Pink "Pseudomorph" after Plagioclase from the Takakumayama Granite, Kagoshima, Japan

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Abstract

Pink "pseudomorphs" after plagioclase of up to about 5 mm in diameter were found in Shinkoji-type granitic rocks from Takakumayama, Kagoshima, Japan, and were studied by chemical and X-ray analyses. Quantitative variations in chemistry were visualized using an X-ray analytical microscope. Elemental image of Ca showed distinct zoning, probably due to abrupt change in growth conditions. There were three zoned regions in the plagioclase: (1) an unzoned region in the core, (2) a dusty zoned region in the mantle, corresponding to the pink altered mineral found in hand specimens, (3) and an oscillatory zoned region in the rim. Alteration is roughly restricted to the mantle of plagioclase. The constituent of this pink altered zone was identified as smectite with a characteristic basal spacing of 15.3 Å under air-dried and untreated conditions. These descriptive mineralogy about the pink "pseudomorph" of smectite after plagioclase imply the abrupt mixing of mafic and felsic magma followed by hydrothermal alteration in a water-saturated condition.

Key words: pseudomorph, plagioclase, zoning, alteration, Tkakumayama granite

Introduction

During the fieldwork of granitic rocks and their constituent minerals in the Takakumayama district, Kagoshima Prefecture, Japan, pink altered plagioclases of up to 5 mm in diameter were found at Sarugajo Valley, Honjo River. As they are surrounded by relatively flat planes and are easily singled out from the host rock, they appear as pseudomorphs after plagioclase to the unaided eye. A number of studies have been reported on the alteration of plagioclase (e.g., Fournier, 1965; Page and Wenk, 1979; Peters and Hofmann,

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1984; Kamineni et al., 1993; Que and Allen, 1996). These studies concluded that the alteration of plagioclase is mainly related to hydrothermal fluid. For the plagioclase of this district, point analyses were conducted after the introduction of electron-probe microanalyzer (EPMA) to mineralogy, whereas compositional maps are much less frequent and often not linked to crystal morphology. The purpose of this work is to investigate and record the textural, chemical and structural characteristics of the pink "psuedomorphs" after plagioclase from the Takakumayama granite (Oba, 1958). The characteristic feature of the pink altered plagioclase make the crystal grain easily distinguishable in the granitic rock. Therefore, they are considered to be good teaching materials for the people, including primary school and junior high school students, which are interested in the rock-forming mineral in nature.

Occurrence

Takakumayama, the locality of the pink altered plagioclase is on the west side of the Osumi Peninsula, approximately 25 km southeast of Kagoshima City. Takakumayama granitic stock is among the Middle Miocene granitoids that intrude the Late Mesozoic accretionary complex, the Takakumayama Formation, of the Shimanto Belt in the Outer Zone of Kyushu. The granitic rock is divided into two types, the Shinkoji-type and the Sarugajo-type, because of their differences in petrological characteristics (Kawachi, 1961). They are classified as granodiorite and aplitic adamelite, respectively. The detailed geology and petrology of this stock has been also reported (e.g., Oba, 1958, 1963, 1967; Shibata, 1961; Ishihara and Kawachi, 1961; Ota, 1963; Ota and Kawachi, 1965; Kawachi, 1969; Tsusue, 1973). To understand the formation of the Takakumayama granite, chemical and X-ray powder diffraction studies were carried out on the potassium

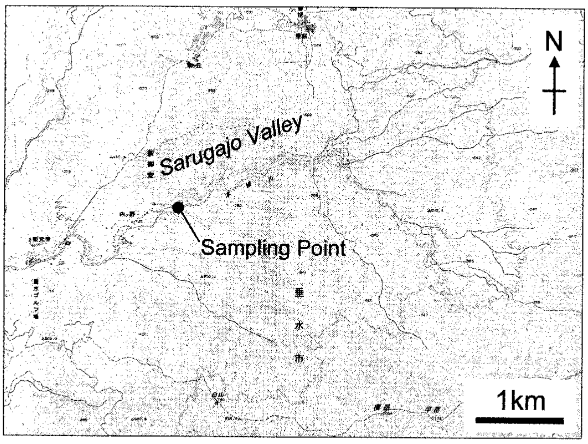

Fig.1. Location of Sarugajo Valley in Takakumayama, sampling point of plagioclase with pink altered zone. Topographic map is a part from 1: 25,000 "Kamiharaigawa" published by Geographical Survey Institute of Japan.

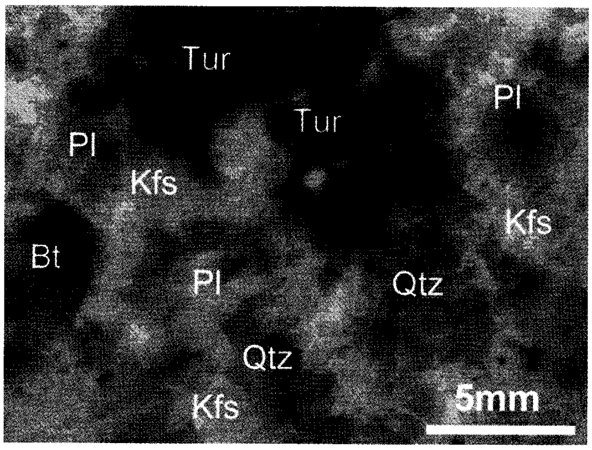

Fig.2. Macroscopic observation of the Shinkoji-type granodiorite from Takakumayama. Plagioclases with pink altered zone are shown in the figure. Abbreviations: Bt, biotite; Kfs, K-feldspar; Pl, plagioclase; Qtz, Quartz; Tur, tourmaline.

feldspar, and heating experiments were conducted in the air (Yamamoto, 1975). As a result, the crystallization temperatures were estimated above 700°C and 800°C for granodiorite and aplitic adamellite, respectively. Hydrothermal experiments revealed that the granite had been formed in water-saturated conditions at a pressure below 1 kbar, and at a temperature of about 720°C (Yamamoto, 1976, 1977). Miyachi (1985) determined the zircon fission-track age (12.7 ± 1.2 m.y.) for the granitic rock in this district.

The pink altered plagioclase which is found as euhedral granular crystal of up to 5 mm across was obtained from the Shinkoji-type granodiorite at Sarugajo Valley, Honjo River. The location of the samples taken is shown in Fig. 1. The granodiorite is composed of mainly quartz, K-feldspar, plagioclase, biotite and the accessory minerals muscovite, zircon, apatite, magnetite, garnet and tourmaline. The plagioclase is sorted into two groups because of their size (Ishihara and Kawachi, 1961). One shows a granular euhedral shape of up to 5 mm across and has remarkable optical zoning with albite-carlsbad twin and dusty zoning. The other measures about 1 mm, and has a subhedral shape with optical zoning and albite-carlsbad twin. The pink altered plagioclase studied here seems to correspond to the former (Fig. 2). K-feldspar shows no evidence of alteration and red pigmentation due to iron oxides.

Analytical methods

Rock fragments of the Shinkoji-type granodiorite from Takakumayama were polished to thin sections, and were observed under a polarizing microscope. For mineral identification, powder X-ray diffraction patterns were measured on the Rigaku X-ray diffractometers with Ni-filtered Cu$K\alpha$ radiation (Miniflex and RU-200). The unit-cell parameters were measured on the Enraf-Nonius CAD-4F diffractometer using graphite-monochromatized Mo$K\alpha$ radiation. Compositional maps were obtained by using the HORIBA XGT-5000 X-ray analytical microscope. Chemical analyses were performed with the JEOL JAX-8621 EPMA. ZAF on-line full matrix corrections were used for quantitative analyses (Reed, 1996).

Microscopic observation

A photomicrograph (with crossed polars) of the pink altered plagioclase is shown in Fig. 3. In thin sections, the plagioclase can be divided into the following three zones: (1) an unzoned region in the core, (2) a dusty zoned region in the mantle, corresponding to a pink altered mineral found in hand specimens, (3) and an oscillatory zoned region in the rim. Alteration is roughly restricted to the mantle of plagioclase. It seems that the initial alteration began in the mantle zone, then diffused into the core and the rim along defects like cleavages. In the core, the albite-carlsbad twin is remarkable and inclusions of biotite are present. The outline of the boundary between the core and the mantle shows an euhedral crystal form, which may exhibit its growth fronts. The oscillatory zoned region in the rim which is free of inclusion is built up of an aggregation of several grains of plagioclase. Macroscopically, regions of the core and the rim are colorless and transparent.

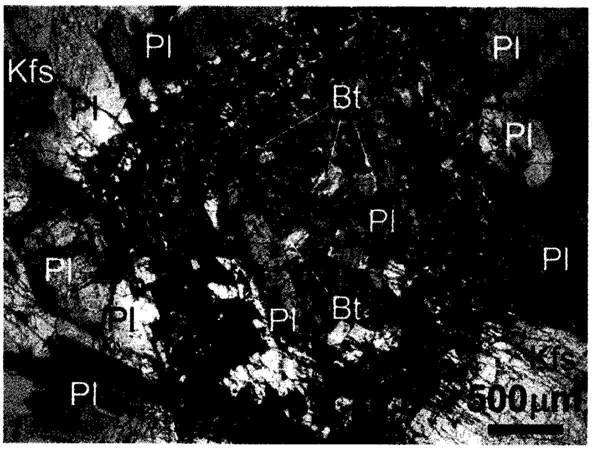

Fig.3. Photomicrograph of the plagioclase with pink altered zone (with cross polars). Abbreviations of mineral names are as in Fig. 2.

X-ray analyses

Identification of the minerals were made by X-ray powder diffraction. For the mineral from pink altered zone of the plagioclase, the basal spacing is 15.3 Å under air-dried and untreated conditions, which implies the presence of smectite. Precise identification of this clay mineral requires further treatment with water ethylene glycol, glycerol, cation exchange, and heating. The unit cell parameters of average structure were determined for the single-crystal of the unzoned region in the core of the plagioclase using a measurement from an X-ray diffraction photograph, and were refined using the setting angles of 25 reflections. They are a = 8.167(3), b = 12.850(6), c = 7.108(2) Å, α = 93.62(2), β = 116.21(2), γ = 89.87(3)°, V = 667.7(4) $Å^3$. The data are shown in Table 1.

Table 1. Cell parameters of average structure and anorthite (An) content for the plagioclase crystal from the core region surrounded by pink altered zone.

An (mol%)	a (Å)	b (Å)	c (Å)	α (°)	β (°)	γ (°)	V ($Å^3$)
52.4	8.167(3)	12.850(6)	7.108(2)	93.62(2)	116.21(2)	89.87(3)	667.7(4)

Chemistry

Representative microprobe analyses of the plagioclase in the granodiorite from Takakumayama are given in Table 2. In the plagioclase crystal examined, five elements, Si, Al, Ca, K and Na were detected, but Fe was not detected. The calculated end-members are $CaAl_2Si_2O_8$ (An), $NaAlSi_3O_8$ (Ab), $KAlSi_3O_8$ (Or), and $\square Si_4O_8$. $\square Si_4O_8$ which is an excess silica component in feldspar is calculated for the core samples. There is an exsolution in the core region. An contents in the samples of the core are 52.4 (mol%) and 42.0 in the An-rich region and Ab-rich region, respectively. Both the rim of the plagioclase with pink altered zone and the plagioclase without altered zone are about 25 (mol%) in An content.

Quantitative variations in chemistry were visualized using an X-ray analytical microscope (Fig. 4). Elemental image of Ca shows distinct zoning, probably due to abrupt change in growth conditions. K, Mn and Fe are concentrated in the altered zone, and these contents vary independently of the Ca content.

Table 2. Representative microprobe analyses of plagioclases with pink altered zone compared with plagioclase without altered zone in the same host rock of the Shinkoji-type granodiorite from Takakumayama.

	PlP (core)		PlP (rim)	Pl
	An-rich	Ab-rich		
SiO_2	55.31	57.75	61.09	62.05
Al_2O_3	28.48	26.55	23.87	24.13
CaO	10.77	8.82	5.60	5.47
Na_2O	5.14	6.46	8.21	8.52
K_2O	0.16	0.17	0.34	0.32
Total	99.86	99.75	99.11	100.49
Cations per 8 oxygens				
Si	2.490	2.590	2.734	2.740
Al	1.511	1.404	1.260	1.256
Ca	0.520	0.424	0.269	0.259
Na	0.449	0.562	0.713	0.729
K	0.009	0.010	0.020	0.018
Total	4.979	4.990	4.996	5.002
Designation by feldspar end-members				
$CaAl_2Si_2O_8$	52.4	42.0	26.9	25.7
$NaAlSi_3O_8$	45.3	55.8	71.2	72.5
$KAlSi_3O_8$	0.9	1.0	2.0	1.8
$\square Si_4O_8$	1.4	1.2	-	-
Total	100.0	100.0	100.0	100.0

Abbreviations: PlP, plagioclase with pink altered zone; Pl, plagioclase without altered zone.

Discussion

The texture of plagioclase with pink altered mantle is quite similar to the plagioclase with dendritic mantle which underwent magma mixing (Hibbard, 1981). Alteration, which is restricted to the mantles of plagioclase, is associated with defects or dendritic texture which are abundant in the mantles, but absent in the cores and the rims. Absence of alteration in potassium feldspar may have been due to the low density of defects in the potassium feldspar to the infiltrative hydrothermal fluids at the time of alteration. It is postulated that the alteration resulted from the action of externally derived hydrothermal fluids, which gained access to the defects or dendritic texture in the plagioclase through now sealed microfractures, formed by crystallization during cooling of the Takakumayama granite. The petrogenetic environment estimated by these descriptive mineralogy is in accordance with the water-saturated condition in crystallization (Yamamoto, 1976, 1977).

Though further investigation is required for completely understanding the formation of the Takakumayama granite, this new work on the crystal chemistry of the pink "pseudomorph" of smectite after plagioclases provides fundamental information about the mineralogy of the Takakumayama granite.

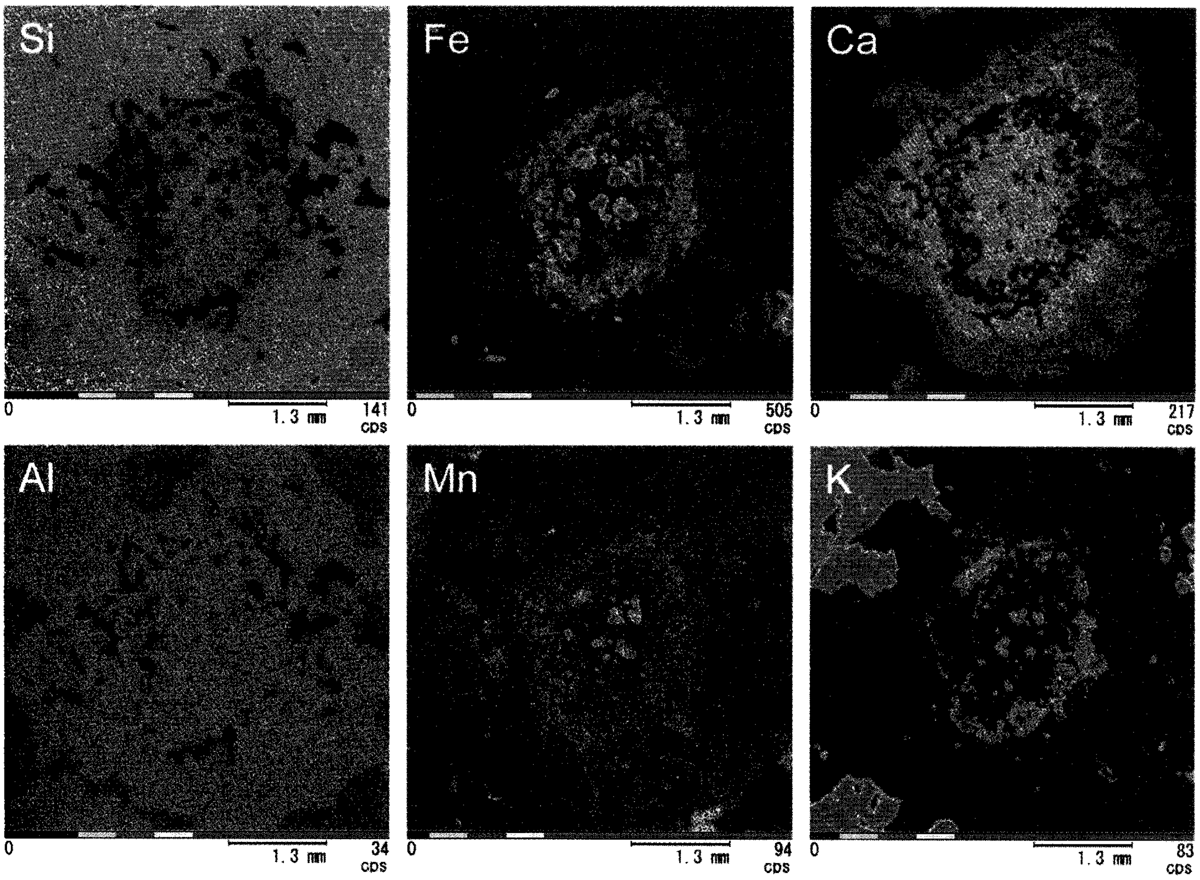

Fig.4. Compositional maps of the whole plagioclase with pink altered zone in the Shinkoji-type granodiorite from Takakumayama.

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References

Fournier, R. O. (1965) Montmorillonite pseudomorphic after plagioclase in a porphyry copper deposit. *Amer. Min.*, **50**, 771-7.

Hibbard, M. J. (1981) The magma mixing origin of mantled feldspars. *Contrib. Mineral. Petrol.*, **76**, 158-70.

Ishihara, S. and Kawachi, Y. (1961) On the Takakuma-yama granitic stock and related uraniferous ore deposit of Nagao-ko at Tarumizu mine, Kagoshima Prefecture. *Rep. Geol. Surv. Japan,* **190**, 333-49 (in Japanese with English abstract).

Kamineni, D. C., Kerrich, R. and Brown, A. (1993) Effects of differential reactivity of minerals on the development of brittle to semi-brittle structures in granitic rocks: textural and oxygen isotope evidence. *Chem. Geol.*, **105**, 215-32.

Kawachi, Y. (1961) Granitic rocks and related uraniferous metallic ore deposits in Southern Kyushu. *Rep. Geol. Surv. Japan*, **190**, 93-104, (in Japanese with English abstract).

Kawachi, Y. (1969) The structure of Takakumayama granitic stock. *Rep. Geol. Surv. Japan*, **232**, 145-54 (in Japanese with English abstract).

Miyachi, M. (1985) Fission track ages of some granitic rocks in the Outer Zone of Kyushu, Japan. *J. Japan. Assoc. Min. Petr. Econ. Geol.*, **80**, 406-9.

Oba, N. (1958) The Takakumayama granite mass, Osumi Peninsula, Kagoshima Prefecture. *Sci. Rep. Kagoshima Univ.*, **7**, 19-30 (in Japanese with English abstract).

Oba, N. (1963) Chemical composition of the Kyushu Outer Zone granitic rocks. *Sci. Rep. Kagoshima Univ.*, **12**, 35-51.

Oba, N. (1967) Granitic rocks in the western district of the Shimanto terrain, Southwest Japan. *Professor Hidekata Shibata Memorial Volume*, 34-40, in Sudo, T., ed., Tokyo, Meeting for Commen. Professor H. Shibata (in Japanese with English abstract).

Ota, R. (1963) Explanatory text book of the geologic map of of Japan, Scale 1:50,000, Tarumizu. *Geol. Surv. Japan*, 25p. (in Japanese with English abstract).

Ota, R. and Kawachi, Y. (1965) Explanatory text book of the geologic map of of Japan, Scale 1:50,000, Kanoya. *Geol. Surv. Japan*, 56p (in Japanese with English abstract).

Page, R. and Wenk, H. R. (1979) Phyllosilicate alteration of plagioclase studied by transmission electron microscopy. *Geology*, **7**, 393-7.

Peters, Tj. and Hofmann, B. (1984) Hydrothermal clay mineral formation in a biotite-granite in northern Switzerland. *Clay Miner.*, **19**, 579-90.

Que, M and Allen, A. R. (1996) Sericitization of plagioclase in Rosses Granite Complex, Co. Donegal, Ireland. *Mineral. Mag.*, **60**, 927-36.

Reed, S. J. B. (1996) *Electron microprobe analysis and scanning electron microscopy in Geology.* Cambridge Univ. Press, Cambridge, 201p.

Shibata, H. (1961) Chemical composition of Japanese granitic rocks in regard to petrographic provinces, Part IX. Normative minerals. *Sci. Rep. Tokyo Kyoiku Daigaku, Sec. C*, **8**, 19-32.

Tsusue, A. (1973) The distribution of manganese and iron between ilmenite and granitic magma in the Osumi Peninsula, Japan. *Contrib. Mineral. Petrol.*, **40**, 305-14.

Yamamoto, M. (1975) Potassium feldspars from the Takakumayama granite, Kagoshima Prefecture, Japan. *Rep. Fac. Sci, Kagoshima Univ. (Earth Sci., Biol.)*, **8**, 15-26.

Yamamoto, M. (1976) Crystallization of granitic glasses at 700°C and 1kbar. *Rep. Fac. Sci, Kagoshima Univ. (Earth Sci., Biol.)*, **9**, 9-20.

Yamamoto, M. (1977) Hydrothermal experiments and petrogenesis of the Takakumayama granite, Kagoshima Prefecture, Japan. *Rep. Fac. Sci, Kagoshima Univ. (Earth Sci., Biol.)*, **10**, 29-39.