DIFFUSION CONCENTRATION GRADIENT IN AN ORTHOCLASE FROM A GRANODIORITE OF THE IBARAGI GRANITIC COMPLEX

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Abstract

An orthoclase perthite phenocryst from coarse-grained granodiorite of the Nose pluton of the Ibaragi granitic complex exhibits concentration gradients of Na and K within the host orthoclase. This concentration gradient can be explained as the result of unmixing of the albite lamellae.

Introduction

Material transfer within minerals in the binodal region of the phase diagram has received considerable attention recently, inspired by the rapid progress of electron-microscopy (Cf. review by MORIMOTO, 1973). During a mineralogical study of the chemistry of rock-forming minerals of the Ibaragi granitic complex, Osaka Prefecture, we have found concentration gradients of K and Na, induced by perthite formation, in an orthoclase perthite from a granodiorite.

Chemistry of Orthoclase

The orthoclase perthite studied in detail is a phenocryst from a coarse-grained porphyritic granodiorite of the Nose pluton, a member of the Ibaragi granitic complex, the geology of which has been described by one of us (TAINOSHO, 1971). The host granodiorite contains orthoclase perthite, plagioclase and a few hornblende phenocrysts (5—10 mm) embedded in the groundmass, which consists of medium-grained (4—5 mm) plagioclase, alkali feldspar (Or_{88-91}), quartz and

biotite along with accessory apatite, allanite, sphene and zircon. The orthoclase phenocryst is subhedral and is surrounded by an aggregate of fine-grained quartz as sketched in Fig. 1A. The $2V_x$ is 40° and the $\Delta 2\theta_{(131-1\bar{3}1)}$ is nearly zero. Zonal structure is not conspicuous under the microscope, but minute quartz (Qz) and plagioclase (Pl) inclusions are arranged subparallel to the morphology of the orthoclase (Fig. 1A). Albite lamellae are present over the whole crystal except at the very marginal part. The lamellae are elongated parallel to (010) of the orthoclase (Fig. 1B).

The compositions of the host orthoclase and the lamellar albite were determined by electron-probe microanalyser, Hitachi model XMA 5A, operated at 15KV and 0.028 μ A specimen current. Examples of composition profiles across the crystal is shown in Fig. 2A, 2B. The composition of a few spots on the profile were determined using adularia and albite crystals as standards. Table 1 gives the representative compositions.

A remarkable feature of the composition profile is the fact that conspicuous compositional gradients of K and Na are observed in the orthoclase host.

Discussion

We may expect that local chemical equilibrium would be reached within each phase of the perthite as well as across the boundary between them. Equilibrium between two conjugate phases of a binary solid solution is reached only when the composition of those phases lie on the opposite side of the binodal line of the phase diagram. The albite lamellae are rather wide (15—20 μ

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maxima) and hence the contribution from the surface and strain energies near the boundary between the lamellae and host will be minimal. If the composition of the coexisting phases are inside the binodal, then the chemical potential of at least one component

is discontinuous across the boundary where its flux becomes infinite. Therefore, if the unmixing of macroscopic phase, or phases large enough to ignore the contribution of surface energy, proceeds at the same temperature, we might expect the composition of

Fig. 1. Sketch figure of orthoclase perthite (A) and its enlargement (B) which shows the path of composition profile shown in Fig. 2A and Fig. 2B.

Pl : plagioclase, Kf : orthoclase, Qz : quartz, Bi : biotite, Or : host orthoclase, Ab : albite lamella.

Fig. 2A. Composition profile of orthoclase perthite.

Fig. 2B. Composition profile of albite lamella.

Table 1. Electron-probe analysis of orthoclase phenocryst.

		1	2	3
wt. %	SiO ₂	66.4	66.3	68.6
	Al ₂ O ₃	18.5	19.4	18.9
	CaO	0.04	0.07	0.86
	Na ₂ O	1.22	0.67	11.2
	K ₂ O	13.8	14.6	0.23
	Total	99.9 ₆	101.0 ₄	99.7 ₉
Mole fraction	Or*	0.88 (0.87)	0.93 (0.94)	0.01 (0.02)
	Ab	0.12	0.06	0.95
	An	0.002	0.004	0.04

1. Orthoclase far from albite lamella

2. Orthoclase close to albite lamella

3. Albite lamella

* Partial analysis at Dept. Geology, University of Manchester, in parenthesis.

the conjugate phases to be kept constant at the boundary. It follows that the lamellae should be homogeneous and the concentration gradient is set up within the host such as shown in Fig. 2A, by which outward flow of Na and inward flow of K are made possible within the host orthoclase. The lamellar albite very often shows heterogeneous composition profile, but this could be due to a

complicated intergrowth geometry within the lamellae such that minute orthoclase wedges are present and affected X-ray intensity. It was possible to obtain simple compositional profile of the lamellae as shown in Fig. 2B, and in such a case significant concentration gradient could not have been detected.

With time, the pattern of the concentration gradient within the host orthoclase changes tending to reduce the gradient. Hence the K-poor and Na-rich portion of the host does not necessarily give the initial composition of orthoclase. However, on the composition profile there is a rather wide homogeneous region which may have a composition close to the original one.

Because we could not obtain a clear and quantitative composition profile within the albite lamellae, we were unable to detect whether the unmixing took place over wide temperature range or not. The composition profile within the host orthoclase does not serve to detect the temperature change during the unmixing.

The compositions of orthoclase and albite at the boundary are 0.92–0.93 and 0.02 in mole fraction of Or(KAlSi₃O₈), respectively. If the possible maximum and minimum temperature of the unmixing of orthoclase can be inferred from the binodals given by BACHINSKI and MÜLLER (1971) on microcline-low albite system (*r-s* method) and from that given by THOMPSON and WALDBAUM (1969) on sanidine-high albite series, respectively, it follows that the unmixing of the perthite in question took place about 400–500 °C, the temperature significantly lower than that of the solidification of granodiorite.

In this connection, it is noteworthy that SMITH and MACKENZIE (1958) considered that the unmixing of alkali feldspar could proceed well below 500 °C and even as low as 100 °C on a submicroscopic scale, even though the growth of lamellae as large as 20 μ may have occurred at the temperature much higher than 100 °C.

The alkali feldspar binodal is pressure sensitive (WALDBAUM and THOMPSON, 1969), but the specimen we have dealt comes from a shallow depth intrusion and hence the pres-

sure effect need not be considered.

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茨木花こう岩複合岩体の花こう閃緑岩の正長石中の組成勾配

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(要 旨)

茨木花こう岩複合岩体の能勢岩体の粗粒花こう閃緑岩の正長石パーサイトの母体正長石中に、カリウムとナトリウムの濃度勾配が検出された。温度がほぼ一定の条件で、粗い曹長石の薄層が正長石中で生長するためには、薄層と母体との境界で、それぞれの相の組成は一定でな

ければならない。その結果、ほぼ組成の一定な曹長石の薄層と、境界に向ってカリウムが増加、ナトリウムの減少する正長石母体とが形成される。パーサイト形成時の温度は 400～500°C 程度だったろうと推定される。