Olivine sand from Kawashiri Beach in Kagoshima, Japan

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Abstract

The olivine sand from Kawashiri Beach was studied by chemical and X-ray analyses. At least six groups of olivine are mixed in the olivine sand in this region, and they are classified according to the composition of the silicate-melt inclusions in them. The composition of the olivine sand ranges from Fo_{70} to Fo_{75}, and the sum of the Mn_2SiO_4 and Ca_2SiO_4 content is less than 1 (mol %). These crystal chemical data for the olivine sand not only provide basic mineralogical information about it, but they also help us to estimate the origin of it.

Introduction

Kawashiri Beach is situated approximately 3 km east of Kaimon-dake volcano, approximately 50 km south of Kagoshima City, and measures about 2 km in length (Fig. 1). Beach sand in Kawashiri is composed of quartz, plagioclase, olivine, pyroxene, amphibole, magnetite, hematite and several kinds of rock fragments (Fig. 2a). The olivine sand in question is deposited as sediment especially on the surface of the backshore.

The mineral name olivine is used to call members of the solid solution between forsterite (Fo), Mg_2SiO_4 and fayalite (Fa), Fe_2SiO_4. The (Mg,Fe)-olivines are common and important rock-forming minerals, and are particularly characteristic of ultrabasic and basic igneous rocks. Their composition is a good indication of the differentiation stage of the parent magmas in which they crystallized. With respect to the physical

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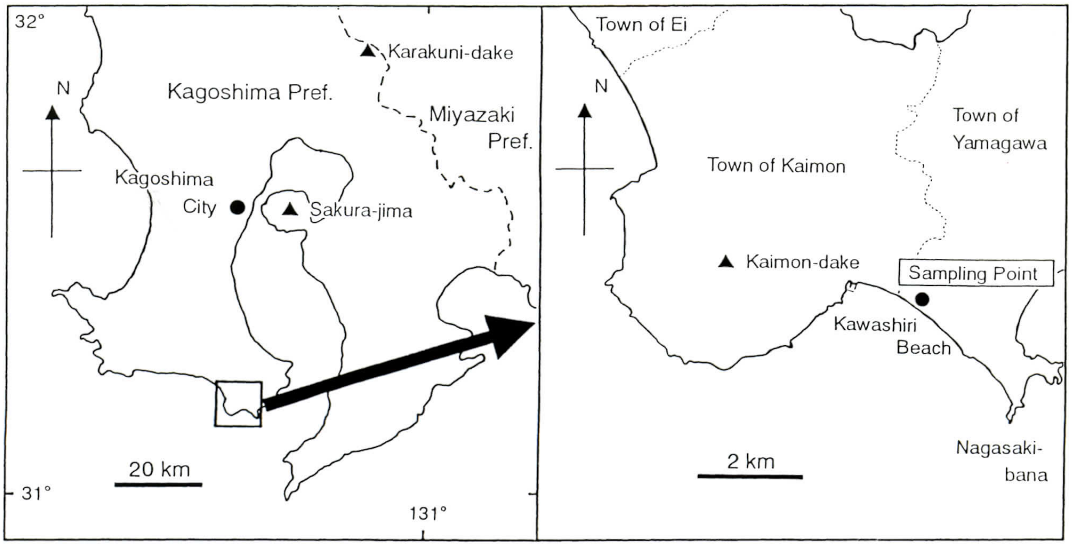

Fig.1 Location of Kawashiri Beach and sampling point of the olivine sand.

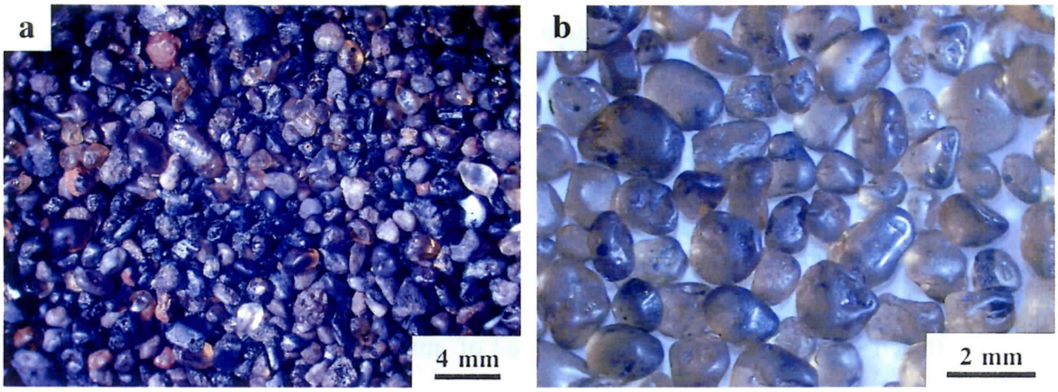

Fig.2 Beach sand in Kawashiri. a: mass of the beach sand on the surface of the backshore, b: the olivine sand picked up from the mass of the beach sand.

properties observable under the stereoscopic zoom microscope, olivines have no cleavage, and the samples rich in Fo content are transparent and often have a beautiful greenish to yellowish colour. These characteristic features make the olivine sand easily distinguishable in the sediments on the beach. Therefore, olivine sand is a good teaching material for the general public, including elementary school and junior high school students, who are trying to understand the rock-forming mineral cycle in nature. The cycle illustrates various geological processes that act to transform one rock type into another.

It has been well-known that the origin of the olivine sand in Kawashiri Beach is from Mt. Kaimon-dake volcano, but it has not been confirmed by chemical and X-ray analyses. The purpose of this work is to investigate and record the chemical and structural characters of the olivine sand from Kawashiri Beach.

Experimental procedure

Before the experiments, olivine sand sampled was washed in distilled water by ultrasonic cleaning to desalt it. The olivine sands which were polished to a thin section were observed under a polarizing microscope. Powder X-ray diffraction patterns for mineral identification were measured on a Rigaku X-ray diffractometer with Ni-filtered CuKα radiation (Miniflex). The program UnitCell (Holland & Redfern, 1997) was used for refinement of the unit-cell parameters of the olivine crystal in orthorhombic symmetry. Chemical analyses were performed with an electron-probe microanalyzer (EPMA), JEOL JAX-8621. ZAF on-line full matrix corrections were applied to quantitative analyses (Reed, 1996).

Results and discussion

The olivine sands from Kawashiri Beach are about 1 mm in diameter on average, and some specimens reach a maximum size of about 4 mm in diameter (Fig. 2b). Many crystals are of a pale yellow to greenish yellow colour, and are often abundant in black spherical inclusions. The olivine sand also shows a wide variation in its shape, which mainly depends on the degree of roundness. However, it is difficult to discriminate the sand grain with its original shape before erosion from one with the roundness after friction. The most euhedral crystal typically exhibits a shape of forsterite (Deer *et al.*, 1992), which is surrounded by well-developed {110}, {021}, {010}, {001} and {101} (Fig. 3).

In thin sections, the olivine sands are almost colourless or slightly yellowish in colour. All crystals of the olivine sand are homogeneous in the interference colours with high birefringence. There are no cleavages in the crystals. The black spherical inclusions mentioned above are present as opaque inclusions in thin sections. It is worthy of note that there are some glass inclusions in almost all grains of the olivine sand. For the sake of convenience, samples of the olivine sand were classified into five groups on the basis of the characters observed under the stereoscopic zoom microscope and the polarizing microscope (Fig. 4).

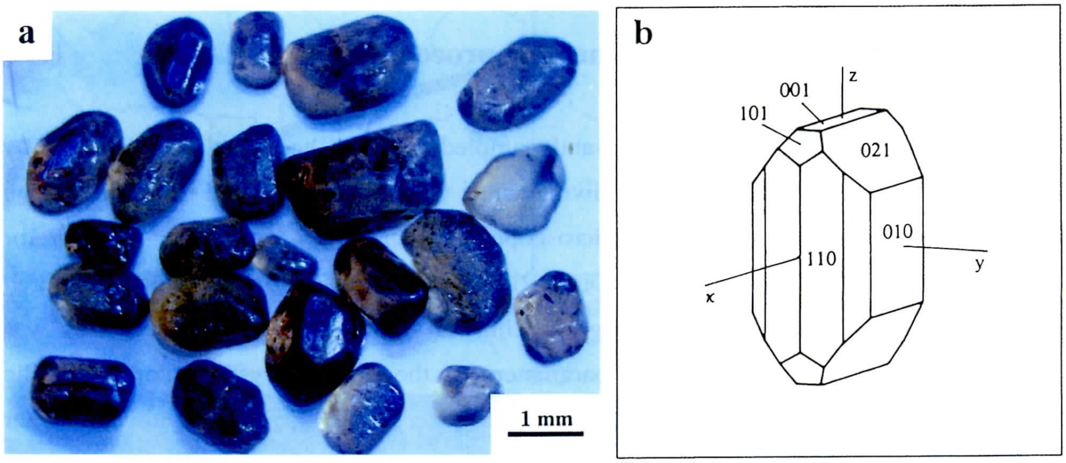

Fig.3 Characteristic externals of olivine crystal. a: euhedral olivine sand from Kawashiri Beach, b: ideal morphology of forsterite crystal, modified after Deer *et al.* (1992).

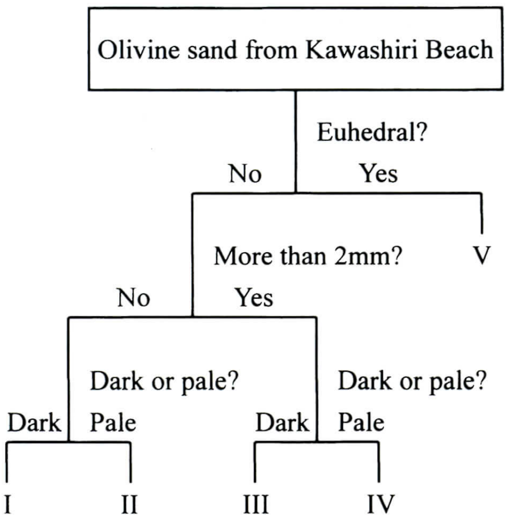

Fig.4 Scheme for the assignment of the number for samples on the basis of observation under the stereoscopic zoom microscope and the polarizing microscope.

X-ray analyses and the cell parameters

Identification of the olivine sand was made by X-ray powder diffraction. Using the PC-program UnitCell (Holland & Redfern, 1997), unit cell parameters for mass of the olivine sand were obtained by the least square refinement of 25 reflections (Table 1). The space group *Pbnm* with orthorhombic symmetry was used in the refinement of this study. The Fo (mol %) content is the mean value for 57 samples of the olivine sand, which was obtained by using EPMA described later. The cell parameters and Fo contents were compared with synthetic forsterite (Schwab & Künster, 1977) and hyalosiderite from the Skaergaard intrusion (Smith, 1966). Because Fe^{2+} and Mg are not the same size (Shannon, 1976), change in composition result in change in cell parameters.

Table.1 Comparison between cell parameters and Fo (forsterite) contents for the olivine sand from Kawashiri Beach. The data for forsterite and hyalosiderite are referenced.

Sample name	Fo (mol %)	*a* (Å)	*b* (Å)	*c* (Å)	*V* (Å^3)
Forsterite*	100	4.7540	10.1971	5.9806	-
Olivine sand**	74(1)	4.768(2)	10.284(4)	6.017(3)	295.0(2)
Hyalosiderite***	53.5	4.784	10.318	6.027	-

*: Synthetic forsterite (Schwab & Künster, 1977).
**: This study. Fo (mol %) is the mean value for 57 samples of the olivine sand.
***: Hyalosiderite from the Skaergaard intrusion (Smith, 1966).

Chemical analyses

Representative microprobe analyses for the six kinds of olivine from Kawashiri Beach are given in Table 2. Because, in the olivine of group III, it was proved that two kinds of glass inclusion, opaque and transparent, always existed separately in the different crystals, it was subdivided into two groups, IIIa and IIIb, respectively. Five elements, Si, Fe, Mn, Mg and Ca were detected by EPMA in every olivine sand crystal examined. Calculated end-members are Mg_2SiO_4, Fe_2SiO_4, Mn_2SiO_4 and Ca_2SiO_4. The last occurs very rarely in nature with olivine structure (Bridge, 1966); it is used here for the sake of convenience. The Fo content in the samples range from 70 to 75 (mol %), and the components of Mn_2SiO_4 and Ca_2SiO_4 are present in very small amounts. Thus olivine sands from Kawashiri Beach are chemically confirmed as chrysolite.

Back scattered electron image of the olivine sand by EPMA is shown in Fig 5. Two kinds of corroded inclusions, bright and dark, can be seen in these pictures.

Table.2 Representative microprobe analyses of the olivine sands from Kawashiri Beach.

	I		II		IIIa		IIIb		IV		V	
SiO_2	37.55		38.28		38.97		38.96		38.80		38.33	
FeO*	25.60		24.39		22.73		24.70		23.33		23.55	
MnO	0.46		0.48		0.36		0.49		0.53		0.40	
MgO	35.39		37.58		38.83		37.81		38.68		37.95	
CaO	0.10		0.13		0.15		0.12		0.11		0.14	
Total (wt. %)	99.10		100.86		101.04		102.08		101.45		100.37	
Number of cations on the basis of 4 O												
	obs.	calc.**	obs.	calc.**	obs.	calc.**	obs.	calc.**	obs.	calc.**	obs.	calc.**
Si	1.003	0.998	0.997	1.002	1.003	0.996	1.002	0.999	0.999	1.000	0.999	1.000
Fe	0.572	0.572	0.531	0.532	0.489	0.490	0.531	0.532	0.502	0.502	0.513	0.514
Mn	0.010	0.010	0.011	0.010	0.008	0.008	0.011	0.012	0.012	0.012	0.009	0.008
Mg	1.409	1.410	1.459	1.458	1.489	1.490	1.450	1.450	1.484	1.484	1.474	1.474
Ca	0.003	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.003	0.002	0.004	0.004
Total	2.997	2.994	3.002	3.006	2.993	2.995	2.997	2.997	3.000	3.000	2.999	3.000
Designation by olivine end-members												
Mg_2SiO_4	70.5		72.9		74.5		72.5		74.2		73.7	
Fe_2SiO_4	28.6		26.6		24.5		26.6		25.1		25.7	
Mn_2SiO_4	0.5		0.5		0.4		0.6		0.6		0.4	
Ca_2SiO_4***	0.2		0.2		0.2		0.2		0.1		0.2	
Total (mol %)	99.8		100.2		99.6		99.9		100.0		100.0	

*: Total irons were calculated as FeO.

**: Calculated on the basis of end-member.

***: Ideal end-member for the sake of convenience.

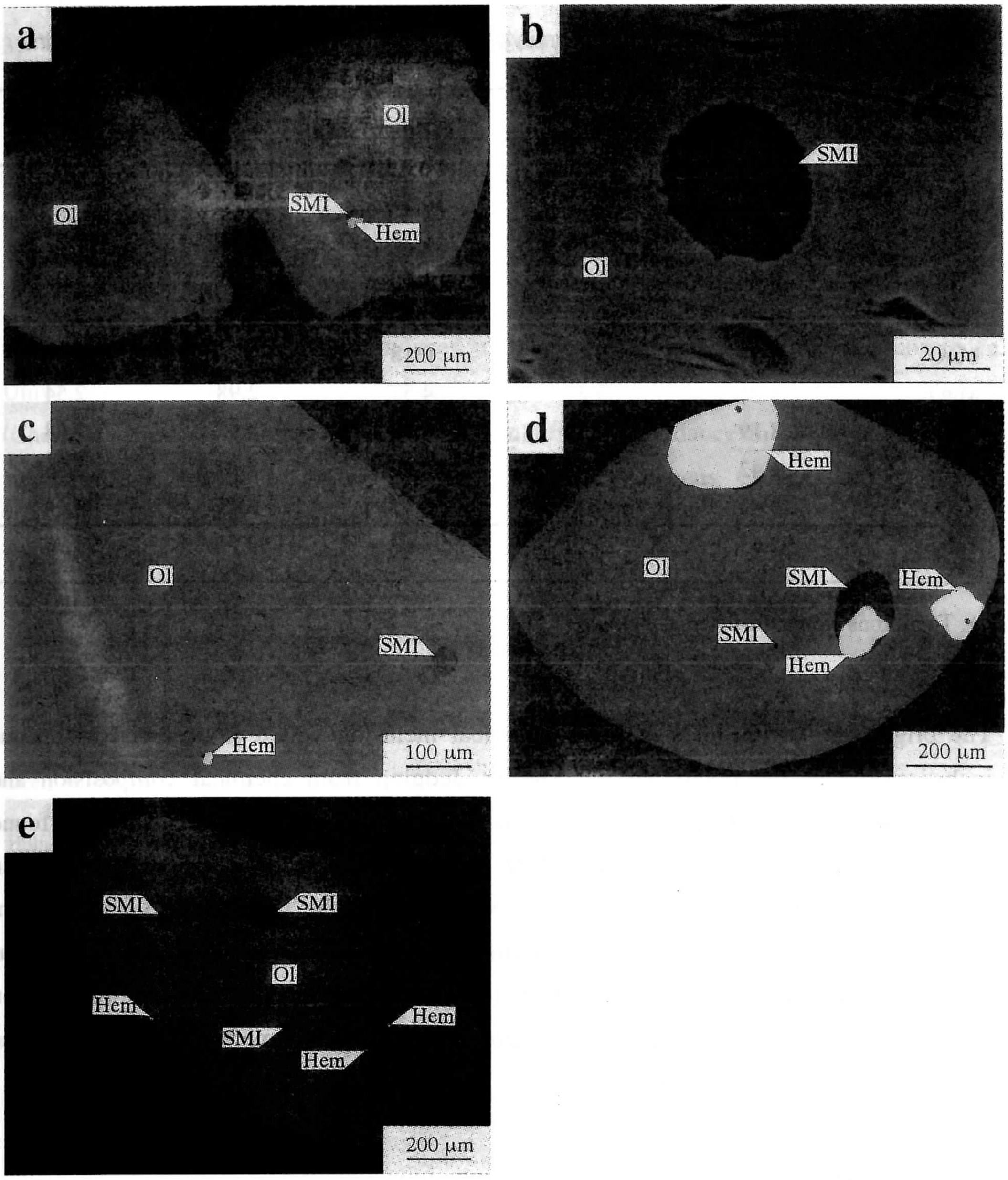

Fig.5 Back scattered electron images of the olivine sand from Kawashiri Beach. Except for sample II, all samples bearing silicate-melt inclusions are showed. Photographs of a, b, c, d and e correspond to the sample of group I, IIIa, IIIb, IV and V, respectively. Ol: olivine, SMI: silicate-melt inclusion, Hem: hematite.

Table.3 Representative microprobe analyses of silicate-melt inclusions in the olivine sand from Kawashiri Beach.

	I	IIIa	IIIb	IV	V
SiO_2	49.64	48.55	50.57	53.30	55.15
Al_2O_3	15.98	17.88	16.78	18.88	17.27
TiO_2	0.96	1.16	1.03	1.21	1.09
FeO^*	10.77	9.40	9.70	5.79	7.52
MnO	0.25	0.22	0.18	0.20	0.21
MgO	4.01	3.27	4.57	2.98	2.54
CaO	8.19	9.30	8.39	8.95	7.68
Na_2O	2.42	2.93	2.90	2.97	1.86
K_2O	0.43	0.43	0.51	0.45	0.64
Total	92.65	93.14	94.63	94.73	93.96

*: Total irons were calculated as FeO.

The bright one corresponds to black spherical inclusion which is observed as opaque inclusions under the polarizing microprobe. Judging from chemical composision and atomic ratio, the bright inclusion seems to be hematite. Another inclusion was found to be a silicate-melt inclusion, and their chemical compositions are in Table 3. In addition to Si, Al, Ti, Fe, Mn, Mg, Ca, Na and K in the table, considerable amount of P, S and Cl are detected on the qualitative analyses. If these silicate-melt inclusions in the olivine sand from Kawashiri Beach are primary, they provide information about the conditions of parent silicate magma, and the environment that the host olivine crystal surrounding them grew in.

Conclusions

The results of the study described here, suggest the following conclusions:

1) At least six groups of olivine are mixed in the olivine sand from Kawashiri Beach, and they are classified according to the silicate-melt inclusions in them.
2) The composition of the olivine sand ranges from Fo_{70} to Fo_{75}, and the sum of

the Mn_2SiO_4 and Ca_2SiO_4 content is less than 1 (mol %).

3) The opaque inclusion that is present in every olivine sample from Kawashiri Beach seems to be hematite.

This new work on crystal chemistry of the olivine sand from Kawashiri Beach not only provides basic mineralogical information about it, but also helps us to estimate the origin of it.

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