MEMOIRS OF THE FACULTY OF SCIENCE, KYOTO UNIVERSITY, SERIES OF GEOL. & MINERAL.
Vol. XXXV, No. 2, pp. 139-147

The Coexistence of Two Sorts of Plagioclase in a Relationship of Polysynthetic Twinning

By

Tateo UEDA and Masahisa TATEKAWA*

(Received Sept. 25, 1968)

Abstract

The contiguous polysynthetic twin lamellae in labradorite from Labrador and in andesine from Sannidal are not always the same sort of plagioclase. In some cases, one side lamella is built up from a high albite lattice, while the other side lamella from an intermediate plagioclase lattice, whose X-ray photograph is characterized by pairs of weak (e)-reflexions.

Introduction

It has been recognized that contiguous lamellae in a polysynthetic twin of an intermediate plagioclase feldspar show in some cases a considerable difference between them optically. COULSON (1932) observed a marked difference, as great as more than 10% *An* in composition. EMMONS and GATES (1943) confirmed COULSON's observation. EMMONS and MANN (1953) studied the compositional differences in polysynthetic twin lamellae of the plagioclase feldspars in a range from intermediate to more calcic. Determinations were made by means of Fedorow migration curves. Compositional differences between contiguous lamellae were observed in almost all cases, although the differences were not constant even in one specimen. The greatest difference, which reaches as high as 20% *An*, was found in a certain specimen twinned after the pericline law. GAY (1956) examined by an X-ray single crystal method the plagioclase feldspars from forty different localities whose compositions ranging from about 20% *An* to about 70% *An*, A majority of these specimens showed in rotation photographs an intermediate plagioclase pattern characterized by pairs of weak subsidiary layer lines which variably separate. The degree of separation of these layer lines was found to be a linear function of the composition over the whole compositional range.

These observations described above suggest that if we take an X-ray photograph of an intermediate plagioclase feldspar having two contiguous twin lamellae, we might obtain a photograph showing two patterns which bear a certain relation to

* Faculty of Education, Shiga University, Otsu.

each other, each of which being accompanied with pairs of weak subsidiary reflexions. Separations of them will reveal the compositions of the twinning individuals respectively.

Experimental

Specimens examined in the present investigation are labradorite from Labrador, Canada and andesine from Sannidal, Norway. The former shows the characteristic play of colours. The bulk compositions of these specimens are shown in Table 1. Components of the labradorite and andesine are, therefore, An_{52}

Table 1. Chemical compositions of the specimens from Labrador and Sannidal.

Constituent	from Labrador	from Sannidal
SiO_2	55.18 %	59.68 %
Al_2O_3	28.36	25.29
Fe_2O_3	0.04	0.21
FeO	———	0.27
MgO	———	0.11
CaO	10.77	7.00
Na_2O	5.26	7.13
K_2O	0.33	0.25
$H_2O^{(+)}$	0.05	0.07
$H_2O^{(-)}$	0.02	0.19
Total	100.01	100.20
Ab	46	64
An	52	35
Or	2	1

and An_{35} respectively. Under the microscope the labradorite shows albite twinning and the andesine pericline twinning. Slender cleavage splinters for taking X-ray photographs were carefully picked up under the microscope to select splinters which consist of two contiguous lamellae. With such splinters the authors took rotation and Weissenberg photographs. Before taking photographs, however, some considerations were made as follows:

(1) *In case that a specimen is twinned after the albite law.* Let the crystallographic axes of a twinning individual be $+a_A$, $+b_A$ and $+c_A$, and its reciprocal axes $+a_A^*$, $+b_A^*$ and $+c_A^*$. (Fig. 1-A) Since a twin plane of an albite twin is (010), by reflecting the sets of axes by (010) we obtain the crystallographic axes $+a_B$, $-b_B$ and $+c_B$ of the other individual and its reciprocal axes $+a_B^*$, $-b_B^*$ and $+c_B^*$; $+a_B$ falling

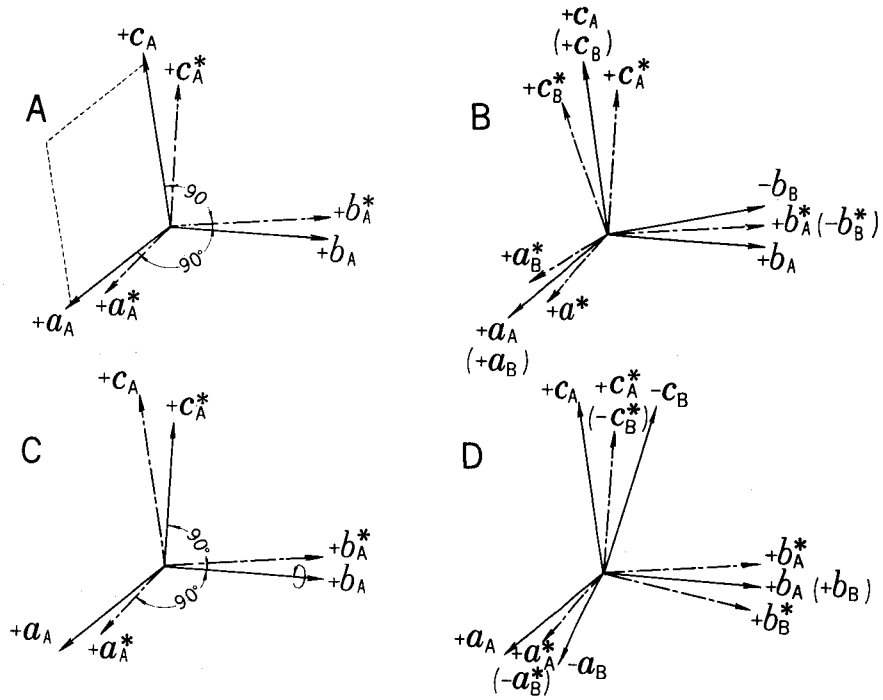

Fig. 1. Relationships between crystallographic and reciprocal axes (A, C), and those in albite twin (B) and in pericline twin (D).

into exact coincidence with $+a_A$ and $+c_B$ with $+c_A$, and $-b_B^*$ being nothing else than $+b_A^*$. (Fig. 1–B) Among these axes there are the following relationships:

$$+a_A(+a_B)\perp+b_A^*(-b_B^*),\ +c_A^*,\ +c_B^*;$$
$$+b_A\perp+a_A^*,\ +c_A^*;\ -b_B\perp+a_B^*,\ +c_B^*;$$
$$+c_A(+c_B)\perp+a_A^*,\ +a_B^*,\ +b_A^*(-b_B^*)\ .$$

Hence, when we take rotation and/or Weissenberg photographs about the $+a_A(+a_B)$- or $+c_A(+c_B)$-axis, we can observe simultaneously the reflexions from both the twinning individuals, but not about the $+b_A$- or $-b_B$-axis.

(2) *In case that a specimen is twinned after the pericline law.* Let the crystallographic axes of a twinning individual be $+a_A$, $+b_A$ and $+c_A$, and its reciprocal axes $+a_A^*$, $+b_A^*$ and $+c_A^*$. (Fig. 1–C) Since a twin axis of a pericline twin is [010], by rotating the sets of axes by 180° about the $+b_A$-axis we obtain the crystallographic axes $-a_B$, $+b_B$ and $-c_B$ of the other individual and its reciprocal axes $-a_B^*$, $+b_B^*$ and $-c_B^*$; $-a_B^*$ falling into exact coincidence with $+a_A^*$ and $-c_B^*$ with $+c_A^*$, and

$+b_B$ being nothing else than $+b_A$. (Fig. 1–D) Among these axes there are the following relationships:

$$+a_A \perp +b_A^*,\ +c_A^*(-c_B^*);\ -a_B \perp +b_B^*,\ -c_B^*(+c_A^*);$$
$$+b_A(+b_B) \perp +a_A^*(-a_B^*),\ +c_A^*(-c_B^*);$$
$$+c_A \perp +a_A^*(-a_B^*),\ +b_A^*;\ -c_B \perp -a_B^*(+a_A^*),\ +b_B^*.$$

Hence, when we take rotation and/or Weissenberg photographs about the $+b_A(+b_B)$-axis we can observe simultaneously the reflexions from both the twinning individuals, but not about any other axes. However, when the angle γ is 90° or very nearly 90°, as in the case of intermediate plagioclase feldspars, $-a_B$ fall into exact or almost exact coincidence with $+a_A$, and it may be expected that in the rotation and/or Weissenberg photographs about the $+a_A$- or $-a_B$-axis we might be able to observe simultaneously the reflexions from either of the twinning individuals.

Specimen from Labrador

The specimen from Labrador showed in the c-axis rotation photogarph a pattern with weak pairs of subsidiary layer lines, the δ_c being 143°. The spedimen showed, in the main layer Weissenberg photographs about the same axis, a pattern which consists of two sets of reflexions, showing $+a_A^*$, $+a_B^*$ and $+b_A^*(-b_B^*)$ reciprocal axes in the zero layer Weissenberg photograph; while in the subsidiary layer Weissenberg photographs about the same axis a normal pattern. The specimen showed in the a-axis rotation photograph a normal pattern, in the Weissenberg photographs about the same axis a pattern which consists of two sets of reflexions, showing the $+b_A^*(-b_B^*)$ and $+c_A^*$, $+c_B^*$ reciprocal axes in the zero layer Weissenberg photo graph, (Fig. 2–A, Fig. 2–B) one set of reflexions being accompanied with generally weak subsidiary reflexions. The specimen showed in one of the b-axes rotation photograph a normal pattern, in the Weissenberg photographs about the same axis a pattern with generally weak subsidiary reflexions; in the other b-axis rotation photograph a normal pattern too, while in the Weissenberg photographs about the same axis, a pattern without subsidiary reflexions. One of the twinning individuals of the labradorite is, therefore, composed of a lattice which shows weak subsidiary reflexions.

Referring to the works made by the previous investigators, the one set of reflexions which is accompanied with subsidiary reflexions was indexed on the basis of a 14 Å c-axis, and the other set which is not accompanied with subsidiary reflexions was on the basis of a 7 Å c-axis. In the former, main reflexions appear when $h+k=2n$ and $l=2n$, and pairs of subsidiary reflexions appear taking the place of reflexions,

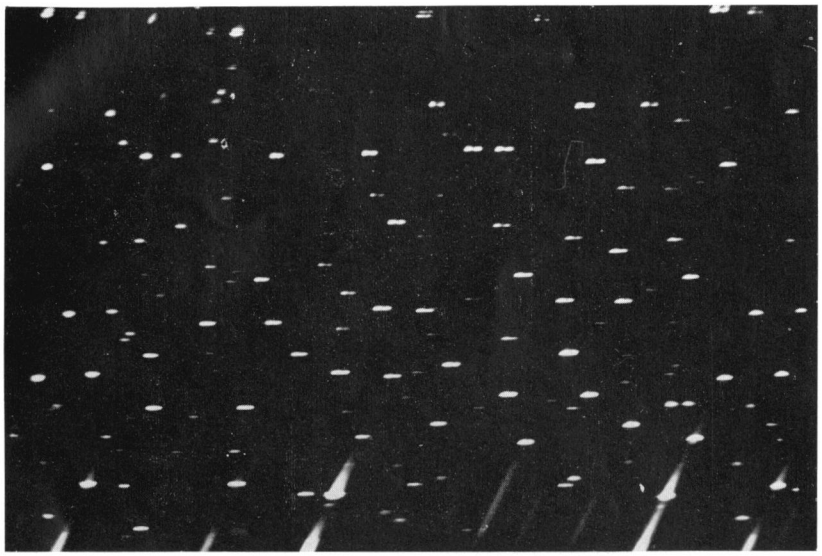

Fig. 2–A. Zero layer Weissenberg photograph about the *a*-axis taken with labradorite from Labrador.

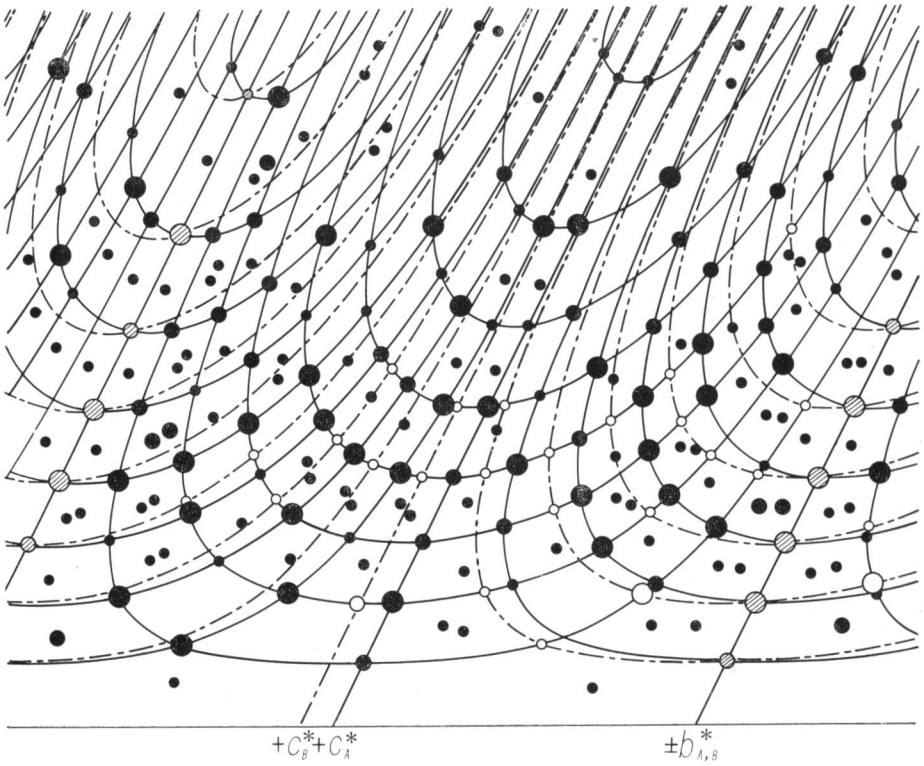

Fig. 2–B. Zero layer Weissenberg diagram obtained from the photograph shown in Fig. 2–A. Solid circles denote the reflexions due to one side twinning individual and open circles the reflexions due to another side individual.

indices of which bear such relationships as $h+k=2n+1$ and $l=2n+1$; while in the latter, reflexions appear when $h+k=2n$, hence, C-lattice. The lattice dimensions are as follows:

$a = 8.20\pm0.01$ Å	$a = 8.20\pm0.01$ Å
$b = 12.87\pm0.01$ Å	$b = 12.87\pm0.01$ Å
$c = 14.26\pm0.01$ Å	$c = 7.13\pm0.01$ Å
$\alpha = 93°29'$	$\alpha = 93°29'$
$\beta = 115°56'$	$\beta = 115°56'$
$\gamma = 90°17'$	$\gamma = 90°17'$.

Consequently, one of the twinning individuals is composed of an intermediate plagioclase lattice, X-ray photograph of which is characterized by weak (e)-reflexions, the other a high albite lattice.

Specimen from Sannidal

The specimen from Sannidal showed in one of the c-axes rotation photograph a pattern with weak pairs of subsidiary layer-lines, the δ_c being 125°. The specimen showed in the main layer Weissenberg photographs about the same axis a normal pattern, in the subsidiary layer Weissenberg photographs about the same axis a normal pattern too. The specimen showed in the other c-axis rotation photograph a pattern without subsidiary layer lines, in the Weissenberg photographs about the same axis a normal pattern. The specimen showed in one of the a-axes rotation photograph a normal pattern, in the Weissenberg photographs about the same axis a pattern which consists of two sets of reflexions, showing the $+b_A^*$, $+b_B^*$ and $-c_A^*(+c_B^*)$ reciprocal axes in the zero layer Weissenberg photograph, (Fig. 3–A, Fig. 3–B) one set of reflexions being accompanied with generally weak subsidiary reflexions. The authors could not find another a-axis, this must have been caused by the fact that the $+a_A$ and $-a_B$ axes were in almost coincidence in dircetion with each other. The assumption has been verified by the observation that in the zero layer Weissenberg photograph about the other a-axis both the $+b_A^*$ and $+b_B^*$ reciprocal axes have appeared as said above. The specimen showed in the b-axis rotation photograph a normal pattern, in the zero layer Weissenberg photograph about the same axis a pattern with subsidiary reflexions, and in the 1st, 2nd and 3rd equiinclination Weissenberg photographs a pattern which consists of two sets of reflexions, one set of reflexions being accompanied with subsidiary reflexions and the other set not being accompained. One of the individuals of the twin of the andesine is, therefore, composed of a lattice which shows weak subsidiary reflexions. The reflexions were indexed in the same way and obtained the same results as in the case of the specimen from Labrador. The lattice dimensions are as shown below,

Fig. 3–A. Zero layer Weissenberg photograph about the *a*-axis taken with andesine from Sannidal.

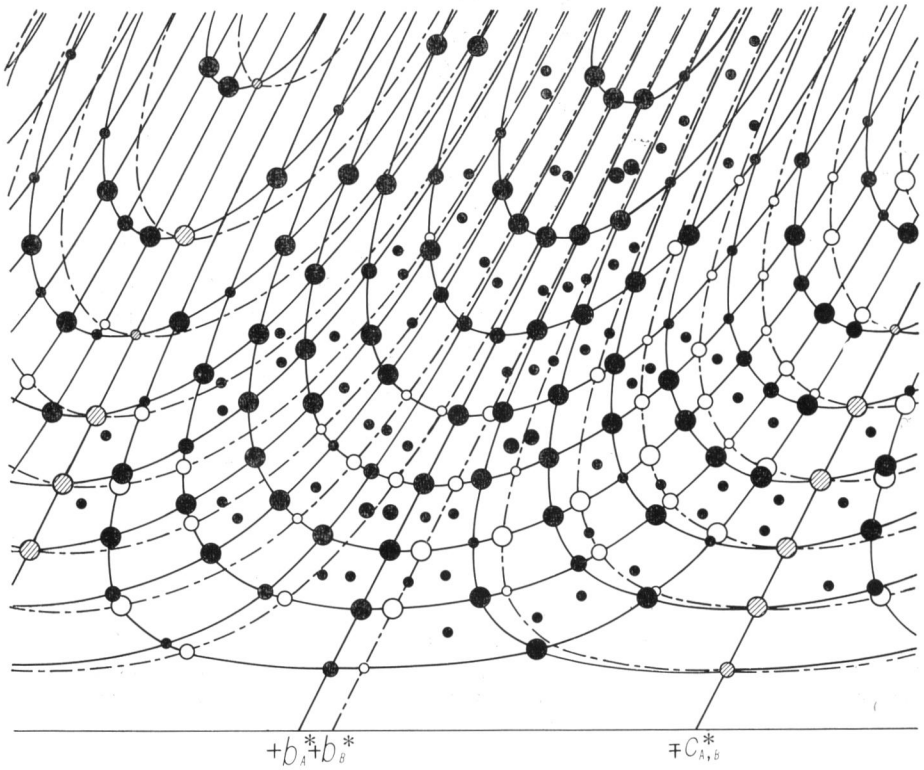

Fig. 3–B. Zero layer Weissenberg diagram obtained from the photograph shown in Fig. 3–A. Solid circles denote the reflexions due to one side twinning individual and open circles the reflexions due to another side individual.

$a = 8.17 \pm 0.01$ Å	$a = 8.17 \pm 0.01$ Å
$b = 12.85 \pm 0.01$ Å	$b = 12.85 \pm 0.01$ Å
$c = 14.28 \pm 0.01$ Å	$c = 7.14 \pm 0.01$ Å
$\alpha = 93°54'$	$\alpha = 93°54'$
$\beta = 116°30'$	$\beta = 116°30'$
$\gamma = 90°18'$	$\gamma = 90°18'$.

Like the specimen from Labrador, one of the individuals of the twin is composed of an intermediate plagioclase lattice, whose X-ray photograph is characterized by weak (e)-reflexions, the other a high albite lattice.

Conclusions

As said earlier, the authors expected that they may be able to obtain an X-ray photograph showing two intermediate plagioclase patterns which reveal the compositions of the twinning individuals respectively, provided that they take an X-ray photograph with an intermediate plagioclase feldspar crystal having two contiguous polysynthetic twin lamellae. Contrary to this expectation, the authors obtained photographs showing two patterns, one being an intermediate plagioclase pattern, the other a high albite pattern. The δ_c's obtained are 143° for the labradorite and 125° for the andesine. According to GAY (1956) these figures correspond to about An_{55} and about An_{38} respectively. The components, An_{55} and An_{38}, should be attributed to the twinning individuals which showed the subsidiary reflexions respectively. They are somewhat high as compared with those of the bulk compositions of the specimens respectively. The components of the individuals of the twins which have no subsidiary reflexions, therefore, must be less in An than those obtained from the bulk compositions respectively.

Accordingly, the individuals of the contiguous twin lamellae of these specimens are different from each other not only in lattice type but also in chemical composition. Moreover, it is interesting that one individual of the twin is high temperature form (high albite lattice), and the other individual is low or medium temperature form (intermediate plagioclase lattice). The cause of internal scatter observed by VOGEL (1964) may be attributed to such a twinning.

References

COULSON, A.L. (1932): On the zoning and difference in composition of twinned plagioclase feldspars, in certain rocks from Sirohi State, Rajputana. *Geol. Survey India* **65,** 163–172.

EMMONS, R.C. and R.M. GATES (1943): Plagioclase twinning. *Bull. Geol. Soc. Am.* **54,** 287–304.

EMMONS, R.C. and V. MANN (1953): A twin-zone relationship in plagioclase feldspar. Selected petrogenic relationships of plagioclase. *Geol. Soc. Am. Mem.* **52,** 41–54.

GAY, P. (1956): The structure of the plagioclase felspars: VI. Natural intermediate plagioclases. *Mineral. Mag.* **31,** 21–40.

VOGEL, T.A. (1964): Optical crystallographic scatter in plagioclase. *Am. Mineral.* **49,** 614–633.