77
0.07	0.19	0.15	0.08	0.17	0.11	0.09	0.12	0.15	0.05	0.44	0.08
2.55	3.22	2.52	1.39	2.96	3.11	2.17	2.04	3.26	2.20	6.29	0.75
0.37	0.35	0.32	0.52	0.41	0.26	0.25	0.41	0.48	0.23	0.19	0.60
0.50	1.25	1.17	2.53	1.60	3.80	1.23	1.54	1.40	1.11	1.47	3.00
0.04	0.16	0.12	0.21	0.16	0.05	0.10	0.09	0.00	0.20	0.00	0.05
39.83	25.13	34.98	30.80	29.70	28.00	30.03	30.61	38.95	34.72	36.91	41.33
2.21	1.13	0.76	0.57	1.32	0.47	1.40	1.27	1.58	0.95	0.64	0.76
0.11	1.94	1.33	0.76	1.60	1.65	1.02	0.98	1.36	1.24	3.12	0.11
0.02	0.19	0.10	0.06	0.14	0.15	0.30	0.20	0.16	0.09	0.27	0.01
98.76	97.06	98.99	97.33	97.95	98.33	98.13	98.63	98.26	98.89	99.62	98.46

135	136	137	138	139	140	141	142	143	144	146	147
C	R	R	C	C	T	R	T	C	P	R	R
51.03	65.66	59.83	54.41	49.65	100.25	61.49	99.07	50.51	55.38	57.25	58.06
0.16	0.05	0.10	0.06	0.14	0.00	0.10	0.00	0.15	0.10	0.07	0.07
2.60	2.13	1.83	1.69	1.98	0.00	1.96	0.02	2.71	1.05	1.40	1.62
0.83	0.09	0.41	1.19	0.63	0.00	0.19	0.03	0.26	0.32	0.53	0.53
2.34	1.82	1.74	5.51	3.35	0.20	1.40	0.40	1.10	1.33	1.80	2.92
0.20	0.12	0.15	0.12	0.00	0.00	0.13	0.00	0.05	0.01	0.02	0.17
39.20	26.62	32.42	34.92	40.64	0.00	29.54	0.17	42.52	38.32	35.89	31.69
2.97	1.68	0.73	1.57	2.26	0.00	0.92	0.00	1.95	0.89	0.64	1.19
0.09	0.73	0.99	0.55	0.11	0.04	1.08	0.03	0.51	0.23	0.60	0.83
0.00	0.07	0.05	0.11	0.02	0.00	0.07	0.00	0.03	0.02	0.04	0.04
99.48	98.97	98.25	100.13	98.78	100.49	96.88	99.72	99.79	97.65	98.24	97.12

	148	149	150	151	152	153	154	155	156	157	158
	R	P	C	C	U	C	R	C	C	C	P
SiO2	59.97	52.48	59.41	55.43	39.23	48.37	54.92	51.43	61.28	48.80	58.63
TiO2	0.03	0.18	0.11	0.20	0.22	0.13	0.02	0.15	0.13	0.20	0.07
Al2O3	1.25	4.03	1.50	1.33	5.30	0.74	0.27	1.41	1.75	3.06	3.82
Cr2O3	0.43	0.38	0.71	0.61	0.29	0.57	1.55	0.39	0.41	0.35	0.28
FeO	2.43	2.85	3.99	2.20	11.11	3.44	10.68	2.61	2.33	2.03	1.50
MnO	0.21	0.30	0.21	0.29	0.12	0.07	0.14	0.07	0.25	0.00	0.14
MgO	30.71	33.91	29.68	35.50	38.08	44.09	31.20	40.42	28.58	42.13	30.43
CaO	0.84	3.12	1.57	2.69	5.00	1.30	0.41	1.91	1.49	2.64	0.65
Na2O	0.73	1.03	0.44	0.21	0.62	0.17	0.04	0.05	0.41	0.54	2.20
K2O	0.08	0.08	0.09	0.02	0.01	0.01	0.02	0.00	0.05	0.02	0.17
Total	96.68	98.36	97.71	98.48	99.98	98.89	99.25	98.44	96.68	99.77	97.89

159	160	161	166	167	169	171	172	174	175	200	201
P	C	R	C	U	B	C	U	C	R	C	C
53.49	56.07	60.65	62.20	50.84	51.84	48.92	37.26	52.53	65.77	53.44	48.74
0.09	0.05	0.10	0.12	0.21	0.13	0.13	0.80	0.09	0.21	0.01	0.05
1.45	1.31	1.79	2.37	4.35	4.29	1.29	26.63	0.52	3.64	0.44	0.34
0.39	1.37	0.68	0.60	0.53	0.32	0.85	0.01	0.60	0.32	0.81	0.53
1.36	7.72	1.93	3.12	2.65	8.94	4.94	0.47	4.46	1.29	2.38	5.01
0.05	0.09	0.12	0.32	0.04	0.27	0.00	0.11	0.15	0.14	0.09	0.00
39.29	30.79	29.29	28.73	36.34	28.99	41.64	22.17	41.71	22.90	43.14	44.81
1.26	1.76	0.92	1.31	3.47	2.68	1.33	8.65	0.88	2.80	0.35	0.43
0.30	0.57	0.92	0.68	0.57	0.74	0.13	2.97	0.08	0.69	0.06	0.05
0.03	0.14	0.08	0.06	0.05	0.05	0.00	0.42	0.00	0.05	0.00	0.02
97.71	99.87	96.48	99.51	99.05	98.25	99.23	99.49	101.02	97.81	100.72	99.98

202	205	206g	208	209	210	211c	213g	215c	216	217	219g
T	C	C	C	C	C	C	C	C	C	C	C
100.01	57.19	72.73	59.60	52.44	53.56	57.94	54.00	58.58	51.07	56.55	59.19
0.00	0.02	0.07	0.10	0.12	0.07	0.00	0.09	0.04	0.03	0.00	0.45
0.00	0.02	1.82	2.07	0.99	0.38	0.10	2.48	0.39	0.02	0.13	12.84
0.00	1.30	0.03	0.25	0.20	0.46	0.43	0.73	0.38	0.88	1.08	0.22
0.36	3.67	0.77	0.25	0.82	0.71	0.23	10.68	1.50	3.42	6.00	1.01
0.07	0.11	0.06	0.02	0.02	0.04	0.01	0.14	0.18	0.37	0.15	0.14
0.03	36.66	23.36	35.84	43.95	44.83	40.84	28.58	38.42	44.00	36.79	14.44
0.03	0.09	0.25	1.40	0.55	0.22	0.13	2.17	0.94	0.02	0.22	6.60
0.00	0.07	0.70	0.30	0.15	0.18	0.21	0.58	0.19	0.19	0.06	5.48
0.00	0.01	0.21	0.02	0.00	0.01	0.05	0.04	0.05	0.02	0.01	0.51
100.50	99.14	100.00	99.85	99.24	100.46	99.94	99.49	100.67	100.02	100.99	100.88

220	221g	222g	225	226	230	231	233	236	237	238	240
C	C	C	C	P	C	C	C	C	U	P	R
61.72	56.78	57.10	60.25	56.90	50.68	55.44	55.07	62.69	42.06	59.80	57.86
0.08	0.11	0.24	0.09	0.09	0.15	0.08	0.12	0.28	0.10	0.27	0.13
1.83	2.70	5.48	3.51	1.63	4.01	0.90	2.77	5.26	5.10	4.59	3.14
0.15	0.77	0.16	0.35	0.42	0.63	0.80	0.73	0.20	0.51	0.23	0.24
1.13	4.57	0.57	2.68	1.18	3.84	2.65	5.05	2.14	5.20	0.93	2.21
0.04	0.51	0.12	0.20	0.07	0.14	0.16	0.15	0.19	0.08	0.19	0.17
31.68	31.92	32.46	29.85	36.97	36.62	37.45	33.84	20.65	43.21	26.51	32.69
1.11	2.70	2.86	2.21	0.78	3.39	0.84	2.25	2.39	3.13	2.66	0.86
0.54	0.93	1.35	0.60	0.31	0.10	0.06	0.28	2.80	0.50	2.09	1.63
0.05	0.19	0.18	0.04	0.05	0.02	0.02	0.04	0.23	0.02	0.70	0.12
98.33	101.18	100.52	99.78	98.40	99.58	98.40	100.30	96.83	99.91	97.97	99.05

	242	244	245	246	248c	249	250	251	252	254	255
	C	P	C	R	C	C	P	R	P	R	C
SiO2	50.78	53.06	53.95	57.84	52.33	58.76	56.84	59.33	55.82	58.45	53.20
TiO2	0.03	0.19	0.19	0.11	0.11	0.16	0.09	0.08	0.12	0.12	0.12
Al2O3	0.03	2.92	3.25	2.65	3.39	2.32	2.42	1.85	0.74	2.46	3.24
Cr2O3	0.72	0.39	0.73	0.47	0.62	0.74	0.47	0.31	0.36	0.41	0.63
FeO	12.20	2.15	2.47	1.93	6.31	3.08	1.70	1.62	1.33	1.50	1.46
MnO	0.23	0.41	0.02	0.08	0.14	0.15	0.05	0.17	0.19	0.13	0.00
MgO	35.02	36.27	35.47	34.72	33.39	31.54	34.11	32.23	39.48	33.69	38.70
CaO	0.33	2.46	1.80	1.67	2.43	1.32	1.13	0.57	0.87	0.99	2.79
Na2O	0.09	0.82	0.52	0.88	0.97	1.03	1.19	0.99	0.29	1.23	0.11
K2O	0.02	0.07	0.04	0.09	0.05	0.11	0.10	0.07	0.02	0.13	0.00
Total	99.45	98.74	98.44	100.44	99.74	99.21	98.10	97.22	99.22	99.11	100.25

256	257	258	259	260	261	263	264	265	266	267	268
P	T	C	B	C	P	C	B	C	B	B	R
58.60	99.08	53.30	48.78	50.50	57.26	52.00	46.66	55.52	49.29	48.32	61.91
0.20	0.00	0.00	0.28	0.19	0.11	0.08	0.25	0.16	0.22	0.30	0.14
3.42	0.00	0.00	4.17	1.48	3.15	0.71	5.16	4.12	3.37	5.67	2.25
0.49	0.06	1.19	0.62	0.55	0.35	0.67	0.41	0.71	0.80	0.40	0.35
1.77	0.30	3.07	4.77	1.23	1.82	2.31	4.22	0.89	3.29	1.54	1.66
0.19	0.00	0.00	0.09	0.00	0.14	0.00	0.08	0.21	0.08	0.02	0.12
32.30	0.28	41.44	36.27	43.61	33.45	44.73	37.14	32.14	38.29	36.90	29.40
2.29	0.09	0.12	4.05	1.28	0.74	0.55	4.82	2.73	3.26	5.04	1.06
0.39	0.00	0.30	0.08	0.20	1.67	0.14	0.06	1.13	0.12	0.32	1.22
0.05	0.60	0.00	0.02	0.00	0.13	0.00	0.04	0.24	0.01	0.01	0.11
99.70	100.41	99.42	99.13	99.04	98.82	101.19	98.84	97.85	98.73	98.52	98.22

269	270	271	273	274	276	300	302	303
R	C	T	T	T	T	U	U	U
60.79	55.97	99.51	99.47	99.65	100.16	48.72	38.47	38.64
0.11	0.00	0.00	0.00	0.00	0.05	0.06	0.20	0.14
2.07	0.10	0.00	0.02	0.00	0.01	0.23	3.61	4.47
0.42	1.60	0.11	0.05	0.01	0.00	0.65	0.62	0.60
1.62	7.53	0.67	0.32	0.16	0.19	10.36	11.26	12.45
0.34	0.29	0.00	0.00	0.17	0.00	0.24	0.12	0.07
30.15	35.35	0.21	0.01	0.15	0.00	38.38	42.69	41.38
1.49	0.32	0.00	0.00	0.04	0.03	0.40	3.01	2.10
1.19	0.05	0.00	0.02	0.00	0.02	0.06	0.75	1.10
0.13	0.00	0.00	0.00	0.02	0.05	0.01	0.04	0.04
98.31	101.21	100.50	99.89	100.20	100.51	99.11	100.77	100.99