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Autor: Callegari, Ezio / De Pieri, Renzo

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Crystallographical Observations on some Chess-Board Albites

By *Ezio Callegari* and *Renzo De Pieri* (Padova)

With 7 figures in the text

Abstract. Chess-board albites from different sources have been investigated by the X-ray precession method and chemically analysed by means of the electron-probe. Two normally twinned albites, associated with the chess-board albites, have also been investigated. Broad, diffuse and elongated reflections were obtained from the X-ray pictures of the chess-board albites. These features seem to be connected with the peculiar mode of development of the twinning. Only albite twinning was found in the selected crystals. A discussion is given of the genetical interpretation of the observed X-ray features.

Riassunto. Cristalli di albite a scacchiera, provenienti da rocce diverse, sono stati studiati ai raggi X col metodo di precessione ed anche analizzati chimicamente per mezzo dell',,electron-probe". Sono stati presi in considerazione anche due cristalli di albite a geminazione ,,normale", che si trovano associati nella stessa roccia con l'albite a scacchiera. I films di precessione dell'albite a scacchiera sono caratterizzati da riflessioni ampie, diffuse ed allungate. Questi caratteri sembrano connessi col particolare modo di sviluppo della geminazione. Tutti i cristalli analizzati rivelano solo la geminazione albite. Viene discusso il significato genetico dei caratteri röntgenografici osservati.

Introduction

The simultaneous development of a chess-board albite and of an essentially untwinned albite has been recently recorded from the green tuffs and tuffites (the so called "pietra verde") of the lower Ladinian of the Dolomites (Callegari and De Pieri, 1966). It was shown that the chess-board albite originated only from the replacement of a sanidine-cryptoperthite, whereas the untwinned albite developed at the expense of an andesine plagioclase.

Preliminary X-ray investigations on the two coexisting albites from the "pietra verde" have stimulated us to extend our researches to chess-board albites from other sources, especially on account of the relatively sparse attention hitherto devoted to this particular type of albite.

Studied materials

The albite crystals selected for the present study were separated from the following rocks:

Sample 23 c: Green crystal tuff from the outcrops of "pietra verde" at Brusè (on the road to Col di Lana, Alta Valle Cordevole, Dolomites).

The rock contains fragments of sanidine-cryptoperthites, which suffered a partial diagenetic albitization with development of chess-board albite. Single crystals of chess-board albite have originated from the complete replacement of the sanidine-cryptoperthites. These albites show many spindle-shaped twinning lamellae, whose continuity through the crystal is often interrupted, so that the lamellae alternate each other in a manner resembling the tiles of a roof. On some sufficiently broad lamellae it was possible to measure on the U-stage the optic axial angle, which resulted in $2V_\alpha = 81°—86°$. Measurements by means of the electron-probe gave the following composition for the chess-board albite: $Ab_{99.61}$ $An_{0.03}$ $Or_{0.36}$. Beside the chess-board albite this rock also contains an essentially untwinned albite which originates from the replacement of the andesine plagioclases. For the optical and compositional characters of this albite see the sample Li 1.

Sample Li 1: Grey crystal tuff from the outcrops of "pietra verde" at Col Toront (Monti Alti di Ornella, Val Cordevole, Dolomites).

The rock contains abundant authigenic albite developing at the expense of volcanic plagioclases. It is normally untwinned and contains many little inclusions of micaceous products. A twinned crystal with only two broad lamellae was chosen for the X-ray study. The optic axial angle was found to be: $2V_\alpha = 80°—83°$; this means that this albite has a "transitional" character. Electron-probe determinations gave the following composition: $Ab_{99.67}$ $An_{0.15}$ $Or_{0.18}$.

Sample A Giu 49: Albitite from Giustino (Valle Rendena, Trento).

From this rock two coexisting types of Na-feldspar have been separated, a chess-board albite and a normally twinned albite. Both of them have a metasomatic origin (Ogniben, 1956). According to Ogniben the chess-board albite formed at the expense of pre-existing microcline. The optic axial angle was found to be the same for both the types of albite ($2V_\alpha = 98°—96°$). Electron-probe measurements gave the following composition: for the chess-board albite $Ab_{98.49}$ $An_{1.36}$ $Or_{0.15}$; for the normally twinned albite $Ab_{98.63}$ $An_{1.24}$ $Or_{0.13}$.

Sample Co 36: Porphyroid from Pala degli Orti, q. 2500 m (Comelico).

This rock contains many phenoblasts of chess-board albite, which, according to Sassi and Zirpoli (1965), have originated from the metasomatic replacement of orthoclase. The chess-board albite often contains very small inclusions of micas

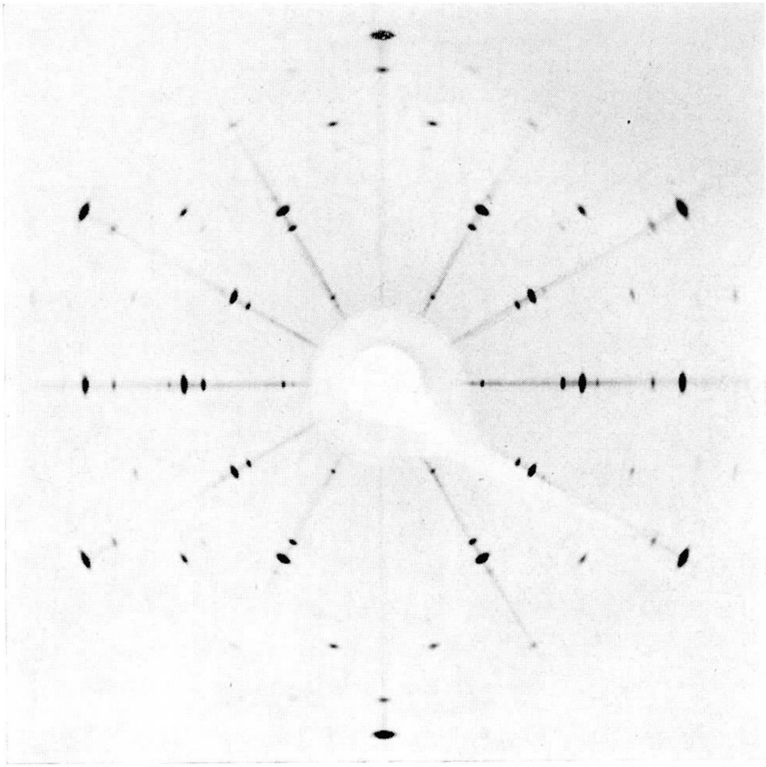

Fig. 1. Chess-board albite 23c. a^* b^* precession photograph, Cu unfiltered radiation (b^*-axis horizontal).

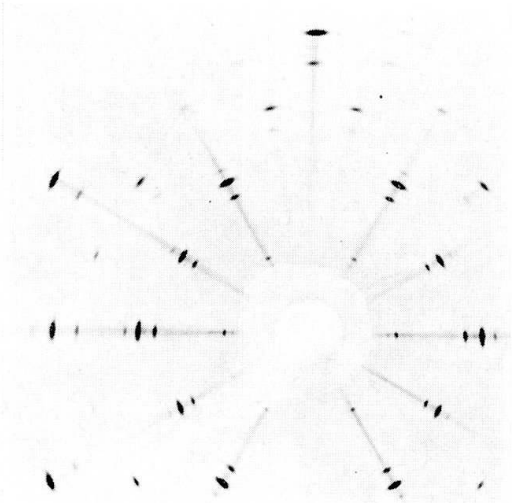

Fig. 2. Chess-board albite A Giu 49. a^* b^* precession photograph, Cu unfilt. rad. (b^*-axis horizontal).

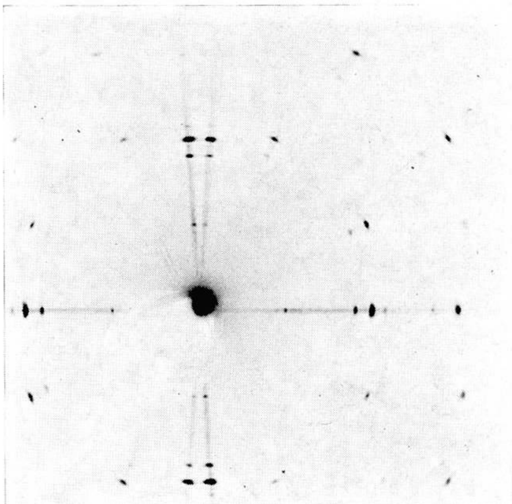

Fig. 3. Chess-board albite A Giu 49. b^* c^* precession photograph, Cu unfilt. rad. (b^*-axis horizontal).

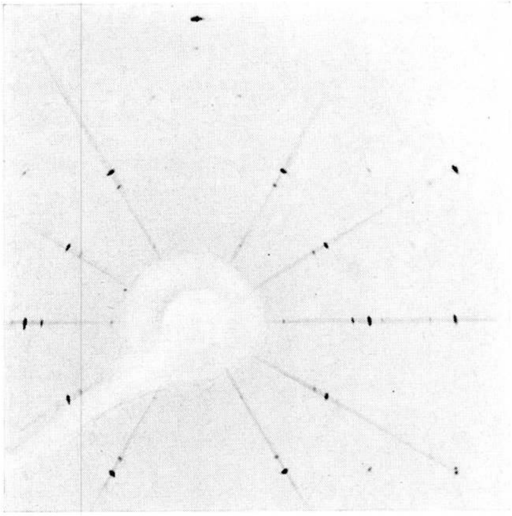

Fig. 4. Normally twinned albite A Giu 49. $a^* b^*$ precession photograph, Cu unfilt. rad. (b^*-axis horizontal).

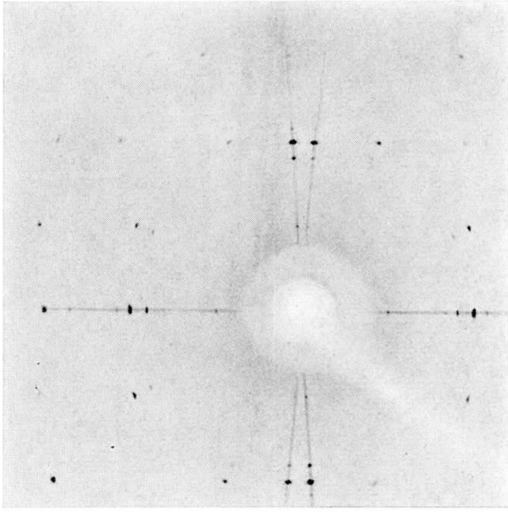

Fig. 5. Normally twinned albite A Giu 49. $b^* c^*$ precession photograph, Cu unfilt. rad. (b^*-axis horizontal).

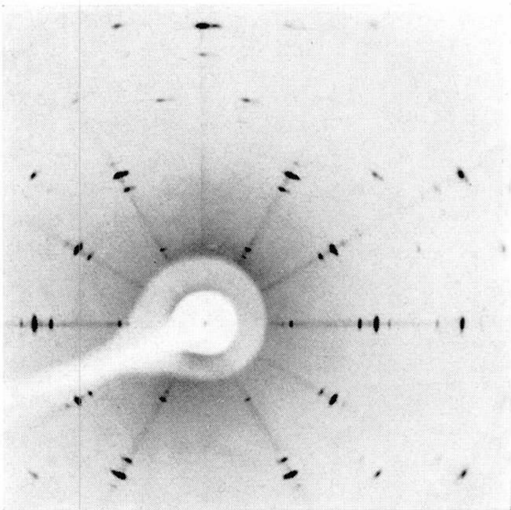

Fig. 6. Intermediate albite Li 1. $a^* b^*$ precession photograph, Cu unfilt. rad. (b^*-axis horizontal).

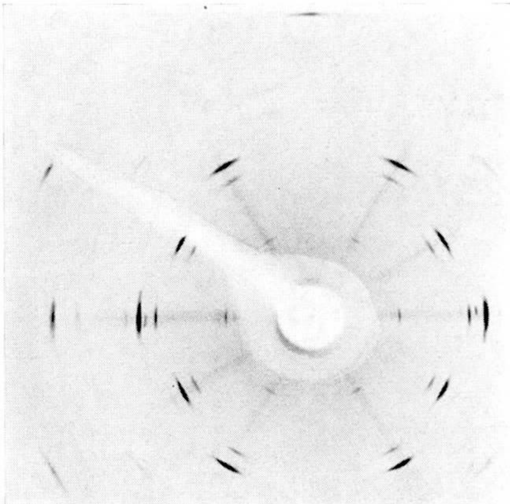

Fig. 7. Chess-board albite 0—166. $a^* b^*$ precession photograph, Cu unfilt. rad. (b^*-axis horizontal).

and epidote. The measured optic axial angle is $2V_\alpha = 90°$. The composition of the chess-board albite as deduced from electron-probe measurements is as follows: $Ab_{99.76}\ An_{0.03}\ Or_{0.21}$.

Sample 0—166: Epimetamorphic tonalite from Orcas Isle (S. Juan Islands, Washington, U.S.A.).

The rock shows a cataclastic structure. It contains small amounts of chess-board albite, which seems to have developed from the partial replacement of some plagioclase crystals. The chess-board-patterned feldspar chosen for the X-ray analysis showed no trace of deformation. Chemical determinations by means of the electron-probe gave the following composition for the chess-board albite: $Ab_{98.55}\ An_{1.04}\ Or_{0.41}$.

Sample DBL 71: „Arolla orthogneis" from the Ghiacciaio del Leone (Cervinia, Piemonte).

The rock contains many phenoblasts of water-clear chess-board albite, which, according to Stutz (1940), is derived from the replacement of microcline under epizonal conditions. The chess-board albite from this rock differs somewhat from the other selected albites in having a better defined chess-board pattern, with twinning lamellae often truncated by a plane (001).

X-ray study

From each of the above rock samples good cleavage flakes (about ·01—0.2 mm) were carefully chosen under the binocular and controlled under the polarizing microscope before being analysed by the X-ray precession method.

All but one of the selected chess-board albites gave amost identical X-ray patterns. The *a*-axis precession pictures are characterized by diffuse and broadened reflections. The crystals show only albite twinning (Fig. 3). The *c*-axis precession photographs again show diffuse and broadened reflections, which are elongated according to arcs of concentric circles (see Fig. 1 and 2). The elongation of the spots is very pronounced in the precession pictures obtained from the sample 0—166 (Fig. 7). In the a^* b^* precession photographs the albite twinning appears unresolved owing to the broadening of the spots, so that a γ^* angle of $\simeq 90°$ results (see fig. 1 and 2).

Of all the selected specimens, only the chess-board albite DBL 71 gave a "normal" X-ray pattern, corresponding to that of a low-albite. The reflections are sharp and the albite twinning is clearly resolved both in the a^* b^* and in the b^* c^* plane.

It is interesting to compare the X-ray behaviour of the chess-board albites 23 c and A Giu 49 with the "normal" albites found associated with them in the same rock specimen.

Table 1. *Lattice constants*[1])

Sample No.		α^*	β^*	γ^*	α	β	γ	a Å	b Å	c Å
23 c[2])	I	86° 33′	63° 30′	≅90°	93° 51′	116° 33′	88° 17′	8.134	12.787	7.178
	II	86° 37′	63° 30′	≅90°	93° 47′	116° 33′	88° 19′	8.137	12.823	7.173
Li 1		86° 4′	63° 30′	88° 51′	93° 49′	116° 35′	89° 19′	8.140	12.801	7.180
A Giu 49[3])	I	86° 24′	63° 30′	≅90°	94° 1′	116° 33′	88° 12′	8.126	12.766	7.180
	II	86° 22′	63° 30′	90° 25′	94° 17′	116° 35′	87° 43′	8.146	12.794	7.173
Co 36		86° 29′	63° 30′	≅90°	93° 56′	116° 33′	88° 15′	8.140	12.787	7.179
0—166		86° 38′	63° 30′	≅90°	93° 46′	116° 33′	88° 19′	8.12	12.80	7.18
DBL 71		86° 29′	63° 30′	90° 21′	94° 6′	116° 35′	87° 51′	8.159	12.786	7.175
AG 1[4])		86° 36′	63° 27′	89° 23′	93° 30′	116° 33′	89° 1′	8.117	12.797	7.172
AG 3[4])		86° 35′	63° 30′	90° 00′	93° 49′	116° 33′	88° 18′	8.143	12.784	7.178

[1]) Except for the sample 0—166, the estimated error for the lattice constants is $\pm 5'$ for the angles and $\pm 0.07\%$ for the spacings. The β^* angles were assumed to be 63° 30′. The β values, calculated from the reciprocal angles listed above agree well with the β angles measured on the dial of the precession camera.

[2]) The symbols I and II refer to two distinct chess-board crystals from the same rock specimen.

[3]) The symbol I refers to chess-board albite, whereas the symbol II refers to normally twinned albite found in the same rock specimen.

[4]) Authigenic albites structurally intermediate between albite and analbite (values from Baskin, 1956).

The normally twinned albite from the sample A Giu 49 exhibits an X-ray pattern corresponding to that of a low-albite, with sharp spots and well resolved albite twins both on *c*- and *a*-axis precession photographs. The different X-ray pattern exhibited by the two coexisting albites from the sample A Giu 49 are seen in fig. 2 to 5.

The "normal" albite, associated with the chess-board albite in the green tuffs of the lower Ladinian of the Dolomites (the s.c: "pietra verde"), gave an X-ray pattern corresponding to that of an "intermediate" albite, as deduced from the comparison of the measured lattice parameters with the reported lattice parameters for some authigenic "intermediate" albites (BASKIN, 1956) (see Tab. 1).

The reflections appear somewhat diffuse and broadened as in the associated chess-board albite, but the albite twinning is clearly resolved both on the $a^* b^*$ and on the $b^* c^*$ plane, the measured γ^* angle being 88° 51′ (Fig. 6). It is interesting to note that an "intermediate" state for this albite may also be inferred from its optic axial angle $2V_\alpha = 80°$—83°[1]).

Concluding remarks

No sactisfactory explanation has yet been given which makes understandable the reason why in some circumstances Na-feldspar develops a chess-board pattern of twinning. It is known since BECKE (1906) that chess-board albite frequently originates from the metasomatic replacement of K-feldspar (BECKE, 1906; DE LAPPARENT, 1909; SCHOKLITISCH, 1934; ANDERSON, 1937; STUTZ, 1940; BEARTH, 1948; EXNER, 1949; OGNIBEN, 1956; STARKEY, 1959; SASSI and ZIRPOLI, 1965; CALLEGARI and DE PIERI, 1966, and many others). Chess-board albite, however,

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[1]) To prove the intermediate character of the albite Li 1 the intensities of the reflections (hk0) and ($h\bar{k}0$) have been measured by means of the "flying spot" integrating microdensitometer of Joyce, Loebl and Co. in order to compare the observed differences with the intensity differences found by LAVES and CHAISSON (1950) for high- and low-albite. The measured differences agree well with the assumption of an intermediate structural state. So, for instance, using the symbols as proposed by LAVES and CHAISSON (1950), we found for (110) and ($1\bar{1}0$) an intensity difference -0.7, which is intermediate between the values obtained for high-albite (-4) and low-albite (0); for (170) and ($1\bar{7}0$) we found an intensity difference -2.1 (high-albite -4, low-albite -0.5).

Assuming a continuous variation of the F_c values to occur as a function of the Si/Al order-disorder, the intermediate character of this albite also results from the F_0 values of the studied albite as compared with the F_c values quoted by FERGUSON et al. (1958) for high- and low-albite.

was less frequently found developing at the expense of plagioclases (EXNER, 1949; VANCE, 1961). In some instances a primary origin was claimed for chess-board albite (TILLEY, 1919; BATTEY, 1955).

There is no doubt that in many circumstances the development of chess-board albite seems to be strictly connected with the replacement of a pre-existing K-feldspar. Otherwise it would be very difficult to explain why when two types of albite (normal and chess-board-patterned) develop simultaneously in the same rock it was found that only the albite replacing K-feldspar exhibits the chess-board twinning, whereas the albite replacing plagioclases and the newly formed albite are either untwinned or "normally" twinned (OGNIBEN, 1956; SASSI and ZIRPOLI, 1965; CALLEGARI and DE PIERI, 1966).

As to the origin of the chess-board twinning, some Authors claimed either a structural inheritance, such as the pre-existing twin pattern of the replaced K-feldspar (VOLL, quoted in STARKEY, 1959), or the influence of stresses (STARKEY, 1959). In his study of the chess-board albite found in the regionally metamorphosed porphyries at New Brunswick, Canada, STARKEY (1959, p. 143) stated that "... it is reasonable to assume that (this) stress is casually related to chess-board pattern and that the chess-board twinning is a deformation twinning just as the more normal type of polysynthetic twinning".

We do not believe that the inheritance of a pre-existing twin pattern (e.g. that of microcline) can explain the development of the chess-board twinning, for chess-board albite has been found replacing not only microcline (BECKE, 1906; DE LAPPARENT, 1909; ANDERSON, 1937; STUTZ, 1940; BEARTH, 1948; EXNER, 1949; OGNIBEN, 1956) but also orthoclase (ANDERSON, 1937; SASSI and ZIRPOLI, 1965) as well as sanidine (CALLEGARI and DE PIERI, 1966). Moreover the writers have found the chess-board albites to be twinned only according to the albite law.

The above discussion indicates that the observed relationship between the development of chess-board twinning and the replaced K-feldspar does not depend on any particular modification of the pre-existing K-feldspar.

The chemical data (from the microprobe measurements) exclude the possibility that the development of the chess-board pattern may depend on compositional factors: in fact the two coexisting albites (normal and chess-board patterned) found in the same rock specimen have almost identical composition. All the analysed chess-board albites were found to be almost pure Na-feldspars (more than 98% Ab, by weight), with very low amounts of K-feldspar (less than 0.41% Or) and of anorthite (less than 1.36% An). The measurements made by means of the electron-probe revealed that no zoning is present in the selected crystals. As to the chemical composition, it would be interesting to know the upper limit of the anorthite content still compatible with the development of the chess-board pattern.

Further comments on the development of the chess-board twinning arise from the inspection of the X-ray features of the studied chess-board albites. As noted, the chess-board albite and the "normal" albite found associated in the same rock revealed a marked difference in the X-ray behaviour. On one hand, the chess-board albite gave precession pictures with diffuse and broad reflections, elongated according to arcs of concentric circles; moreover, the γ^* angle being $\simeq 90°$, the albite twinning appears to be unresolved in the a^* b^* plane. In the coexisting "normal" albite, on other hand, the albite twinning is well resolved both in the a^* b^* and in the b^* c^* plane. The reflections may be either sharp (as in the low albite A Giu 49) or somewhat diffuse (as in the intermediate albite Li 1).

From the above comparison it may be concluded that the particular X-ray behaviour of the chess-board albites seems to be connected with this peculiar mode of development of twinning.

To explain the observed X-ray behaviour of the chess-board albites the following interpretations may be offered. One explanation would be to consider that the diffuseness and the broadening of the reflections are due to a "transitional" character, i.e. that the albite lamellae have an intermediate degree of Al/Si ordering. In this case the measured γ^* angle $\simeq 90°$ may really correspond to the γ^* angle of a transitional structure. The diffusion of the reflections may be due to a mosaic-like condition, as suggested by BASKIN (1956) for his intermediate albites. This interpretation would be in accordance with the measured 2V angles of the chess-board albites 23 c ($2V_\alpha = 81°$—$86°$) and Co 36 ($2V_\alpha = 90°$); it does not hold true, however, either for the chess-board albite A Giu 49 ($2V_\alpha = 96°$—$98°$) or for the chess-board-patterned feldspar DBL 71, this latter giving a pattern typical of a low-albite. Moreover, it is to be noted that the "assumed" transitional X-ray pattern of the chess-board albite would be quite different from that of the true intermediate-albite found by us as authigenic albite replacing plagioclases (sample Li 1).

Another explanation would be to consider the diffuseness and the broadening of the reflections as due to slight angular differences between both the a^* and b^* axes of the twinning lamellae, as a consequence of a "disordered growth" occurring in such a manner that either single lamellae or groups of lamellae are slightly rotated with respect to each other around the *c*-axis. This would account for the elongation of the reflections observed in the X-ray pictures. This explanation seems to agree well with the microscopical observations of some Authors concerning the disordered growth of this type of albite, sometimes giving rise to "mosaic-like" structures (BATTEY, 1955; STARKEY, 1959). The assumption of a disordered growth for the chess-board-patterned Na-feldspar agrees well with the peculiar X-ray behaviour of the albite 0—166, which gave a pattern resembling that of a fiber arrangement. Sometimes, however, as in the case of the chess-board albite DBL 71, the development of the chess-board pattern may occur in a more ordered manner (perhaps due to particular environmental factors connected with metamorphism). In this case the Na-feldspar exhibits a better defined chess-board pattern as proved both optically and by X-ray examination.

As to the origin of the chess-board twinning it may be reasonably assumed that its development is favoured by strains or stresses, in accordance with the evidences supported by some authors (BEARTH, 1948; STARKEY, 1959). Internal strains could develop during the replacement of K-feldspar by albite on account of the marked difference between the cell volumes[2]). This fact could give a sactisfactory explanation of the different behaviour exhibited by the Na-feldspar in the rock sample 23 c, where chess-board albite develops replacing sanidine, and untwinned intermediate albite develops replacing volcanic plagioclases.

No volume differences can be advanced as explaining the origin of the chess-board twinning when albite develops at the expense of plagioclases. The influence of stresses, under particular circumstances, could be assumed as a possible cause for the development of the chess-board pattern of twinning.

Considering that this is the first attempt to study chess-board albite by means of X-ray single-crystal methods, we cannot yet draw definite conclusion on this subject, which remains open to future work.

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[2]) Cell volumes according to COLE et al. (1949, 1951): Orthoclase = 719.294 Å^3; albite = 664.16 Å^3; labradorite (An_{55}) = 667.64 Å^3.

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