NOTES ON PETROGRAPHY AND ROCK-FORMING MINERALOGY (7) ZONAL STRUCTURE OF ALBITE PORPHYROBLAST FROM BASIC SANBAGAWA SCHISTS IN CENTRAL SHIKOKU

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Albite porphyroblasts consist of the core rich in inclusions and the clear rim free from them. Compositional maps of An content of albite porphyroblasts show that the albite is zoned, and the types of zoning are different between the core and clear rim. The clear rim grew around the core preferentially along the lineation. The compositional maps and the microscopic observations show that the core of the porphyroblast was originally constructed of the aggregate of minute grains. There are two types of zonal structure of albite porphyroblasts: one is the simple type in which the An content decreases from the core to the clear rim, and the other is the complex type in which the An content decreases from the center to margin within the core, but it increases in the clear rim and again decreases at the outermost part of the clear rim. The variation of An content is very small, from about 0 to 3 An per cent, and even the An-richest composition is still albite in plagioclase nomenclature. The difference of zonal structures between the complex and simple types suggests that the formational stages of the porphyroblasts were different.

INTRODUCTION

Albite is a main constituent of the Sanbagawa metamorphic rocks. Many geologists have divided the Sanbagawa metamorphic belt into two zones, i.e., the spotted and non-spotted zones based on the presence and absence of albite porphyroblasts.

Recent study of albite porphyroblasts was commenced by Toriumi (1975a, b) who proposed a dynamic model for their origin that the porphyroblasts grew by collision and annealing of minute albite grains. He also showed that the compositional range of epidotes included in the porphyroblasts is nearly equal to that of epidotes in the matrix. Itaya (1978) found that retrograde

TiO₂-minerals are often included in the porphyroblasts. Hosotani (in press) concluded that the zonal structure of garnets included in the porphyroblasts is the same as that of garnets in the matrix. Based on these facts, Itaya and Hosotani have considered that albite porphyroblasts were formed during the retrograde stage of the Sanbagawa metamorphism. Hara *et al.* (1977) and Takagi and Hara (1979) have also attempted to clarify the formational stage of albite porphyroblasts using the fabric of the porphyroblasts and chemical information of amphibole inclusions in them. They have concluded that the formational stage of the clear rim (the mantle in their papers) coincided with the maximum temperature

phase of metamorphism.

The chemical compositions of albite in the Sanbagawa metamorphic belt have been reported by several authors, Ernst *et al.* (1970), Kurata and Banno (1974), Toriumi (1975a) and Watanabe (1977). Their data suggest that the anorthite content of albite increases with advancing metamorphic grade, but only slightly from about 0.1 to about 3 An per cent. Kurata and Banno (*ibid.*) have noticed that different porphyroblasts could have slightly different compositions in one specimen, where an albite porphyroblast has about 0.5 An per cent and another 0.95 An per cent, but did not pursue further investigation.

During the petrologic works of basic schists of the Asemi River area, belonging to the Sanbagawa metamorphic belt in central Shikoku, the present author has noticed that albite porphyroblasts have significant zonal structures. The zonal structure of albite porphyroblast gives important information in deciphering the growth history of albite porphyroblasts. In the following, the present author intends to describe the zonal structures of albite porphyroblasts from the Asemi River area with some petrologic discussions.

OUTLINE OF GEOLOGY

Recently the zonal mappings of the Sanbagawa metamorphic belt in central Shikoku were performed by Kurata and Banno (1974), Higashino (1975), Higashino *et al.* (1977) and Banno *et al.* (1978). The metamorphic zonal map of central Shikoku is shown in Fig. 1. The mineral zones in the figure are the chlorite, garnet and biotite zones in the ascending order of metamorphic grade and are defined by the mineral parageneses in the pelitic schists. The

Fig. 1. Metamorphic zonal map of central Shikoku, modified after Higashino *et al.* (1977). Sample localities are shown.

non-spotted zone comprises almost all the chlorite zone, and the spotted zone does the garnet and biotite zones and a part of the chlorite zone. Hence, the spotted zone belongs to the higher grade part of the Sanbagawa metamorphic belt same as in the other areas of the belt. In basic rocks, albite porphyroblasts are conspicuous as white patches.

MODE OF OCCURRENCE OF ALBITE PORPHYROBLAST

The zonal structures of albite porphyroblasts were studied in the basic schists along the Asemi River (Fig. 1). Albites in the non-spotted zone are almost pure albite, up to 0.5 An per cent, and do not have zonal structures, but albite porphyroblasts in the spotted zone are commonly zoned. Typical examples of such zonal structures will be described in this paper. Three specimens TH25, MO40 and MO55 studied in details belong to the higher biotite zone, the lower

Fig. 2. Photomicrographs of albite porphyroblasts which were cut parallel to tectonic b-c axes. Scale bars show 0.1 mm. The core rich in inclusions and the clear rim free from inclusions are well distinguished, and the boundary between them is rather sharp. a: TH25, open nicol. The clear rim develops well parallel to the lineation, but is poor or absent perpendicular to the lineation. b: MO55, open nicol. The core can be divided into two parts on the basis of the abundance of inclusions. The clear rim does not develop well in this albite porphyroblast. c: MO40, the left hand is open nicol and the right hand is crossed nicols. The clear rim develops well parallel to the lineation. This albite porphyroblast can be divided into four parts on the basis of the difference of extinction positions.

biotite zone and the garnet zone, respectively (Fig. 1). The mineral assemblages of TH25, MO40 and MO55 are hornblende+epidote+chlorite+stilpnomelane+sphene+rutile+ilmenite+pyrite, hornblende+epidote+chlorite+tourmaline+sphene+rutile+hema-

tite+ilmenite, and hornblende+epidote+chlorite+apatite+calcite+sphene+magnetite+hematite+ilmenite+chalcoppyrite, respectively. Albite, quartz and muscovite are ubiquitous in these specimens. The photomicrographs of albite porphyroblasts in these

specimens which were cut parallel to b-c tectonic axes are shown in Fig. 2. The mean grain-size of albite porphyroblasts is $0.63 \times 0.29 \text{ mm}^2$ on *MO55*, $0.88 \times 0.54 \text{ mm}^2$ on *MO40* and $1.7 \times 0.86 \text{ mm}^2$ on *TH25*. Grain size of albite porphyroblast increases with increasing metamorphic grade.

Albite porphyroblasts consist of the core rich in inclusions and the clear rim free from inclusions. The boundary between the two is rather sharp. Becke lines, however, could not be observed at the boundary. Every phase of basic schists is included in albite porphyroblasts, but common inclusions are epidote, amphiboles, sphene, rutile, ilmenite and hematite. On the other hand, chlorite, muscovite and calcite are usually absent in albite porphyroblasts. The distributions of inclusions in albite porphyroblasts are rather heterogeneous, as is most distinct in specimen *MO55* where the core of the porphyroblast can be divided into two parts on the basis of the abundance of inclusions (Fig. 2b). The clear rims are well developed along the lineation defined by the arrangement of elongated minerals such as hornblende, chlorite and muscovite, but poor or absent along the direction perpendicular to the lineation. Albite porphyroblasts of *TH25* and *MO55* are optically homogeneous, and the extinction position is the same within the grain and twinning is absent. On the other hand, an albite porphyroblast of *MO40* is divided into four parts by the difference of extinction positions (Fig. 2c). Optically homogeneous albite porphyroblasts, however, are also contained in this specimen.

ZONAL STRUCTURE OF ALBITE PORPHYROBLAST

The compositional maps of albite porphyroblasts in three specimens *TH25*,

Fig. 3. The compositional maps of albite porphyroblasts which are shown in Fig. 2. There are two types of zonal structures: One is the complex type of (a) *TH25*, and the other is the simple type of (b) *MO55* and (c) *MO40*. Explanations are given in text.

MO40 and *MO55* are shown in Fig. 3. The maps were constructed on the partial analyses of 354 points for *TH25*, 130 for *MO40* and 288 for *MO55*. The analyzed points were selected on the grid of tens of micron interval, but in analyzing the cores of the porphyroblasts, which contain abundant inclusions, the points were selected carefully to avoid the contamination by the inclusions. The analytical error is about ± 0.2 An per cent. The variation of An content of the porphyroblasts is only from nearly 0 to 3 An per cent, but is distinct. The orthoclase component is always less than 0.3 per cent, and no zonal structure in regard to K could be recognized.

The zonal structure of the porphyroblast in *TH25* is as follows: The An content is about 1.5 per cent at the center of the core and decreases towards the margin of the core, down to 0.5 per cent at the boundary between the core and clear rim. Entering the clear rim, it increases up to 3 per cent in maximum an intermediate part of the clear rim, but further outwards, it again decreases to 0.3 per cent. The An-rich rim in the compositional map coincides with the clear rim, but the zoning in the clear rim is not concentric, but the area with An more than 2 per cent is arranged subvertical to the schistosity. The zonal structure of the porphyroblasts in *MO40* and *MO55* is as follows: the core consists of albite with An more than 1 per cent, but no maximum of An content appears in the clear rim. As described above, there are two types of zonal structure, one is the complex type represented by *TH25*, and the other is the simple type represented by *MO40* and *MO55*.

Albite porphyroblasts are chemically and optically heterogeneous. The optical heterogeneity is represented by the presence and the absence of inclusions on the one hand, and by the difference in the extinction position on the other, even though the latter is not commonly observed. The former heterogeneity is confirmed by the chemical zoning on the compositional maps, which suggests that the clear rim grew around the core and was formed at the different physical conditions from the core. In specimen *MO40*, there are several area with An more than 1 per cent, and they correspond to the parts with the different extinction positions. Thus the core of the porphyroblast in this specimen had been formed by the aggregation of four minute grains with abundant inclusions, which was

enclosed by the clear rim. The core of the porphyroblast in specimen *MO55* consists of two inclusion rich parts which correspond with areas with An more than 1 per cent, although the porphyroblast shows homogeneous extinction throughout the grain different from the above example. The core of this specimen may be considered as the aggregate of two inclusion-rich grains, which was probably annealed to give homogeneous extinction. Toriumi (1975a, b) has proposed that some albite porphyroblasts had been formed by the collision of a few albite grains, which were later annealed to have led to the homogeneous extinction. He has interpreted the inclusions as being captured during the collision. Even though the albite porphyroblasts described here do not offer the evidence to test Toriumi's idea of the genesis of the inclusions, the growth by collision and later annealing seems to have operated in the examples described here as well.

In addition to the difference in the pattern of chemical zoning, the complex and simple types of albite porphyroblasts have different chemistry of amphibole inclusions. The use of chemical information of inclusion minerals in determining the formational stage of albite porphyroblasts was attempted by Itaya (1978), Takagi and Hara (1979) and Hosotani (in press). The preliminary results of the present author's investigation is described briefly here. The cores of the complex type porphyroblast contain hornblende, while those of the simple type both hornblende and actinolite, even though the host rock contains hematite. Otsuki and Banno (in preparation) have concluded that in hematite-bearing basic schists, the amphibole is crossite in the lower-grade basic schists, and it is replaced by barroisitic hornblende in the higher-grade ones.

However, the retrograde recrystallization gives rise to the formation of actinolite instead of crossite, suggesting that metamorphic pressure prevailed was higher during the prograde metamorphism than during the retrograde metamorphism. It follows that the core of the simple type of albite porphyroblasts was formed later than that of the complex type of the porphyroblasts. The view that the cores of some albite porphyroblasts were formed during the retrograde metamorphism is in harmony with the observation of Itaya (1978), who has shown that retrograde TiO_2 -minerals were included in the cores of some albite porphyroblasts. As discussed above, the detailed studies of the compositional zoning of the albite porphyroblasts and of the inclusion mineralogy could cast light to elucidate the thermal history of the Sanbagawa schists. The study along this line is being in progress by the present author.

ACKNOWLEDGEMENTS

The author sincerely thanks Dr. S. Banno for his continuous encouragement and the critical reading of the manuscript. His thanks are also due to Dr. Y. Nakamura and Dr. M. Toriumi for encouragements and discussions, and Prof. H. Onuki for the critical reading.

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四国中央部三波川塩基性片岩中に見られる曹長石斑状変晶の累帯構造

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四国中央部汗見川地域の塩基性片岩において、曹長石斑状変晶中にアノーサイト量に関する累帯構造が見られることを発見した。その変化幅は0から3 An%で少ない。曹長石斑状変晶のアノーサイト量に関する組成図を描いてみると次の事がわかる。曹長石斑状変晶の核は小さな曹長石粒子の集合体であり、包有物を包まない縁は核の出来た後、核を取巻くようにし線構造方向へ成長していった。曹長石斑状変晶には2種の累帯構造が見られる。1つは核がアノーサイト量に富み、縁で乏しい simple 型であり、もう1つは縁の方が核よりアノーサイト量に富む complex 型である。この2種の累帯構造の違いは曹長石斑状変晶の出来た時期の違いを反映していると考えられる。