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Minerals in the Volcanic Ash Erupted from Shin-dake in Kuchinoerabu Island in 1980

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Abstract

The volcanic ash from 1980 eruption of Shin-dake in Kuchino-erabu Island, Kagoshima Prefecture was investigated. Alunite, gypsum, cristobalite, feldspar, quartz, kaolinite, smectite, pyrophyllite, chlorite and 10 Å-halloysite are the identified minerals present, but the amount of alunite is noted to be abnormally much. The energy dispersive X-ray analysis indicates that the alunite is K-rich. Small amounts of kaolinite, smectite, chlorite, 10 Å-halloysite, and pyrophyllite are clay minerals present. The existence of pyrophyllite indicates that it was formed together with alunite at relatively high temperatures before the eruption, whereas smectite and 10 Å-halloysite were formed at relatively low temperature.

Introduction

Shin-dake in Kuchinoerabu Island, located in southern Kyushu, erupted on September 28, 1980 after four years of silence. The eruption occurred suddenly without any signs of volcanic earthquakes. Seismic activity of volcanic earthquakes originated in shallow part under the island was however reported in the temporary observation carried out in February, 1980. Eruption occurred only once, and no eruption thereafter has been observed. This eruption yielded small amount of volcanic ash. Based on the authors studies on this material, it was found that volcanic ash is composed of alunite, cristobalite, and some clay minerals besides feldspar and quartz. Pyrophyllite and much amount of alunite are included in the volcanic ash. Reports of alunite and pyrophyllite in the volcanic ejecta of active volcanoes are not many. Alunite was not found in the volcanic ashes of Sakurajima volcano (Oba *et al.*, 1980a, 1980b, 1980c, 1981, 1984) and Shinmoe-dake (Tomita *et al.*, 1993a), although gypsum instead of alunite was noted in the volcanic ashes of Sakurajima

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volcano (Tomita, *et al.*, 1985). Reports of clay minerals identified in the volcanic ejecta of active volcanoes were made by Ossaka (1960) and Kanno *et al.* (1961). Ossaka (1960) reported clay minerals in the ejecta from Sakura-jima volcano in 1955, while Kanno *et al.* (1961) reported clay minerals in the volcanic ash erupted from Shinmoe-dake in 1959. Ossaka and his colleagues have likewise reported the presence of clay minerals in the volcanic ashes of Yake-dake erupted in 1962 (Ossaka and Ozawa, 1966), of Mt. Asama in 1973 (Ossaka *et al.*, 1973) and of Kusatsu-Shirane in 1976 (Ossaka *et al.*, 1976). The most common clay mineral observed in these previous studies is smectite. On the other hand, pyrophyllite in the volcanic ashes have not been reported yet. This paper presents mineralogical data of the volcanic ash erupted from Shin-dake in Kuchinoerabu Island.

Geological setting and activity of 1980

Kuchinoerabu Island belongs to the Tokara Islands. There are two volcanoes in the island, Furu-dake and Shin-dake. Shin-dake is composed of two pyroxene andesite. Its morphology shows a cone with a top crater. Shin-dake erupted on September 28, 1980 after four years of silence, and the eruption occurred suddenly without any signs of volcanic earthquakes. Seismic activity of volcanic earthquakes originated in shallow part under the island was recorded in February, 1980 in the temporary observatory. Eruption occurred only once along a fissure on the east side of the crater-rim. No eruption has been recorded thereafter. Weak fumarolic activity occurs in the area since then. This eruption yielded small amount of volcanic ash. The fall deposits spread out at southwest of the fissure. This fall deposits were composed of two layers. The lower layer contains coarse ejecta and accretionary lapilli, and the upper layer contains fine volcanic ash. The authors collected the volcanic ash on the surface of southwestern slope of Shin-dake at 175m level.

Experimental methods

The sample was collected from the surface of south-western slope of Shin-dake. The collected sample was examined by means of X-ray powder diffraction and thermal analysis. Chemical analysis and scanning electron microscopic observation were carried out for the sample as it is. Fine particles less than $2\mu\text{m}$ were collected by sedimentation and centrifugation. X-ray powder diffraction analysis was carried out with a Rigaku diffractometer (30KV, 15mA) using $1/2^\circ$ divergence and scattering slits. Thermal analysis was carried out with a Rigaku differential thermal analyser. Measurement was made from room temperature to 1000°C with a heating rate of 10°C per minute. Infrared absorption (IR) analysis was made with the Nihonbunko Infrared absorption spectrophotometer. The IR spectrum was recorded by KBr method. Chemical analysis was carried out by energy-dispersive X-ray spectroscopy (EDX) using a HITACHI S-4100H scanning electron microscope. Scanning electron micrograph was obtained with a JEOL JSM-25SII and a HITACHI S-4100H scanning electron microscope.

Mineralogical properties of the volcanic ash

Volcanic ash was collected from a place at 175m level (Fig. 1) on October 3, 1980. Mineralogical properties of the bulk sample and a sample less than $2\mu\text{m}$ collected by sedimentation method were investigated.

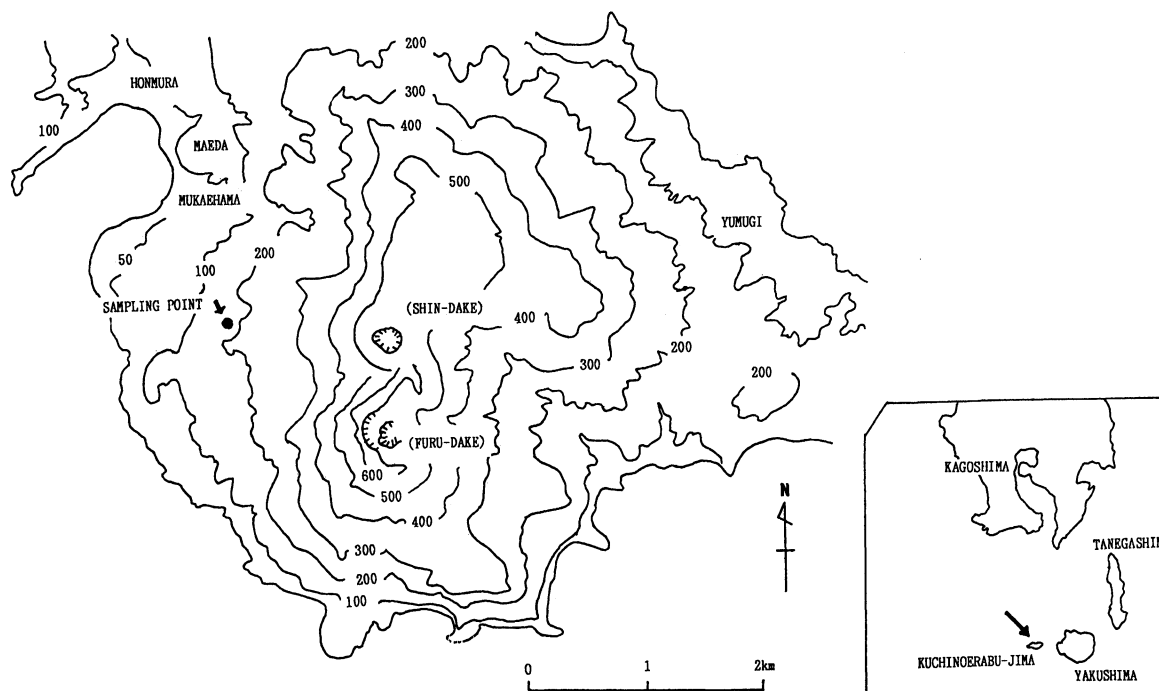


Fig. 1. Sampling location of the volcanic ash.

1. X-ray diffraction analysis

X-ray powder diffraction patterns of the untreated sample and the sample less than $2\mu\text{m}$ after various treatments are shown in Fig. 2. Reflections of alunite, plagioclase, α -cristobalite, pyrite, quartz, kaolinite, gypsum, chlorite and pyrophyllite are observed in the X-ray powder diffraction pattern of the volcanic ash. X-ray powder diffraction pattern of the sample less than $2\mu\text{m}$ shows similar pattern, but peak intensities of plagioclase and quartz decreased. Smectite and 10\AA -halloysite are observed in the sample less than $2\mu\text{m}$. A 15.5\AA peak of smectite moved to 17\AA and 10\AA peak of 10\AA -halloysite moved 11\AA by treatment with ethylene glycol, respectively. It was difficult to collect only clay minerals removing alunite and cristobalite.

2. Thermal analysis

Differential thermal analysis curves of the volcanic ash and the volcanic ash less than $2\mu\text{m}$ are shown in Fig. 3. A small exothermic peak of cristobalite between 200°C and 300°C is observed, and an exothermic peak at 423°C is interpreted by oxydation of sulfides such

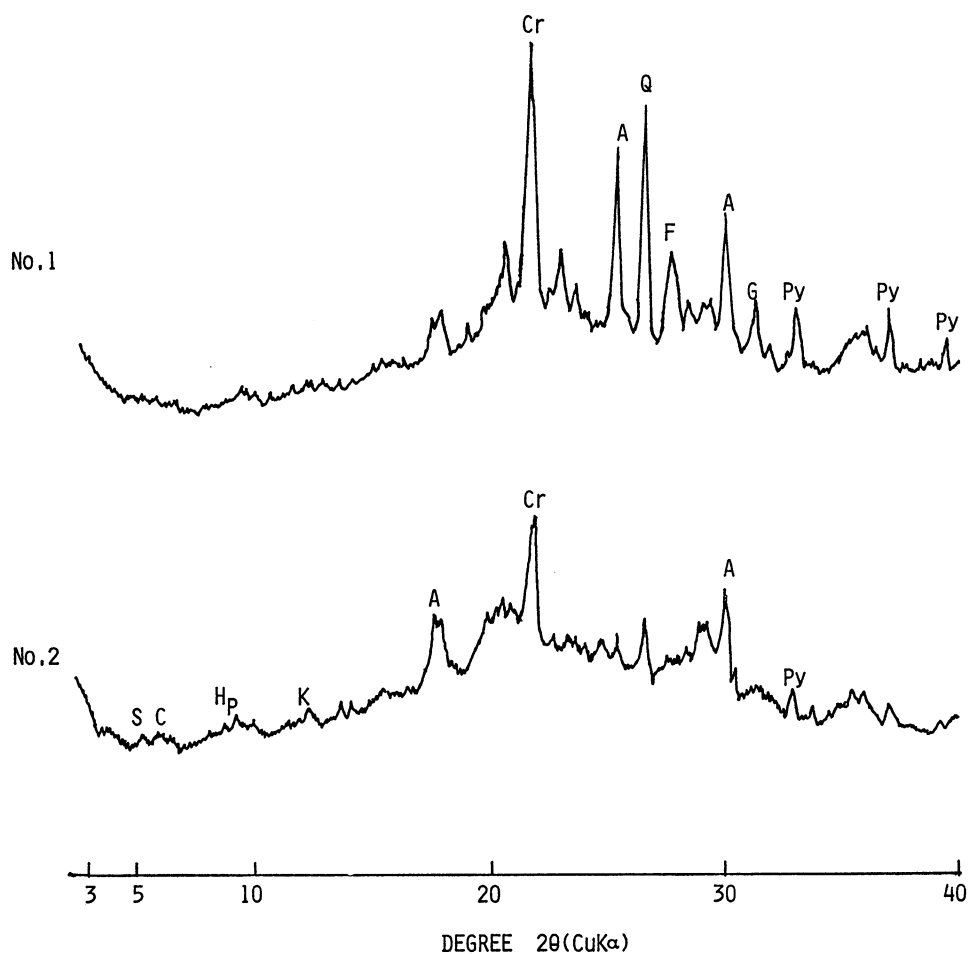


Fig. 2. X-ray powder diffraction patterns of the raw sample and the sample less than $2\mu\text{m}$.
 No. 1. raw sample, No. 2. sample less than $2\mu\text{m}$.
 Cr: cristobalite, A: alunite, Q: quartz, F: feldspar,
 G: gypsum, Py: pyrite, S: smectite, C: chlorite,
 H: 10-halloysite, P: pyrophyllite, K: kaolinite.

as pyrite. Endothermic peaks between 500°C and 600°C indicates clay minerals such as smectite, kaolinite and chlorite, and of alunite. Endothermic peak at 778°C is of pyrite, and endothermic peak at 747°C of pyrophyllite and sulphates are observed in the curve. The endothermic peaks below 200°C are due to dehydration of smectite and gypsum.

3. Infrared absorption analysis

The IR spectrum of the sample less than $2\mu\text{m}$ is shown in Fig. 4. The absorption bands at 3670cm^{-1} and 3620cm^{-1} are hydroxyl absorption of kaolinite. The absorption band at 3450cm^{-1} is due to the interlayer water of the smectite and 10 Å-halloysite. The band at 920cm^{-1} is assigned to the H-O-Al vibration. The absorption band at 1638cm^{-1} is due to bending vibration of OH in the clay minerals.

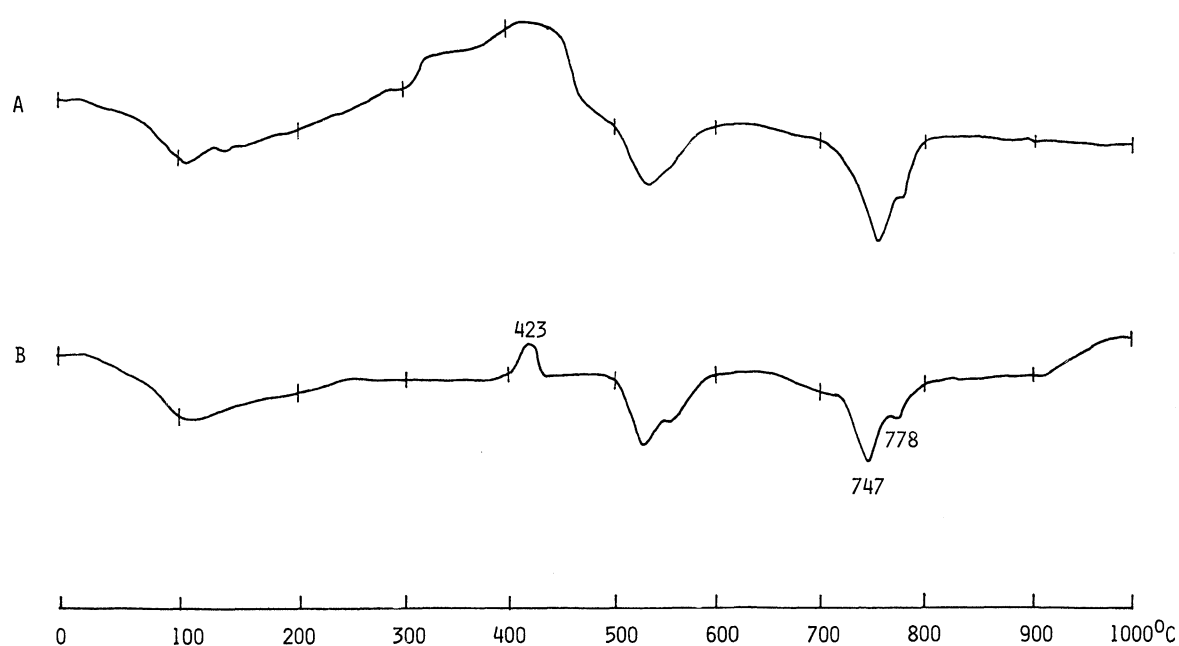


Fig. 3. Differential thermal analysis of the raw sample and the sample less than $2\mu\text{m}$.
A. raw sample, B. sample less than $2\mu\text{m}$.

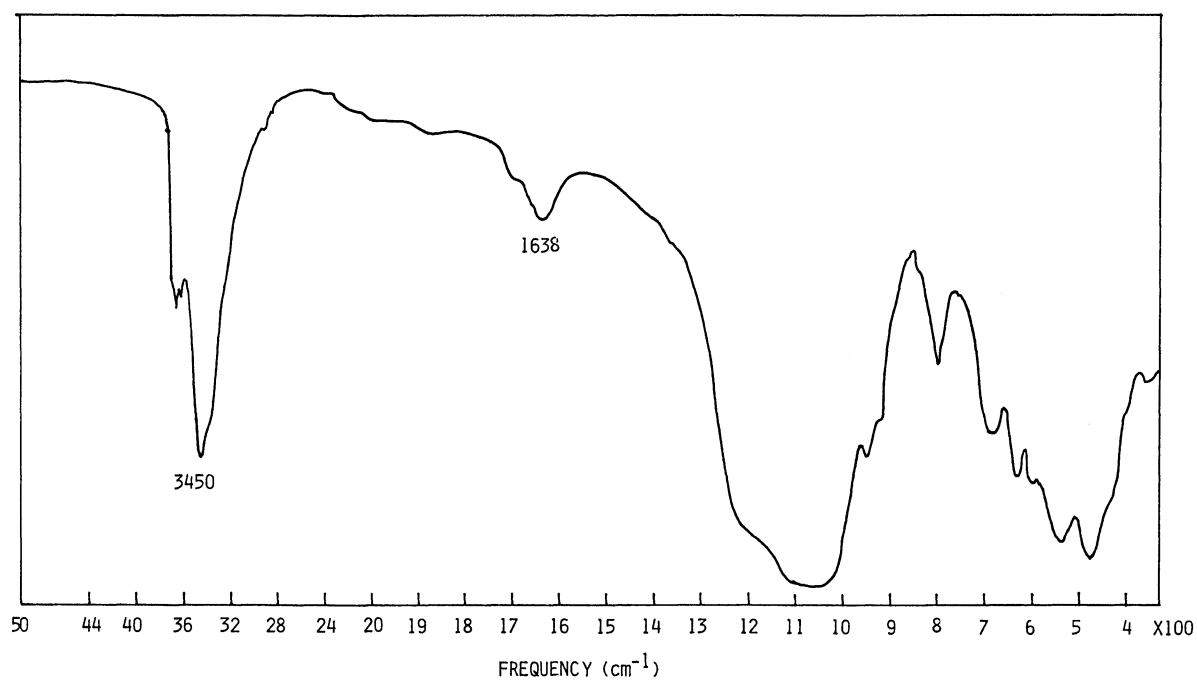


Fig. 4. Infrared absorption spectra of the volcanic ash.

4. Scanning electron microscopic observation

Scanning electron micrographs of the volcanic ash and the sample less than $2\mu\text{m}$ are shown in Fig. 5. Many flakey aggregates are present in the volcanic ash. These flakey crystals are clay minerals such as pyrophyllite, kaolinite and smectite (Fig. 5A, 5B). Foliated

aggregates of curled flakes of smectite are observed. Small round particles are alunite. Particle sizes of these minerals are very small.

5. Chemical analysis

Chemical analyses data for the fine particles of the volcanic ash are listed in Table 1, and semi-qualitative energy-dispersive X-ray spectrum of the sample is shown in Fig. 6. The chemical analysis data of the volcanic ash show high content of Si, and it is due to

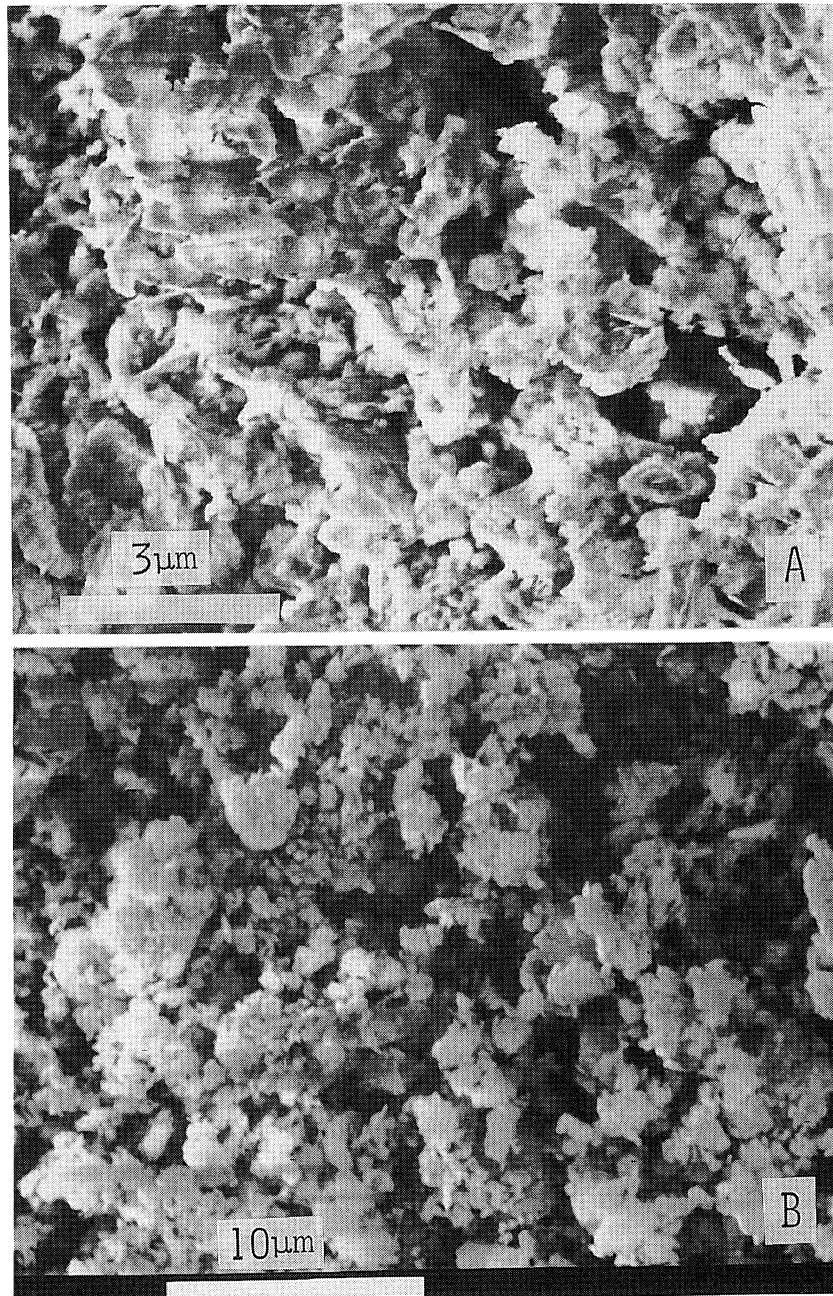


Fig. 5. Scanning electron micrographs of the volcanic ash.
A. raw sample, B. sample less than $2\ \mu\text{m}$.

crystalite. Particles of the sample are very fine, and as alunite, cristobalite, pyrophyllite and kaolinite crystals are stucked each other, it was impossible to separate pyrophyllite and kaolinite from other minerals.

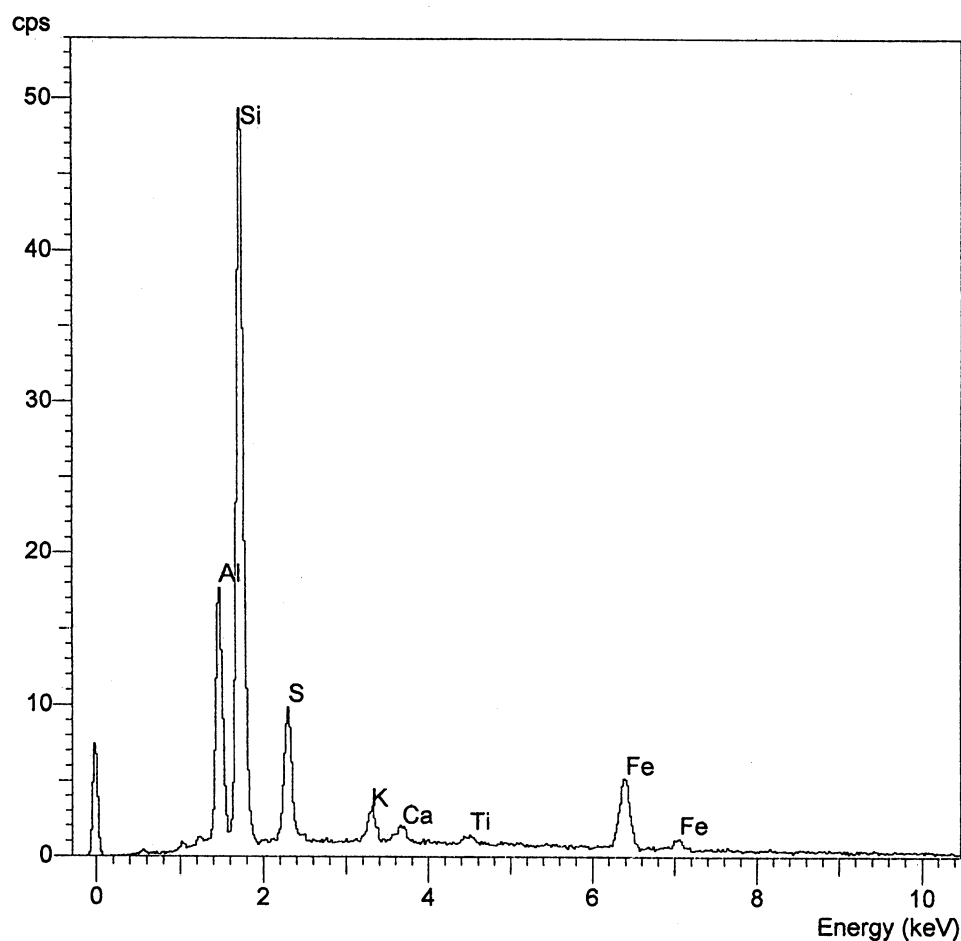


Fig. 6. Energy-dispersive X-ray spectrum of the volcanic ash.

Table 1. Chemical composition of the volcanic ash less than $2\ \mu\text{m}$

SiO ₂	55.11 %
TiO ₂	0.75
Al ₂ O ₃	18.02
FeO	10.30
CaO	0.90
K ₂ O	1.82
SO ₃	13.09
Total	100.00%

Discussion and conclusion

Existence of pyrophyllite in the volcanic ash indicates that alunite and pyrophyllite were probably formed by relatively high temperature hydrothermal alteration. Smectites are common low temperature alteration products. So smectite must have been formed at near surface of the fissure, whereas pyrophyllite was formed at inner part of the fissure. Kaolinite and alunite were probably also formed at the inner part of the fissure. Kristmannsdottir (1979) reported Fe-saponite at temperatures below 200°C in a geothermal well in Iceland. Seyfried and Bischoff (1979) produced Fe-saponite by experimental alteration of basalt by seawater at 150°C. The lowest temperature zone (<325°C) at a Hawaiian geothermal well is montmorillonite-rich (Fan, 1979). Kawano and Tomita (1992, 1993, 1994), Kawano *et al.* (1993), Tomita *et al.* (1993, 1994) synthesized smectite from volcanic glass and/or obsidian under 200°C. To consider these previous findings stated by several researchers, the smectite at Shin-dake was probably formed from components derived from solution and glass before the eruption, and then also probably formed from rock alteration by a geothermal system at the surface of fissure below 200°C. Amount of clay minerals were little in the volcanic ash of Shin-dake in Kuchinoerabu Island. Oosaka and his colleagues (Oosaka, 1960; Oosaka and Ozawa, 1966; Oosaka *et al.*, 1973, 1976; Matsuo *et al.*, 1977) reported clay minerals in the volcanic ejecta, and found out that clay minerals are present in the erupted ejecta after a long dormant state. Shin-dake also erupted after a long dormant period. But amount of clay minerals are not much. Considering that the last eruption of the volcano was four years ago, the periods of time were too short to form much clays. Chemical analysis data revealed that the alunite is a K-rich alunite close to endmember.

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