Mineralogy of “cordierite clusters” in Takakumayama Granite, Kagoshima, Japan

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Abstract

“Cordierite clusters” up to about 3 cm in diameter abundantly found in Sarugajo-type granitic rock (aplitic adamellite) from Takakumayama, Kagoshima, Japan, were examined using optical microscopy, X-ray diffraction, electron probe microanalysis, and X-ray analytical microscopy. The “cordierite clusters” were composed mainly of quartz, alkali feldspar, plagioclase, garnet, cordierite, biotite, muscovite and clinochlore. Compositional maping of the “cordierite cluster” revealed that microcrystalline clinochlore colored the cluster. An abundance of Fe in the cordierite indicates that it was formed in the pegmatitic stage during cooling of the Takakumayama Granite.

Keywords：“cordierite cluster”, clinochlore, granitic rock, Takakumayama

Introduction

Greenish “cordierite clusters” up to about 3 cm in diameter are abundantly found in granitic rocks from Takakumayama district, Kagoshima Prefecture, Japan (Figure 1). The granitic rocks are divided into two types, Sarugajo-type (aplitic adamellite) and Shinkoji-type (granodiorite), on the basis of contrasting petrological characteristics (Kawachi, 1961), and the “cordierite clusters” are found only in the former. A number of studies have reported the constituent minerals of the “cordierite clusters” (e.g., Oba and Ishikawa, 1959a, 1959b; Ishihara and Kawachi, 1961; Ota and Kawachi, 1965), whereas their compositional maps have been reported much less frequently and often have not been linked to the origin of the greenish color. The aim of this work is to describe the mineralogy of the “cordierite cluster” within the Sarugajo-type Takakumayama granite and to determine which mineral colors the clusters.

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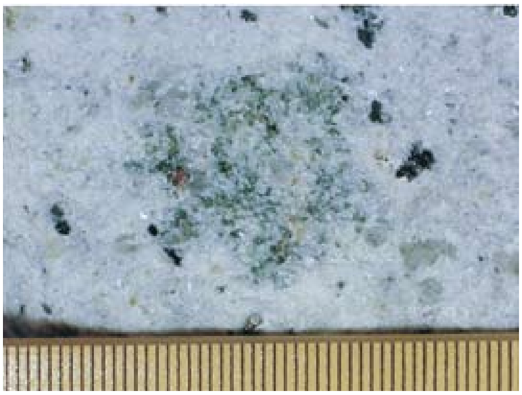

Figure 1. Greenish "cordierite cluster" within the Takakumayama Granite, Kagoshima, Japan.

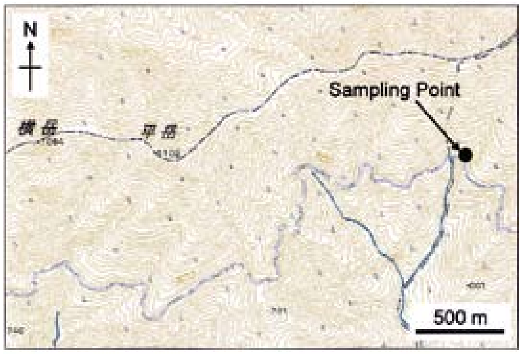

Figure 2. Location of sampling point of the greenish "cordierite cluster" within the Takakumayama Granite. Topographic map is a part from 1:25,000 "Kamiharaigawa" map published by the Geographical Survey Institute of Japan.

Occurrence

Takakumayama, the locality of the greenish "cordierite clusters", is on the west side of central part of the Osumi Peninsula, approximately 25 km southeast of Kagoshima City. The Takakumayama granitic stock is among the Middle Miocene granitoids intruding the Late Mesozoic accretionary complex, Takakumayama Formation, of the Shimanto Belt in the Outer Zone of Kyushu. The granitic rock is divided into two types, namely, Shinkoji-type and Sarugajo-type, based on their differing petrological characteristics (Kawachi, 1961). These types are classified as granodiorite and aplitic adamelite, respectively. The detailed geology and petrology of this stock has been also reported (e.g., Oba, 1958; Ota, 1963; Ota and Kawachi, 1965; Kawachi, 1969). To understand the formation of Takakumayama granite, chemical and X-ray powder diffraction studies have been carried out on the potassium feldspar. Furthermore, from heating experiments in air, the crystallization temperature has been estimated to be above 700 °C and 800 °C for granodiorite and aplitic adamellite, respectively (Yamamoto, 1975). Hydrothermal experiments have revealed that the granite formed in water-saturated environments at pressures below 1 kbar and a temperature of about 720 °C (Yamamoto, 1976, 1977). Miyachi (1985) determined the zircon fission-track age (12.9 ± 1.0 m.y.) for the granitic rock in this district.

Greenish "cordierites", which are found as cluster up to 3 cm across, were obtained from the Sarugajo-type granitic rock at the southern part of the Takakumayama granitic stock. The sampling point of the studied material is shown in Figure 2. The Sarugajo-type aplitic adamellite is composed of mainly quartz, alkali feldspar, plagioclase, biotite, garnet, muscovite, and tourmaline.

Analytical methods

Thin sections were prepared from rock fragments of Sarugajo-type granitic rock from Takakumayama and observed under a polarizing microscope (Nikon, Eclipse E600 POL). Semi-quantitative chemical analyses were performed with an electron microscopic analyzer (Philips, XL30) after observation of the backscattered electron images. For mineral identification, powder X-ray diffraction patterns were obtained using a Rigaku Geigerflex CN4037A1 diffractometer with Ni-filtered CuK_{α} radiation. Chemical analyses were carried out using a JEOL JXA-8621 electron probe microanalyzer. ZAF online full matrix corrections were used for quantitative analyses (Reed, 1996). Compositional maps were obtained using a Horiba XGT-5000 X-ray analytical microscope.

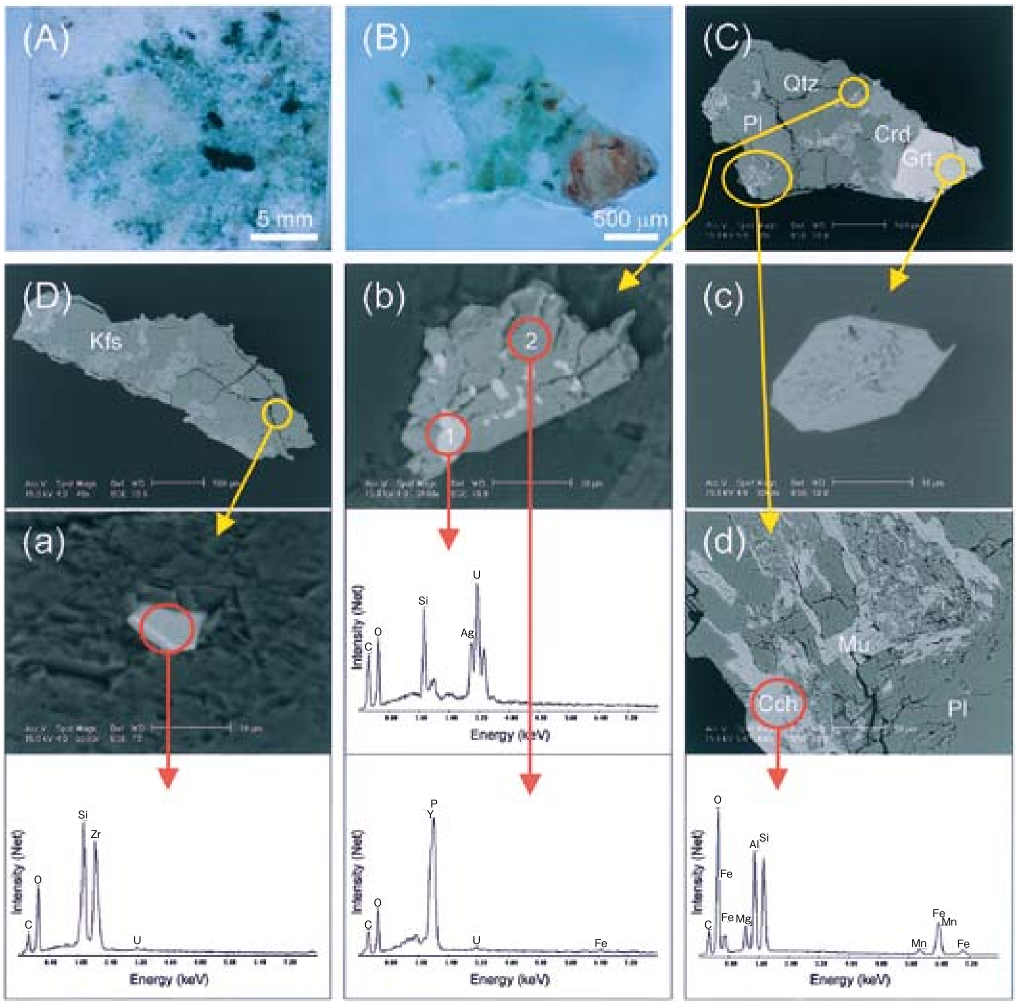

Figure 3. Macroscopic (A) and microscopic (B) observation of fractures of greenish “cordierite cluster”. (C) Backscattered electron image of “cordierite cluster” shown in (B). (D) Other fractures of the greenish “cordierite cluster”. Micro-inclusions shown in (a), (b)1, (b)2, and (c) appear to consist of zircon, uraninite, xenotime, and monazite, respectively. Abbreviations: Kfs, K-feldspar; Pl, plagioclase; Qtz, quartz; Crd, cordierite; Grt, garnet; Ms, muscovite; Cch, clinochlore.

Results

Macroscopic and microscopic observation

A polished section of the “cordierite cluster” is shown in Figure 3(A). Greenish parts were distributed heterogeneously over the “cordierite cluster” in which biotite and garnet grains were observed. Compositional maps show the concentration of Fe and Mn in the greenish parts (Figure 5). Backscattered electron image of the fragment in Figure 3(B) is shown in Figure 3(C). Micro-inclusions of zircon, uraninite, xenotime, and monazite were observed in the sample (Figure 3(a)-(d)).

X-ray analysis

The greenish part of the “cordierite clusters” was powdered and analyzed. As a result, five mineral phases, namely, quartz, plagioclase, muscovite, clinochlore, and cordierite, were observed in the X-ray diffraction patterns of the samples (Figure 4). The dark green clots found within the Takakumayama granitic rocks have been reported previously (e.g., Ota and Kawachi, 1965) to consist of mainly quartz, orthoclase, biotite, garnet, tourmaline, spinel, and cordierite, with some pinite present along cracks.

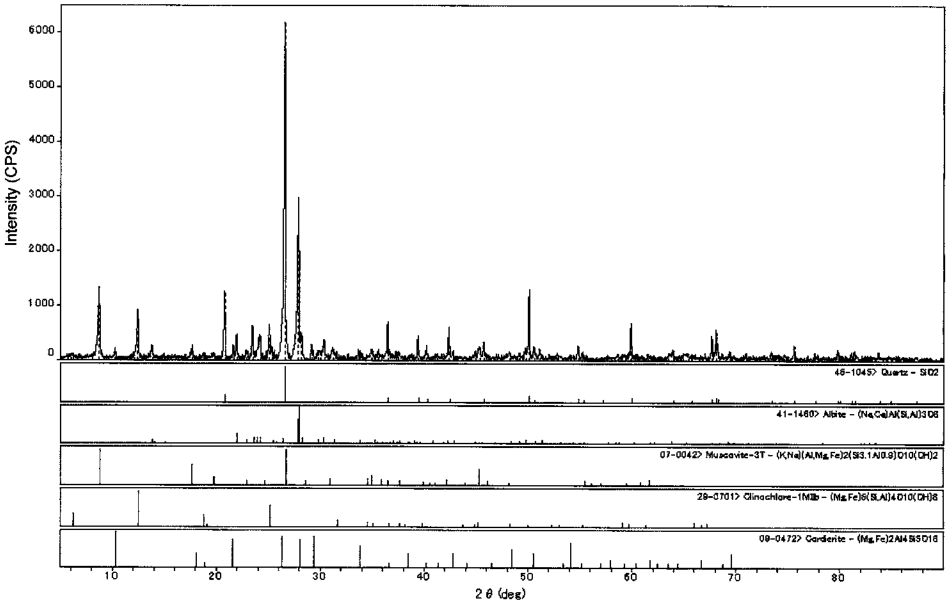

Figure 4. X-ray powder diffraction patterns of the greenish “cordierite clusters”. 40 kV, 20 mA, step: 0.01°, speed: 2°/min. Five minerals, namely, quartz, plagioclase, muscovite, cordierite, and clinochlore, were identified.

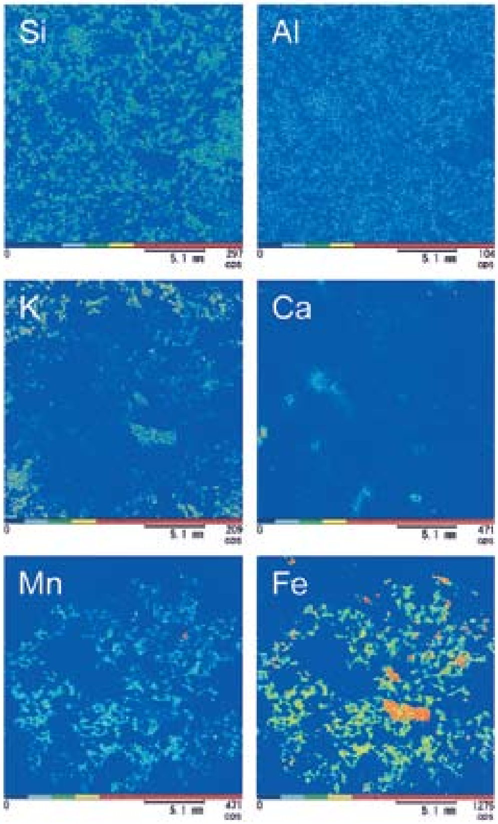

Figure 5. Compositional maps of the greenish “cordierite cluster” shown in Figure 3(A).

Table 1. Representative microprobe analyses of cordierite with a high Fe content.

	Takakumayama	Sugama (Iiyama, 1960)
SiO_2	46.91	44.64
Al_2O_3	30.92	29.96
Fe_2O_3	–	2.72
FeO	11.80*	11.02
MnO	3.61	1.86
MgO	2.23	3.08
Na_2O	1.64	2.05
K_2O	0.07	0.75
H_2O+	–	3.85 (H₂O+ and H₂O– combined)
H_2O-	–	
Total	97.18	99.95

* Total iron as FeO.

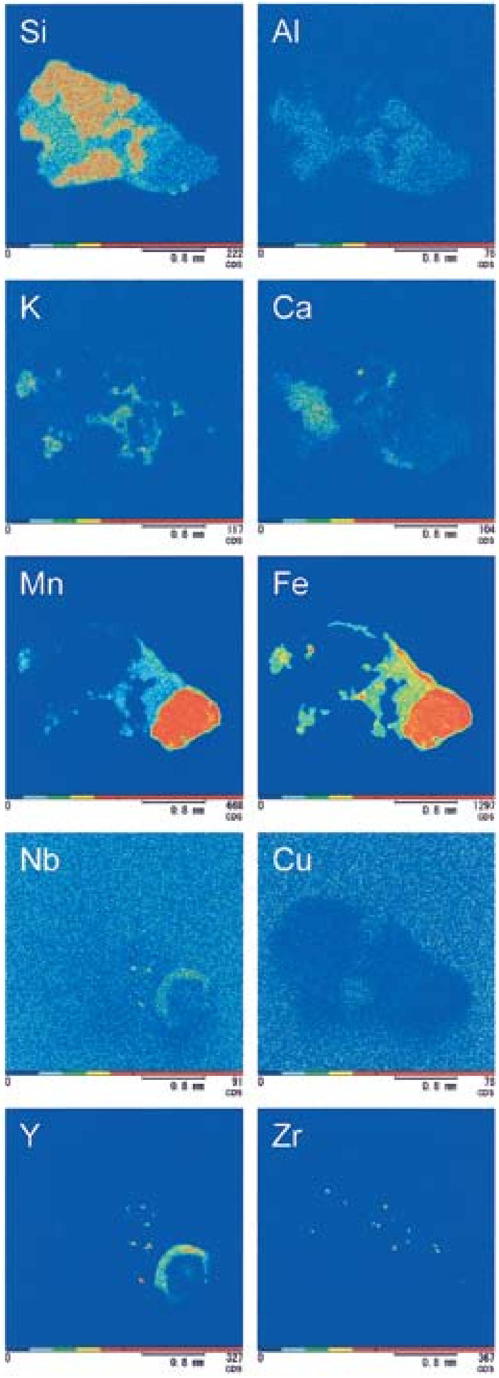

Figure 6. Compositional maps of the greenish “cordierite cluster” shown in Figure 3(B).

Chemical composition

Quantitative variations in chemical composition were determined using an X-ray analytical microscope (Figure 6). The clinochlore appeared to have a high concentration of K, Mn, and Fe, and corresponded to the greenish part of the “cordierite cluster”. Representative compositions of the cordierite in the analyzed samples are listed in Table 1. Seven elements were detected: Si, Al, Fe, Mn, Mg, Na, and K. The cordierite was characterized by high content of FeO. The Mg/(Mg + Fe + Mn) ratio was calculated to be about 21 percent. Iron-rich cordierite is rare and tends to be restricted to pegmatitic occurrences (Deer et al., 1986).

Summary

The conclusions of this work are as follows:

(1) The greenish “cordierite clusters” consist mainly of quartz, plagioclase, alkali feldspar, garnet, cordierite, biotite, muscovite, and clinochlore, and bear micro-inclusions of zircon, xenotime, uraninite, and monazite.

(2) Based on a comparison between the electron backscattered images and microphotographs, it seems clear that the “clusters” are colored by not cordierite, but rather clinochlore.

(3) The Mg/(Mg + Fe + Mn) ratio of the cordierite was calculated to be about 21 percent, which implies it is related to pegmatitic occurrences.

It appears that the cordierites were formed via a pegmatitic occurrence caused by the heterogeneous distribution of volatile components, and have been altered into pinite during cooling of the Takakumayama granitic stock. Then, the greenish “cordierite clusters” were fixed in the aplitic adamellite that constitutes the outer part of the stock.

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